# Design, Analysis and Manufacturing of Gears

# HyGEARS V 5.0 Training

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# What You See Is What You Get

HyGEARS, THE GEAR PROCESSOR, was developed to help Spiral-Bevel and Hypoid gear designers and manufacturers reduce production time while increasing the quality of their products.

HyGEARS may also be used for the analysis of internal and external Spur and Helical gears, Straight bevel gears, Coniflex bevel gears, Hirth couplings, and Face gears.

HyGEARS is built around an advanced Graphic User Interface, which simplifies the operations and the understanding of the results.

All results are given in WYSIWYG mode which means that, in HyGEARS, *what you see is what you get*.

#### Measured Contact Pattern



#### HyGEARS' Simulation



# **Training Outline**

- General presentation of HyGEARS
- Vector simulation of gear manufacturing processes
- Tooth Contact Analysis (TCA)
  - Ease Off Surface
  - TCA, Transmission Error and the Contact Pattern
- Numerical Contact Pattern development
- Cutting processes and machines
- Software calibration
- HyGEARS Graphic User Interface (GUI):
  - Starting HyGEARS
  - Parent Window
  - Display Modes
  - Child Windows
  - Graphic controls
  - Context sensitive Help
  - Geometry Summary editor
  - V-H Settings
- Creating a New Geometry; Spiral bevel / hypoid, Coniflex Spur. Helical, Face gear, Beveloid, Straight bevel
- Production Control: Corrective Machine Settings (Closed Loop) / Reverse Engineering
- 5Axis CnC Manufacturing
- Graphic Display Functions
  - Teeth and Machines: geometry, 5 Axis CNC manufacturing
  - Kinematics: TCA, LTCA
  - Measurement: target file, analysis, Corrective machine settings, Reverse engineering
  - 2D Graphs:
  - FEA meshing; Finite Strips meshing
- Addendums

### **Strengths and limitations**

#### Main HyGEARS features ...

- 3D displays throughout;
- Internal architecture flexibility allows expansions;
- Many different ways to arrive at a given goal;
- Fast and easy to use.

#### Some HyGEARS limitations ...

- Design of face-milled <u>hypoid gears</u> limited to 90° shaft angle;
- Design of face-milled <u>spiral-bevel gears</u> limited to  $\sim 25-140^{\circ}$  shaft angle;
- Design of face-hobbed hypoid and spiral-bevel gears not allowed at this time (import of existing summaries allowed);

#### **HyGEARS** Customers

#### <u>1994-2004</u>

#### Japan:

Yutaka Seimitsu Kogyo Mitsubishi Motors Toyota Motor Corp. Subaru Motors Corp. Subaru Central Labs (Tokyo) Hino Trucks Honda Motors Showa Gears Daihatsu

#### Korea:

KIA Motors KIA Heavy Industries

#### **Europe**:

Romax Technology (UK)

#### USA:

DANA Corp. American Axle and Manufacturing GM Linamar

#### <u>From 2013 -</u>

China:

SEW Eurodrive (Tianjin) miniGears (Suzhou) Harbin Marine Boiler TRI

#### Europe:

Drive System Design (UK) Reliance Precision Ltd (UK) Spirotec (France) Robert Bosch GmbH (Germany) Neugart GmbH (Germany) **PTR-TEC** (Germany) **BMW** (Germany) EWS Weigele GmbH (Germany DEPRAG (Germany) FZG (Germany) ZG Hypoid (Germany) Hoer Innovativ (Germany) MAN Trucks & Bus (Germany) Haas-Multigrind (Germany) ZG Hypoid (Germany) **Eppinger Gears** (Germany) **EWS** Weigele (Germany) Sandvik GmbH (Austria) **GB** Ricambi (Italy) Breton Spa (Italy) **GB** Gearboxes (Italy) MdM Mecatronics (Italy) Tecnogear (Italy) **Kumera** Drives (Finland) **GKN** Driveline (Sweden)

#### USA:

EMCO Gears Dynamic Engineering Rexnord Geared Products GMT Gears DTD Precision Perry Technology Corp Afton Chemical

#### India:

Bevel Gears India Shivam Autotech Eppinger Tools Bharat Forge Limited

#### Israel:

Precision Products

#### Japan:

Takeda Trade Co.

#### Canada:

Usimax Inc

### HyGEARS currently defined CnC machines

DEPO
DMC 65H DuoBlock
DMC 125FD
DMF 260 HT-C
DMG CTXBeta-1250TC
DMG CTXBeta-2000TC
DMG CTXBeta-3000TC
DMG 65 - 840D
DMG 65 MonoBlock
DMG MORI NTX 2500
DNM 200 (Doosan)
DMU 65 - 840D
DMU 50
DMU 100 MonoBlock
DMU 125P
EMCO Hyperturn 65
Fanuc Robodrill T21
Fanuc V-8D
Fryer TR-60
GroB 350
Haas Horizon
Haas Multigrind CB
Haas VF3
Heller MC 16
Hermle C22U
Hermle C30U
Hermle C40U [Siemens]
Index G220
Juaristi TXH5K-MGX12
Kitamura Mytrunnion 5
MAG NBV700
Makino DA300
Makino PS95
Matec 30-HV
Maxima 1600 [Breton]

Mazak IG e-500H

Machines are easily added if the requested one is not already in the list.

Besides, an existing machine may be modified to suit a specific user's needs and then a machine variant is created with a different name.

The supported controllers are:

- Fanuc
- Okuma
- Siemens
- Heindehein
- Mazak

### <u>Short HyGEARS history – the Early Days</u>

- 1983-1985: Master's Thesis Development of a 3D CAD package to analyze spiral-bevel gears
- 1985-1987: PhD Thesis Optimization of the kinematics of spiralbevel gears
- **1989**: DEC VAX-Station Version
- **1991**: *1st Windows 3.1 Version* (VB3 + Fortran)
- **1992**: LTCA Loaded Tooth Contact Analysis
- 1993:1st Meeting with Yutaka Seimitsu, Japan; Calibration on<br/>Yutaka and Gleason machines



# Short HyGEARS history - Coming of Age

1994: 1<sup>st</sup> order Corrective machine settings; JIMTOF 1995: HyGEARS V 1.0 Single precision **1996**: Reverse Engineering 1997: 2<sup>nd</sup> and 2<sup>nd+</sup> order Corrective Machine Settings 1999: *HyGEARS V 2.0* Single+double precision 2000: Contact Elements, Grid output, Spur/Helical, ... **2003**: Face Hobbing Simulation 2006: Lapping Simulation and Prediction 2007: HyGEARS V 2.5 2010: Net-shape Straight Bevel Gears 2011: *HyGEARS V 3.0* Coniflex Universal 5 Axis CnC Interface 2012: *HyGEARS V 4.0* Double precision VS 2010 + .NET 4.0  $\sim$ 390,000 lines of code 2021: *HyGEARS V 5.0* 64 Bits; GPU 3D graphics

VS 2019 + .NET 4.7



# **Vector Simulation – A Short Primer**

In Vector Simulation, a theoretical gear generator is simulated by translations and rotations applied to reference frames that determine the relations between cutting tool and machine.





# **HyGEARS Vector Model**

The coordinates and normal vectors at any point on the tooth flanks are obtained by applying machine specific rotations and translations to the cutter definition.

Point on tooth flank:

 $D = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos(\alpha c) \sin(\alpha c) \\ 0 & -\sin(\alpha c) \cos(\alpha c) \end{bmatrix} \begin{bmatrix} S\cos(\phi) \\ 0 \\ (R \pm S\sin(\phi)) \end{bmatrix}$ 

 $X = \boldsymbol{D} \ [\tau]^3 \ [k]^1 \ [Radial] \ [L_1]^3 [Dist] \ [\gamma_m]^2 [\theta_3]^3$ 

Normal vector on tooth flank:

	1	0	0	$\sin(\phi)$	
N =	0	cos(aa	c) $\sin(\alpha c)$	0	
	0 -	$-\sin(\alpha t)$	$c)\cos(\alpha c)$	$\left[\mp \cos(\phi)\right]$	

 $N_{x} = N \, [\tau]^{3} \, [k]^{1} \, [L_{1}]^{3} \, [\gamma_{m}]^{2} [\theta_{3}]^{3}$ 



### **HyGEARS Vector Model**

Higher order changes can be superimposed to the tool and work piece movements in order to achieve specific kinematic behavior.

#### Higher order cutting changes:

• Modified Roll

$$L_{1m} = \alpha_3 R_r + \frac{2C}{2} (C_r - \alpha_3 R_r)^2 - \frac{6D}{6} (C_r - \alpha_3 R_r)^3 + \frac{24E}{24} (C_r - \alpha_3 R_r)^4 - \frac{120F}{120} (C_r - \alpha_3 R_r)^5 + \frac{720G}{720} (C_r - \alpha_3 R_r)^6$$

where:	$L_{1m}$ :	modified cradle angle
	α <sub>3</sub> :	work piece roll angle
	R <sub>r</sub> :	ratio of roll, cradle to work piece
	$C_r$ :	cradle ref. position
	2C:	2 <sup>nd</sup> Order parameter (Gleason notation)
	6D:	3 <sup>rd</sup> Order parameter (Gleason notation)
	24E:	4 <sup>th</sup> Order parameter (Gleason notation)
	120F:	5 <sup>th</sup> Order parameter (Gleason notation)
	720G:	6 <sup>th</sup> Order parameter (Gleason notation)
		•

#### **HyGEARS Vector Model**

#### Higher order cutting changes:

• Helical Motion

$$\begin{split} X_{bm} &= X_b + \ 1_{st} \left( C_r - \ \alpha_3 \ R_r \right)^{\square} + 2_{nd} \left( C_r - \ \alpha_3 \ R_r \right)^2 \ + \ 3_{rd} \left( C_r - \ \alpha_3 \ R_r \right)^3 \ + \ 4_{th} \left( C_r - \ \alpha_3 \ R_r \right)^4 \ + \ 5_{th} \left( C_r - \ \alpha_3 \ R_r \right)^5 \ + \ 6_{th} \left( C_r - \ \alpha_3 \ R_r \right)^6 \end{split}$$

where:	X <sub>bm</sub> :	modified sliding base
	α <sub>3</sub> :	work piece roll angle
	R <sub>r</sub> :	ratio of roll, cradle to work piece
	C <sub>r</sub> :	cradle ref. position
	1 <sup>st</sup> :	1 <sup>st</sup> Order parameter
	$2^{nd}$ :	2 <sup>nd</sup> Order parameter
	3 <sup>rd</sup> :	3 <sup>rd</sup> Order parameter
	4 <sup>th</sup> :	4 <sup>th</sup> Order parameter
	$5^{\text{th}}$ :	5 <sup>th</sup> Order parameter
	$6^{\mathrm{th}}$ :	6 <sup>th</sup> Order parameter

### HyGEARS Vector Model – Face Milling and Face Hobbing

Simulation of Face Milling and Face Hobbing processes supported for Spiral Bevel gears.



Face Milling (single indexing)



Face Hobbing (continuous indexing)

### **Tooth Contact Analysis (TCA)**

The basis of all kinematics in HyGEARS is the Tooth Contact Analysis, or TCA, whereby the location of the Path of Contact is calculated, red line - left figure below, which leads to the Contact Pattern, blue patch - right figure below.

The location and dimensions of the Contact Pattern can be viewed in several ways, and may be optimized according to the user's wishes using the Contact Pattern Development functions. ("CPat" function button)



The Ease Off Surface represents tooth to tooth separation as meshing proceeds.

It can be seen as a measure of the *discrepancy in conjugacy* between 2 meshing surfaces.



1. The *Ease Off* is displayed in ref. to the Pinion tooth:

#### The displayed elements are:

- Contact Separation Axis
- Face Width Axis
- Radial Axis
- *Ease Off* surface, or discrepancy in *conjugacy*
- Path of Contact (PoC red line)
- Contact Pattern (Blue patch)
- Edge values (0.11, 0.07, etc.)



- 2. The pinion and gear tooth surfaces are <u>digitized</u>, i.e. the *implicit* surface equations are solved; therefore, on each tooth several points are known by:
  - Surface parameters  $\alpha c$ , S,  $\alpha 3$ 
    - αc: cutter blade angular position
    - S: position of a cutter blade to work contact point
    - α3: work piece roll angle

- Coordinates X, Y, Z
- Normal vector Nx, Ny, Nz



- 3. Contact points are calculated at each tooth flank coordinate;
  - A contact point is obtained when:
    - The pinion and gear *Coordinates* are equal in a common ref. frame;
    - The pinion and gear *Normal* are equal and opposed in a common ref. frame;
  - The following are obtained at each contact point,
    - coordinates,
    - normal components,
    - tooth surface parameters ( $\alpha c$ , S,  $\alpha 3$ ) and
    - tooth rotation ( $\theta$ 3,  $\phi$ 3);



- An image of the *Ease Off* or *tooth to tooth meshing separation* is obtained by scanning the pinion and gear teeth for contact points;
- Using 1 ref. point, tooth separation is calculated as function of the T.E. multiplied by the contact radius on the gear at each contact point;
- T.E. is defined as :

$$\delta \phi_3 = \phi_3 - \theta_3 m_g$$

where:  $\delta \phi_3$ :

- $\phi_3$ : angular position of the Gear
- $\theta_3$ : angular position of the Pinion
- m<sub>g</sub>: gear ratio

T.E.



#### **TCA and Transmission Error**



$$\delta \phi_3 = \phi_3 - \theta_3 m_g$$

 $\delta \phi_3$ 

 $\varphi_3$ 

is the gear angular position error, or Transmission Error (TE) value

is the gear calculated angular position error

 $\theta_3 m_g$  is the gear theoretical angular position, equal to the product of the pinion angular position times the speed ratio.

### TCA and Transmission Error / 2



# TCA and Transmission Error / 3



# TCA and Transmission Error / 4



### TCA and Transmission Error / 5: Center CP







### TCA and Transmission Error / 6: High CP







### TCA and Transmission Error / 7: Low CP







### TCA and Transmission Error / 8: Center CP



# TCA and Transmission Error / 9: High CP



## TCA and Transmission Error / 10: Low CP



### LTCA and Transmission Error: Shift in TE curve



## LTCA and Transmission Error: Shift in TE curve



#### **Contact Pattern: Examples**



### **Example: Contact Patterns of an Existing Gear Set**



Tooth Pair	Measured	Simulated 1 Simulated 2		Simulated 3
		(R.E.)	(R.E. + ErrS)	(R.E. + ErrS + Diff.)
P01-G01	-			-
P01-G19	-			- 10000
P01-G33	- Charles			-
P04-G01	-			
P04-G19	-			
P04-G33	-			-

#### EPG, Alignment, Shaft Angle Errors

In TCA and LTCA, HyGEARS can account for positional errors in three directions: *pinion Offset "E", pinion MD "P" and gear MD "G"*. Additionally, pinion and gear Radial may be used directly.

This feature is available for all HyGEARS supported gear types.

Alignment, shaft angle error, and gear eccentricity can also be introduced to predict the behavior under load or in an actual gearbox.

The effects on TE, Contact Pattern and Load Sharing, may be investigated using the convenient V-H Settings Editor .

💒 V-H Settings - [mm] - Hypoid Demo1441-Corr 🗪				
E-P-G Alignment Runout Links				
E: (Pinion Offset)	0.0000	1		
	0.0000	)		
P: (Pinion Axial)	0.0000	Pinion Radial	0.0000	
G: (Gear Axial)	0.0000	Gear Radial	0.0000	
Apply Reset OK Cancel				



#### Numerical Contact Pattern Development

To develop a Contact Pattern, HyGEARS offers sophisticated functions where the *location and bias of the Contact Pattern can be specified*.

The amplitude of the TE curve can also be modified to accommodate specific operating conditions.

Contact Pattern Development can be done on

- Fixed Setting spiral-bevel gears,
- Modified Roll spiral-bevel gears,
- Duplex Helical spiral-bevel gears,
- SimplexT spiral-bevel gears,
- Cyclo-Palloid spiral-bevel gears,
- Face Hobbed spiral-bevel gears,
- Straight bevel gears,
- Coniflex bevel gears


Contact Pattern development is done in several steps:

- The *Ease Off* surface is modified through changes in Pinion machine settings;
- The Gear member is either conjugate to the Generating Gear, for a generated gear set, or is the Generating Gear for a non generated gear set; changes to the *Ease Off* come from the Pinion;
- In practice, the R.E. algorithm is applied using *deviations in ref. to the current pinion surface*, which are reflected in the *Ease Off;*
- CP is centered where requested by the user;
- Bias is modified until user request is reached;
- Bias is calculated between the 1<sup>st</sup> and last points of the PoC along the profile;



- No undercutting check;
- Tooth depth is maintained at mid-face width;



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128.0

154.0

180.0

154.0 180.0

 $\theta_3 \rightarrow$ 

 $\theta_3 \rightarrow$ 





## Numerical Contact Pattern Development Optimization for Gear Noise

Change in CP bias and TE shape/amplitude



High CP/TE=20 arc-sec

Mid CP/TE=0 arc-sec

Low CP/TE=20 arc-sec

# Zerol, Spiral-Bevel, Hypoid Cutting Processes

BI

HyGEARS supports most popular cutting processes, such as :

- Fixed Setting ®
- Modified Roll ®
- Duplex Helical ®
- Spread Blade ®
- Semi-Completing
- Formate ®
- Helixform  $\mathbb{R}$
- Face Hobbing
- Cyclo-Palloid

® The Gleason Works, Rochester, N.Y.

+ SimplexT (Involute Inc.)

Pinion [Spiral-Bevel] [Finishin	g][Nominal] Test-3-Spiral-Bevel.	dat - [mm] [dd 💻 🎽		
ank Cutter TopRem Mach	ine Other Operating Rim-Mater	rial Bearings Links		
Cutting Machine	175U 💌	C[in] ⊙[mm]		
Radial Distance Cutter Tilt Swivel Angle Offset Machine Root Angle Machine Center To Back Sliding Base Rate of Roll Cradle Angle Helical Motion	88.32660           2.7608           25.9734           -0.81897           12.0316           -0.56377           0.55218           3.204817           62.3514           -7.05856			
MRoll 2C MRoll 6D	nion [Hypoid] [Finishing][Nomina	al] M165K-R64.dat - [mi	m] [dd.mm.ss]	×
MRoll 24E Bland	k Cutter TopRem Machine ( Cutting Machine	Other Operating Rim-M	Material Bearings	Links
	Radial Distance Cutter Tilt Swivel Angle Offset Machine Root Angle Machine Center To Back Silding Base Rate of Roll Cradle Angle Helical Motion MRoll 2C MRoll 6D MRoll 24E	86.27400         36.1435         -37.0214         29.68300         -3.0676         -1.06400         25.67500         2.805777         60.4403         0.00000         0.00000         0.00000		
			oply <u>O</u> K	Cancel

### DH vs SimplexT Spiral-Bevel Gears

Duplex Helical: Tilted spread blade pinion cutter Tilted spread blade gear cutter Helical motion <u>Different pinion and gear cutters</u>



### DH vs SimplexT Spiral-Bevel Gears

SimplexT:

Tilted spread blade pinion cutter Non-tilted spread blade gear cutter No helical motion

Identical pinion and gear cutters



# Zerol, Spiral-Bevel, Hypoid Cutting Machines

HyGEARS supports most popular cutting machines:

7A
16
26
102, 106, 108
116, 118, 122
606, 607
613, 631, 641
645, 650, 655, 675
Phoenix (i.e. 175)
Basic (YH 603)

A *Machine Converter*, included in the Geometry Summary Editor, allows machine conversion.

Klingelnberg: Neutral

Gleason:

5Axis CNC machines:

"AC", "BC", "BA" Types



## **Spur/Helical Cutting Processes**

For Spur and Helical gears, HyGEARS supports *Rack* and *Shaping* tools and movements.

Profile modifications may be introduced, up to the 4th order, as well as crowning.

Modules down to 0.1 [mm] and as large as 30 [mm] are easily accommodated by HyGEARS.



# **Straight Bevel Cutting Processes**

Straight Bevel gears are traditionally cut on a 2-tool generator. In HyGEARS, with or without lengthwise crowning, these are referred to as Straight Bevel gears to distinguish with Coniflex.

#### HyGEARS supports:

• Tooth shape for gear box differentials: 2-tool generator type machine; straight edge blade; + M.Roll; often aimed to *forging*.



- Standard tooth shape: 2-tool generator type machine; straight edge blade; M.Roll can be used on CnC machines.
- Both variants can be cut on CnC machines using; CoSIMT, Ball-Mill and End-Mill tools.





# **Coniflex Straight Bevel**

In HyGEARS, Coniflex® refers to the cutting process using a <u>dish-type face mill cutter</u>.

Gleason machines 102, 104, 114 and 134 are supported in native mode. Coniflex® gears can also be cut on 5Axis CnC machines where each side of a tooth is generated using the same cutter on opposite sides of the work piece.



# Fixed Setting Hypoid Pinion



# **Duplex Helical Hypoid Pinion**



# Face Hobbed Gear Set



# Straight Bevel Gears

### Worm Gears













# Splines/Internal Gears

# Helical Gears





# **Beveloid Gears**





# Worm & Helical Gears





# **Spurniflex Gears**





# **Spurved Gears**





# Spiral Face Clutch





# Hirth Coupling





## **Coniflex Bevel Gears**





# Cogged Teeth Coupling





# Curvic Coupling







HyGEARS was calibrated against Gleason's and KIMoS TCA (CP and TE), CMM control, Corrective Machine Settings, LTCA Contact Stresses, etc.

Consistently equivalent results are obtained.





13x24 Face Milled Spiral Bevel gear set

#### Drive Side

Coast Side



8x39 Face Milled Spiral Bevel gear set





#### HyGEARS vs. KIMOS Nominal





#### 8x39 Face Milled Hypoid gear set

#### HyGEARS vs. Gleason - Pinion





#### HyGEARS vs. Gleason - Gear

#### 8x39 Face Hobbed Hypoid gear set

#### HyGEARS vs. Gleason - Pinion









# **HyGEARS Windows: the Parent Window**



# Parent Window Menu

<u>F</u> ile <u>F</u>	Edit	<u>G</u> raphics		<u>M</u> isc.	Window		Display Page	<u>H</u> elp
Open P	Pinion	Pinion		Pinion	Cascade		User Defined	About HyGEARS
Save 6	Gear	Gear		Gear	Tile		BP TCA	HyGEARS Help
Save As N	Number Points	Pinion and Gear		Pinion and Gear	Template 🕨 🕨	Open	BPLTCA	
New Geometry A	Alignment	Reference Frames				Save	Tooth Geometry	
Input Existing Summ C	Configuration				Close		Stock Distribution	
Exit P	Reset Corr Hist			Num. Results	Close All		CMM Nominal	
F	Reset BPat Hist	Tooth−M/C ►	Tooth	Action Trace	Child Windows 🕨	#1	Correction – R.E.	
1 File x P	Registration		Blank			#2	Cutting Machine	
2 File y			Cutter Blade			#3	_	
3 File z			Dia. Over Ball			#4		
4			Caliper Meas.					
5			Full Model					
6			Cutting Machine					
7								
8		Kinematics 🕨 🕨	Path of Contact					
			Bearing Pattern					
			B. Pattern (LTCA)					
			BP Development					
			Sliding Speeds					
			Ease Off					
		Measurement 🕨	Measured Surfaces					
			Tooth Errors					
			Comp. Mes-Sim Surf					
			Stock Distribution					
			Corrective MC Sett					
			Reverse Engineering.					
			CMM Nominal Data					
		2D ( 1						
		2D Graph						
		TE-Peak to Valley						
		Complete Summers						
		complete summary						
		Mashing 🕨	FFA Model					
		wiesimig	Finite Strins					
			rance ourps					

# **HyGEARS Display Modes**

#### HyGEARS can display results in 1 of 2 modes:

- User Defined: user decides what Child window is to be displayed, and where;
- **Pre-defined: 9** displays allow the user to access the most current functions
  - TCA
  - LTCA
  - Geometry
  - Loads (Radial, Axial, Transverse)
  - Stock (Spiral bevel gears; Distribution)
  - Modifications (Spur/Helical gears; Profile, Crowning)
  - CMM (Target file)
  - Corr-RE (Closed Loop; Reverse Engineering)
    - Machine (5Axis CnC)

### **Display Modes: 3D Child Windows**



- Tooth,
- Blank Contour,
- Diameter over Balls,
- Caliper Measurement,
- Full Model,
- Cutting Machine,
- Path of Contact,
- Contact Pattern,
- Ease Off,
- FEA Model,
- Finite Strips,
- Measured Surfaces,
- CMM Nominal Data

### **Display Modes: 2D Child Windows**



- Tooth Errors (thickness and pitch),
- Comparison of Measured and Simulated Surfaces,
- Corrective Machine Settings,
- Reverse Engineering,
- Cutter Blade,
- 2D Graphs

## **Display Modes: TCA**



## **Display Modes: LTCA**



# **Display Modes: Geometry**



# **Display Modes: Tooth Loads**


# Display Modes: Stock (Distribution - Fixed Setting)



# **Display Modes: Modifications (Profile, Crowning)**



# **Display Modes: CMM (Target nominal)**



# **Display Modes: Corr-RE (Closed Loop)**



# **Display Modes: Machine (5Axis CnC)**



### **Display Modes: User**



# **Keyboard Shortcuts**

Dbl-Click maximizes / normalizes the current Child Window

- **^C** copies the content of the current Child Window to the Windows Clipboard,
- Shift<sup>C</sup> copies the content of the current Child Window + Borders to the Windows Clipboard,
- **^E** toggles the current Child Window in and out of the Auto Erase mode,
- **^F** toggles the current tooth flank from Concave to Convex for spiral-bevel and hypoid gears, or from Left to Right for straight-bevel, spur and helical gears,
- ^H cycles through the various possible Hide levels (no, partial, total and rendering) for the current Child Window,
- $\Lambda$  Zooms in one level (max = 10 levels)
- ^J cycles through the various possible display projections for the current Child Window,
- ^M cycles through the various possible Marker levels for the current Child Window,
   ^N toggles the current Child window to use either the coincidence of tooth flank normals (NoSep) or the tooth to tooth separation (Sep) to establish a contact point along the PoC; it is enabled only on those PoC related Child windows such as the PoC, Bearing Pattern and 2D Graphs,
- **^O** to open a geometry data file,
- **^P** sends the content of the current Child Window to the Printer,
- $^{R}$  toggles on and off the display of the Reference Frames,
- **^S** saves the current geometry data file,
- ^T causes the current display to recalculate and send the calculation trace to a Text Results window (Ease Off Child window)
- **^U** Zooms out one level
- <sup>^</sup>Z toggles the current Child Window in and out of the AutoZoom mode.

# **Text Results Window**

Menu	Window Tit	le	Control Butto	ons	*
🖉 Geometry Summary - GS30-15-001.h	уд			_	
File Edit					
* * * * * * * * * * * * * * * * * * * *	* * * * * * * * * * * * * * * * * * * *	*******	*****	***** HyG	ARS V5' ^
WARNING: if any of the foll the values of the	owing values differ : latter will be consid	from the out dered as the	put of the "Summ' reference.	" or "	
HyGEA	RS V 5.0 (C) - Geome	try Summary			
	Quebec, Canada				
Pinion [Nomi: Spiral-Beve	nal]; Gear [Nominal] l - Semi-compl.(Gen),	- GS30-15-0 /Semi-compl.	001.hyg (Gen)	idar Par	~
Date / Time General Units Cutter Units Prepared by Version	: 9/26/2021 / 8:44: : [mm] [D.dec] : [mm] : Claude Gosselin : 5.0.500.10-464	43 PM		ider bar	
GENERAL DATA		PINION	GEAR	_	
Number of Teeth Hand of Spiral Speed Ratio Diametral Ditch	: : :	15 LEFT 2.0000:1	30 RIGHT [Speed Reducer]		U.
<		11./393		*	>

# Context Sensitive Help: F1 Key

🎳 New Geometry Definition - [mm] [[	D.dec] X			
General Cutter Units				
Names Geometry Name Directory Geometry Source File	Test-1-Spiral-Bevel E:\VB SpirBevl.lst			
Types Geometry Type Material	Spiral-Bevel ~	[愛 October 2021] 편 ☆ ♪ 《 應 時		×
Tooth Taper	Left  Standard  V	Hide Back Forward Home Print Options Contents Index Search Favorites Type in the keyword to find:	Navigation: File Input and Output > Creating a New Geometry > General data page	000
Misc Power [Kw] / Torque [N-m] Pinion Speed (RPM) Number of Teeth [Pinion - Gear] Module/Pitch Diameter Gear Tooth Face Width / mn Shaft Angle Depth Factor (Gear) Addendum Factor (Gear) Clearance Factor	298.40       2848.20         1000.00       30       1.333       40         30       1.333       40       338.6667         50.800       6.10323       90.0000         4.000       AGMA / ISO       6.10323         90.0000       AGMA / ISO       0.390         0.125       ISO       ISO	Pto       *         #Tee       #XeY         #XeY       +/-         >>IB       >>OB         Ord 1st 2nd       2D Graphs         2D Graphs Output       2D Graphs Output         2D Graphs Selection Window       3D 2D         3D Graphs Conflex data page       5 Axis CaC Coll Mathematic Action Gamma Collection         3D Graphs Selection Window       3D 2D         3D Graphs Conflex data page       5 Axis CaC Coslift Data Page         5 Axis CaC Coslift Data Page       5 Axis CaC Machine Cycle Data Page         5 Axis CaC Machine Cycle Data Page       5 Axis CaC Machine Definition         5 Axis CaC Machine Definition       5 Axis CaC Machine Definition         5 Axis CaC Machine Definition       5 Axis CaC Machine Patr Reference         5 Axis CaC Machine Patr Reference       5 Axis CaC Oreation data page         5 Axis CaC Machine Patr Reference       5 Axis CaC Oreation data page         5 Axis CaC Machine Patr Reference       5 Axis CaC Probe data page         5 Axis CaC Probe data page       5 Axis CaC Processing         5 Axis CaC Probe data page       5 Axis <cac data="" page<="" probe="" td="">         5 Axis CaC Probe data page       5 Axis         5 Axis CaC Process data page       5 Axis         5 Axis CaC Process data page         5 Axis</cac>	The General data page covers data related to Zerol, Spiral Bevel and Hypoid Gears Straight Bevel and Coniflex Gears Coniflex Gears Spur, Helical and Beveloid Gears	• the gear set blank dimensions, hand of pinion tooth, operating power and speed:          * the gear set blank dimensions, hand of pinion tooth, operating power and speed:         * Mew Generaty Definition - Imma (dd.mm.ml)         * Mew File         * Me
		Actual vs Actual Child Window Actual vs Actual Child Window Function Ang NoAn Arim Arbor Definition Window Autosave Messages Base NoBa Bearing Pattern Bearing Pattern Mathematical States Bearing Pattern Definition Data Page Bearing Pattern Definition Data Page Bearing Pattern Development Bearing Pattern Development Bearing Pattern Development Bearing Pattern Development	Geometry Name * An easy to rememb in the name, as well If the extension is i then be changed at I A Geometry file na charaters. Its extens 	r name for the new Geometry data file must be entered. A good habit is to try to include the tooth numbers as a version number or letter. For example, "14×14", is a 14 tooth pinion with a 41 tooth gear, version A. ot given or is different from "dat", it will either be added or changed to "dat". If desired, this extension can the time of saving the Geometry to disk by using the File -> Save As function. me can be up to 255 characters long, including path and extension; therefore, it should be limited to 32 ion should be nonore than 3 characters long. The following characters are not acceptable: =?](} ame must be entered, including disk name, of the location where the geometry data file is to be stored. The me is "C:hygear30dat". When the New Geometry Definition window is first shown, the Directory field is

HyGEARS offers a *Geometry Summary Editor*, in which all aspects of the geometry, including Machine Settings, can be <u>consulted and modified</u> at any time.

"Pin" -> Pinion Summary Editor

"Gea" -> Gear Summary Editor



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Back A



#### Blank Data ... Spur / Helical / Beveloid

🎳 Pinion [Spu	r-Helical [Ex	t]] [Finishi	ng][Nor	ninal] 24x24	4-Spur-	m3.hy	g - [mm]	[ ×
Blank Cutter	Cutter Edge	Machine	Other	Operating	Rim-Ma	aterial	Bearings	A + +
Pinion (Fini	shing] - Spu	ır-Helical	[Ext]			(in]	۲	mm]
Misc								
# Teeth	24			Pitch Diam	eter	72	2.0000	
Module	3.00	0000						
Part #								
Tooth				Blank				
Tooth Hand	Righ	nt		Minor Diar	neter	64	1.5301	
Face Width	6.00	000		Major Diar	neter	78	3.0046	
Addendum Fa	actor 1.00	800		Addendum	ı	3.	0023	
Dedendum Fa	actor 1.24	150		Dedendun	n	3.	7350	
Fillet Factor	0.25	500		Lead Angl	e	90	0000.	
				Lead / rev	<i>ı</i> .	99	9999.9990	
Front Angle	0.00	000						
Back Angle	0.00	000						
					Apply	,	ОК	Cancel



#### Spiral Bevel Cutter Data ...

🧬 Pinion [Hypoid] [Finishing][Nominal] Demo1441-116-Phoenix.HyG - [mm] [d... 🗙 Blank Cutter TopRem Machine Other Operating Rim-Material Bearings Arbo (in) (mm] Concave-OB Convex-IB Point Diameter 6.0300 6.1600 Blade Angle 10.00.00 28.00.00 B.Edge Rad. 0.0250 0.0250 Point Width 0.0250 0.0250 Cutter Edge Straight Straight  $\sim$ Straight Circular 0.0000 Rad. of Curvature 0.0000 Ref. Height 0.0000 Number of Blades 12 12 Cutter Gaging 0.0000 0.0000 Rad. of Curvature-Ref. Height 0.0000 0.0000 OK Apply Cancel

#### **Fixed Setting**



#### Spiral Bevel Cutter Data ...

🌮 Pinion [Spiral-Bevel] [Finishing][Nominal] Bevel\_Gear\_10x42\_d145\_K08\_Corr.h... 🗙 Blank Cutter TopRem Machine Hi Order Other Operating Rim-Material Bear (in) (mm] Concave-OB Convex-IB Average Diameter 3.5000 Blade Angle 14.0000 26.0000 B.Edge Rad. 0.0310 0.0310 Point Width 0.0571 Cutter Edge Straight Straight  $\sim$ Rad. of Curvature 0.0000 0.0000 Ref. Height 0.0000 0.0000 Number of Blades 12 Cutter Gaging 0.0000 ОК Apply Cancel

#### Spread Blade / DH



#### Spiral Bevel Cutter Data ...

Pinion [Hypoid] [Finishing][Nominal] 13x39 FH.HyG - [mm] [dd.mm.ss] × Blank Cutter TopRem Machine Hi Order Other Operating Rim-Material Bear + + (in) (mm] Concave-OB Convex-IB Point Radius 3.2998 3.4314 Blade Angle 22.8556 16.6742 B.Edge Rad. 0.0468 0.0468 Mean Radius 3.3656 Cutter Edge Circular Circular  $\sim$ Rad. of Curvature 63.6721 59.0689 Ref. Height 0.1898 0.1995 # of Groups/Blade per Group 19 2 Blade Height 0.3248 0.3248 Rad. of Curvature-Ref. Height 0.0000 0.0000 Angular Position 9.4737 0.0000 Blade Thickness 0.4000 0.4000 ОК Cancel Apply

#### Face Hobbing



#### Spiral Bevel TopRem Data ...

Pinion [Hypoid] [F	inishing][Nor	minal] 13x	39 FH.H	yG - [mm	] [dd.mm.ss]	×
Blank Cutter TopRe	m Machine	Hi Order	Other	Operating	Rim-Material	Bear 🔸 🕨
					● [in] (	) [mm]
		Conc	ave-OB		Convex-IB	
TopRem (TM)		No		$\sim$		
TopRem Depth		No A		^	0.0000	
TopRem Angle		AH			0.00.00	
TopRem Radius		AY			0.0000	
Blade Height		BH			0.3859	
Tip Relief Height		BJ BY			0.0	
Tip Relief Angle		BK			0.00.00	
Tip Relief Radius		CH			0.0000	
		CY			-	
		D	l	Арр	ly OK	Cancel





- Linear Blade:
- Linear and Circular TopRem
- Circular Blade:
  - Blade:Circular TopRem only

#### Spiral Bevel Machine Data ...

🎳 Pinio	on (Hyp	ooid] [Finis	hing][Non	ninal] 13x	39 FH.H	yG - [mm]	[dd.mm.ss]	×
Blank (	Cutter	TopRem	Machine	Hi Order	Other	Operating	Rim-Material	Bear 🔸 🕨
Cuttir	ng Macł	nine		Phoenix		~	(in)	) [mm]
Radia	al Distar	ice		119	.03499			
Cutter	er Tilt			24.1	944			
Swive	el Angle			325	.6884			
Offset	t			14.9	9762			
Mach	nine Roo	ot Angle		0.0	141			
Mach	nine Cer	ter To Bac	¢	-0.0	0489			
Sliding	ig Base			25.7	9777			
Rate	of Roll			2.99	9951			
Cradle	e Angle			54.2	2872			
						_		
						Appl	у ОК	Cancel

Changes with the process and machine:

- Fixed Setting
- Modified Roll
- Duplex Helical
- SimplexT
- Non Generated (Formate)
- Face Hobbing
- Cyclo-Palloid
- Etc.

#### Higher Order Data ...

### Controls Modified Roll and Helical Motion up to 6<sup>th</sup> order

🎳 Pin	ion [Hy	poid] [Finis	hing][Nor	ninal] 13x	39 FH.H	yG - [mm]	[dd.mm.ss]	×
Blank	Cutter	TopRem	Machine	Hi Order	Other	Operating	Rim-Material	Bear 🔸 🕨
	Modifi	ed Roll				_		
		1A		0.00	000			
		2C		-0.0	0262			
		6D		0.17	7892			
		24E		-2.5	7423			
		120F		-86.	50411			
		720G		0.00	000			
	Helica	al Motion						
		1st		-0.0	0416			
		2nd		0.41	97			
		3rd		0.00	000			
		4th		0.00	000			
		5th		0.00	000			
		6th		0.00	000			
						_		
						Apply	ок	Cancel

$$L_{1m} = \alpha_3 R_r + \frac{2C}{2} (C_r - \alpha_3 R_r)^2 - \frac{6D}{6} (C_r - \alpha_3 R_r)^3 + \frac{24E}{24} (C_r - \alpha_3 R_r)^4 - \frac{120F}{120} (C_r - \alpha_3 R_r)^5 + \frac{720G}{720} (C_r - \alpha_3 R_r)^6$$

$$X_{bm} = X_b + 1_{st} (C_r - \alpha_3 R_r)^{\square} + 2_{nd} (C_r - \alpha_3 R_r)^2 + 3_{rd} (C_r - \alpha_3 R_r)^3 + 4_{th} (C_r - \alpha_3 R_r)^4 + 5_{th} (C_r - \alpha_3 R_r)^5 + 6_{th} (C_r - \alpha_3 R_r)^6$$

#### Other Data ...

#### Spiral-Bevel / Hypoid

#### Pinion [Hypoid] [Finishing][Nominal] 13x39 FH.HyG - [mm] [dd.mm.ss] $\times$ Blank Cutter TopRem Machine Hi Order Other Operating Rim-Material Bear Misc Speed Increaser Ma 3.0000 Numerical Shaft 90.00.00 Numerical Diff .000500 Tooth Taper Uniform Calculation Trace Nothing M. Distance 116.6000 Err. Surface No Roller-Ball Diameter 9.6520 Tooth Thick 7.5712 Backlash Topland 2.5947 Addendum Factor 0.717 Minimum 0.1016 Depth Factor 4.000 Maximum 0.1524 Apply OK Cancel

### Spur / Helical / Beveloid

Pinion [Spur-Helical [Ext]] [Finishing][Nominal] 24x24-Spur-m3.hyg - [mm] [... X Blank Cutter Cutter Edge Machine Other Operating Rim-Material Bearings A · · Misc Speed Increaser Tooth Thick 4.7113 Numerical Topland 2.1439 Numerical Diff. .000500 Mg 1.0000 Calculation Trace Nothing Shaft 0.0000 Err. Surface No Roller-Ball Diameter 5.1836 Tooth Thick 4.7090 Backlash Epicyclic Gear Crown Speed (RPM) 0 Minimum 0.0508 Number of Planets 1 Maximum 0.1016 Apply OK Cancel

#### Straight-Bevel

lank	Cutter	Cutter Edge	Machine	Hi Order	Other	Operating	Rim-Materia	al B(•
Misc						۲	) [in] C	) [mm]
Spe	ed Increa	aser 🗌						
Mg		1.	2727		Numerica			
Shaf	ft	73	3.30.00					
Toot	th Taper	St	andard		Numerica	al Diff.	.000500	
M. E	)istance	2.	5735	7	Calculatio	on Trace	Nothing	
Rolle	er-Ball Dia	ameter 0.	2800	1	Err. Surfa	ce	No	
Toot	th Thick	0.	1927	1   -				
Top	and	0.	0780	<u> </u>	Backlash			
Add	endum Fa	actor 0.	574		Minimum		0.0020	
Ded	endum Fa	actor 1.	884		Maximum	1	0.0040	



#### Operating Data ...

🎳 Pin	ion [Stra	ight Be	vel [G	enerated]	[Finishin	ig][Nom	iinal] 22x28S	Straight7.5D	P ×
Blank	Cutter	Cutter E	dge	Machine	Hi Order	Other	Operating	Rim-Materia	B + +
Class AGM Tran Surf. Fillet Facto Stree Load Ka: J Ks: S Kv: I Km: Kx: C Kpm J: P J: P	A Class IA Class Is. Quality Finish [u Finish for ors ngth Calc d Position Applicatio Size Dynamic Load Dist Curvature : Mountin inion Left inion Rigl	, in] ulation n tr. g	11 Prec 31.8 31.8 AGM 1.10 1.00 1.00 1.00 1.00 1.00 1.00	ision  9 9 9 1A-Mod  10 10 10 10 10 10 10 10 10 10 10 10 10		Power [H RPM Torque [ Oil Type Oil T. [F] Friction ( Stresses Bending Bending Contact Contact	Ib-in]       Coeff.       [Ksi]       - Left       - Right       - Right	[in] O	
							Apply	ОК	Cancel



**HPSTC**:

Mid-height: Free: Highest point of single tooth contact (or Transfer Point); thus the PoC is first calculated; mid tooth-height, at mid-face width; at tooth tip if AGMA Class < 9; at HPSTC if AGMA Class > 8

\*\*\* HYGEARS OIL DEFINITION FILE \*\*\*

Source: Errichello R., The Lubrication of Gears, Part I, Gear Technology, March/April 1991 Errichello R., The Lubrication of Gears, Part II, Gear Technology, May/June 1991 Equivalences: : TSO AGMA SAE Crankase SAE Gear \_\_\_\_\_ 1500 250 ; 1000 8A 250 (lower) 680 8 140 (upper) 460 7 140 320 6 ; 
 320
 6

 220
 5
 50

 150
 4
 40

 100
 3
 30

 68
 2
 20W-30
 140 (lower) 90-85W 85W 80W 80W 46 1 20W-20 75W This is a comment line that is ignored by HyGEARS. Comment lines should appear at the beginning of the file, and start with a ";" semi-colon character. Each oil definition is made of 2 consecutive lines: one for Absolute Viscosity (uReyns, Reyns or lb/in2) one for Pressure-Viscosity Coefficient (in2/lb, m2/N) 1st Oil data line is given in the following sequence: Oil Name Absolute Viscosity Units (UREYN, REYN, CP) Temperature Units (F, C) (Viscosity-Temperature) Data Sets 2nd Oil data line is given in the following sequence: Oil Name Pressure-Viscosity Coefficient Units (IN2/LB, M2/N) Temperature Units (F, C) Data Sets (Pressure-Viscosity Coefficient-Temperature) ; Warning : the character "-" is a separator between Viscosity and Temperature Pressure-viscosity coefficient and Temperature ISO 1500, UREYN, F, 200-100, 90-120, 47-140, 25-160, 15-180, 9.5-200, 6.1-220, 4.3-240, 3-260 ISO 1500, IN2/LB, F, 2.2-100, 1.9-125, 1.75-150, 1.61-175, 1.48-200, 1.35-225, 1.25-250, 1.15-275, 1.07-300

#### Rim - Material Data ...

🎳 Pin	nion [Stra	aight Be	vel [G	enerated]	] [Finishin	ig][Nom	inal] 22x28	Straight7.5DP	×
Blank	Cutter	Cutter E	dge	Machine	Hi Order	Other	Operating	Rim-Material	B
Rim							۲	[in] ()	[mm]
Rim	Thick.		0.29	22					
Wel	b Thick.		0.00	00					
Wel	b %Rim [(	)->100]	50.0	)		Material			
Ang	le		0.00	)		Material		AISI 4140	$\sim$
Hub	OD		0.00	00		Young [ł	Ksi]	AGMA A-1 AGMA A-2	
Hub	D		1.04	00		Poisson		AGMA A-3	
Rim	-Web Ra	d.	0.00	00		Bending	[Ksi]	AGMA A-4 AGMA A-5	
Wel	b-Hub Ra	d.	0.00	00		Contact	[Ksi]	AISI 4140 AISI 4340	
Hub	(Toe)		0.00	00		Hardnes	s	AISI 8620 NITR 135M	
Hub	(Heel)		0.00	00		R. Densi	ity	2.5% CHRM 16 MpCr 5	
Hee	l Rib OD		0.00	00		Bending	-ISO [MPa]	16 MnCrB 5	
Hee	el Rib Thio	ckness	0.00	00		Contact-	ISO [MPa]	31 CrMo V9	ь
							Apply	ISO_ME ISO_MQ2 ISO_MQ3 ISO_ML CK45	
							, ppiy	POM -40De	



*** HYGEARS MA	TERIAL	FILE	* * *							
; This is com	ment l	ine wl	nich i	s ign	ored					
; by HyGEARS.	Comme	nt li	nes sh	ould	appea	r at '	the			
; beginning o	f the	file,	and s	tart	with a	a ";"	semi	-colo	n cha:	racter.
;										
; Material da	ta is	given	in th	e fol	lowin	g seq	uence	:		
;	Mater	ial N	ame							
;	Bendi	ng St	rength							
;	Compr	essiv	e Stre	ngth						
;	Stren	gth u	nits (	PA, K	PA, M	PA, G	PA, P	SI, K	SI)	
;	Young	Modu	lus							
;	Poiss	on ra	tio							
;	Young	Modu	lus un	its (	PA, K	PA, M	PA, G	PA, P	SI, K	SI)
;	Hardn	ess v	alue							
;	Hardn	ess u	nits (	BHN,	HRC,	HRB)				
;	Relat	ive d	ensity	(rel	ative	to w	ater)			
AGMA A-1	,	200,	630,	MPA,	200,	0.3,	GPA,	180,	BHN,	7.8
AGMA A-2	,	250,	750,	MPA,	200,	0.3,	GPA,	240,	BHN,	7.8
AGMA A-3	,	280,	870,	MPA,	200,	0.3,	GPA,	300,	BHN,	7.8
AGMA A-4	,	320,	1050,	MPA,	200,	0.3,	GPA,	360,	BHN,	7.8
AGMA A-5	,	340,	1150,	MPA,	200,	0.3,	GPA,	400,	BHN,	7.8
AISI 4140	,	270,	1175 <b>,</b>	MPA,	200,	0.3,	GPA,	48,	HRC,	7.8
AISI 4340	,	290,	1125,	MPA,	200,	0.3,	GPA,	46,	HRC,	7.8
NITR 135M	,	295,	1250,	MPA,	200,	0.3,	GPA,	60,	HRC,	7.8
2.5% CHRM	,	415,	1300,	MPA,	200,	0.3,	GPA,	57,	HRC,	7.8

#### Bearing Data ...

🎳 Pin	ion [Straight	Bevel [Ger	nerated]] [	Finishi	ng][Nomina	l] 22x28St	raight7.5	DP	. ×
Cutter	Cutter Edge	Machine	Hi Order	Other	Operating	Rim-Mate	rial Bea	rings	• •
Posit Toe Hee	ion [in] Ref: Back Face	þ.000 0.536				۲	(in] (	) (m	m]
Stiffn Alon Alon Alon	ess Toe [lb/in] g X g Y g Z	20000 20000 20000	00.0		Dimensions I.D. O.D. Width	Toe [in]	0.838 1.257 0.063		
Stiffn Alon Alon Alon	ess Heel [lb/in g X g Y g Z	20000 20000 20000	00.0		Dimensions H I.D. O.D. Width	Heel [in]	0.838 1.257 0.063		
					[	Apply	ОК	С	ancel



# **VH Settings Editor**

#### Bevel Gears ...

<b>""⁵</b> V-H Setti	ings - [in] - Str	aight Bevel [Ger	nerated]	×
E-P-G Align	ment Runout	Links		
E: (Pinion C	(ffset) 0.0000			
P: (Pinion A	xial) 0.0000	Pinion Radial	0.0000	]
G: (Gear Ax	ial) 0.0000	Gear Radial	0.0000	]
				_
	Apply	Reset Of	K Cano	el

×
el



# **VH Settings Editor**

#### Spur / Helical Gears ...

🎳 V-H Settings - [mm] [D.dec] - Spur-Helical [Ex	$\times$
E-P-G Alignment Runout Links	
Center Distance 72.0000	
P: (Pinion Axial) 0.0000	
G: (Gear Axial) 0.0000	
Apply Reset OK Can	cel

🎳 V-H Settings - [mm] [D.dec] - Spur-Helical [Ex	×
E-P-G Alignment Runout Links	
Misalignment 0.0000	
Shaft Angle	
0.0000	
Apply Reset OK Can	icel



# **HyGEARS** Configuration

	🞳 Configuration HyGEA	ARS V 5.0 (C)	×			
	General Units Fonts	Graphics Colors Display				
General Data Page	Bell       1         Language       E         Log File       1         Num. Diff. Increment       0         Auto Save Interval       S         Geometry Folder       E         Support Folder       0         Tool Folder       0	No   English   No   No   No   English   No   No   No   C:\Users\HyGEA\Documents\HyGEA  C:\Users\HyGEA\Documents\HyGEA	 EJ EJ			
	General Units Fonts	Apply OK ARS V 5.0 (C) Graphics Colors Display	Cancel		[in] [	
Units Data Page	Angle Units Linear Units Cutter Units TE Units AGMA/ISO input	Decimal mm mm uRad AGMA	> > > >	Torque Force Stress Power Stiffness Volume Mass Inertia Speed Misalignment Surface Finish	[lb-in] [lb] [Ksi] [HP] [lb/in] [lbm] [lbm] [lbm- in <sup>2</sup> ] [ft/min] [In/in] [μin] [F]	2222
		Apply OK	Cancel	Warp	[/0.1 in]	

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[mm] [N-m] [N]

[Mpa] [Kw]

[N/mm] [mm<sup>3</sup>] [kgm] [kgm-mm<sup>2</sup>] [m/min] [mm/mm] [µm] [C] [/10 mm]

# **HyGEARS Configuration / 2**

	Configuration HyGEARS V 5.0 (C)		🎳 Configuration HyGEARS V 5.0 (C)					×		Font				×
			e .						Eont:		Font style:	<u>Size:</u>		
	General	Units	Fonts	Graphics	Colors	Display			Couner New		Regular		ОК	
									Courier New Credit Valley	<b>-</b>	Regular ^	11	Cancel	
									Cuelz MT		Bold	12		
	Text	Font		Courier	New						Bold Italic	16		
Fonta Data Daga	# poi	nte (Tevt)		10					Edwardian Script IT C	-	-	20 🔻	•	
Fonts Data Page	# points (Text)						Effects		Sample		_			
	Graph	hic Font		Calibri					Strikeout					
	# poi	nts (Grapl	h)	10					Underline		AaBbYy	lz		
	Greek	k Font		Symbol							Script:			
								1			Western	•	•	
	Input	Field For	rt	Microso	ft Sans Se	erit								
					Apply	ОК	Cancel							

General	Units	Fonts	Graphics	Colors	Display	
Hidder	n Lines		Rende	ering		~
Zoom			Auto			~
Projec	tion Typ	е	User [	Defined \	/iew	$\sim$
Refere	ence Fra	nes	No			
Omeg	a X Y Z		238, -	10, 270		
Meas.	AutoSca	ale	Yes			
Rotati	on Increr	ment	2.5			
YMin-	Max XMi	n-Max	-15, 1	5, -15, 15	5	
			1	Apply	ОК	ance

#### Graphics Data Page

# **HyGEARS Configuration / 3**



# **HyGEARS Configuration / 4**

General	Units	Fonts	Graphics	Colors	Display	
What	is display	yed	1: Black I	Lines		$\sim$
			1: Black I	Lines		<b>^</b>
			2: Ease C	91		
Desired color			4: Cutter			
			5: Pinion	Fill	Cutter Dide	
			6: Gear F	ill		
			7: Cutter	Fill		
			8: Cradle			
			9: 100th			
			10: Pressure Angle			
			12: Base I	Pitch		ncel



### Colors Data Page

Configuration HyGEARS V 5.0 (C)							
General Units Fonts G	raphics Colors Display						
@Load Geometry	BP TCA						
@Create Geometry	User Defined BP TCA BP LTCA						
Ease Off is shown Con	Stock Distribution						
	Correction - R.E. Cutting Machine						
	Apply OK Can	cel					

### Display Data Page

In HyGEARS, creating a new geometry is simple.

The New Geometry Definition Window offers basic input fields in which the required data is provided.

The New Geometry can be processed at once, and saved in a file for later retrieval.

At every step, HyGEARS offers *default values* to ease creation.

Entries in <u>yellow</u> must be provided by the user.

🎳 New	Geometry Definition - [mm] [[	D.dec]	×
General	Cutter Units		
Nan	nes		
G	eometry Name	Test-1-Spiral-Bevel	
D	Virectory	E:\VB	
G	eometry Source File	SpirBevI.lst	
Тур	es		
G	eometry Type	Spiral-Bevel	
N	laterial	Beveloid [Ext] Beveloid [Int]	
Т	ooth Taper	Cross Helix Crowniflex	
Mise	c	CurFace Curvic Coupling Face Clutch	
P	ower [Kw] / Torque [N-m]	Face Gear Form Face	1
	lumber of Teeth (Pinion, Cear)	Herringbone Hirth Coupling	
	Auniber of Teetri (Finion - Gear)	Hypoid	
IV	Indule/Fitch Diameter	Involute Spline	
G	ear Tooth Face Width / mn	Shaper [bt]	
S	ihaft Angle	Skiving [Ext]	
D	)epth Factor (Gear)	Skiving [Int] Spiral-Bevel	
A	ddendum Factor (Gear)	Spur-Helical [Ext]	1
C	learance Factor	Spur-Helical [Int]	
		Spurved	
		Straight Bevel [Generated]	
		Worm & Helical Worm Gear	
		Zerol	Cancel
			-

Bevel Gear Macro and Micro Geometry:

- Basic dimensions are established as per AGMA 2005.
- Initial machine settings are established from Basic dimensions and given cutter specs.
- Tooth dimensions are applied as per Depth and Addendum factors; thus, generated members are not checked for undercutting; profile shift is *not modified* if undercutting is present.
- Clearance is calculated on pinion and gear;
- Contact Pattern is *pre-developed*:
  - CP is Centered Length wise on Gear Tooth
  - CP is Centered Depth wise on Gear Tooth
  - Any Bias *is ignored* at this time
- Design is displayed for user evaluation.

#### Bevel Gear Macro Geometry

Basic dimensions are based on AGMA 2005:

- Depth and Addendum Factors
- Clearance
- Outer Cone Distance
- Face Width
- Cutter Diameter
- Pitch Angle
- Addendum and Dedendum Angles



#### Bevel Gear Macro Geometry

For Hypoid gears:

Spiral Angle (based on Offset)

$$\psi_P = 25 + 5 \sqrt{\frac{N}{n}} + 90 \frac{E}{D}$$

FApx-Xp	(A)
RApx-Xp	(B)
PApx-Xp	(C)
C-Xp	(D)
FC-Xp	(E)



#### Bevel Gear Macro Geometry

#### Tooth Taper (Zerol, Spiral Bevel, Hypoid):








# Creating a New Geometry

### Bevel Gear Macro Geometry:

### Dedendum Angle

Depthwise taper	Sum of dedendum angles (degrees)
Standard	$\Sigma \delta_S = \arctan\left(\frac{b_P}{A_{mG}}\right) + \arctan\left(\frac{b_G}{A_{mG}}\right)$
Uniform depth	$\Sigma \delta_U = 0$
Duplex	$\Sigma \delta_D = \left(\frac{90.0}{P_d A_{oG} \tan \phi \cos \psi}\right) \left(1 - \frac{A_{mG} \sin \psi}{r_c}\right)$
	$\Sigma \delta_D = \left(\frac{m_{et} 90.0}{A_{oG} \tan \phi \cos \psi}\right) \left(1 - \frac{A_{mG} \sin \psi}{r_c}\right) \qquad (M)$
TRL	$\Sigma \delta_T = \Sigma \delta_D$ or 1.3 $\Sigma \delta_S$ , whichever is smaller

Depthwise taper	Dedendum angles (degrees)
Standard	$\delta_P = \arctan\left(\frac{b_P}{A_{mG}}\right)$
	$\delta_G = \Sigma \delta_S - \delta_P$
Uniform depth	$\delta_P = \delta_G = 0$
Duplex	$\delta_P = \Sigma \delta_D \frac{a_G}{h}$
	$\delta_G = \Sigma \delta_D - \delta_P$
TRL	$\delta_F = \Sigma \delta_T \frac{a_G}{h}$
	$\delta_G = \Sigma \delta_T - \delta_P$

# Creating a New Geometry

### Straight, Zerol and Spiral Bevel Gears

item	Pinion	Both pinion and gear	Gear	Item	Pinion	Both pinion and gear	Gear
Pitch diameter	$d = \frac{n}{P_d}$		$D = \frac{N}{P_d}$	Mean circular pitch (metric)		$\left(p_m = \pi m_{el} \frac{A_m}{A_o}\right)$	
(metric)	$(d = n m_{et})$		$(D = N m_{et})$	Mean addendum	$a_P = h - a_G$		$a_G = c_1 h$
Bitch apple	sinΣ		<b>F</b> = <b>F</b>	Mean dedendum	$b_P = h_m - a_P$		$b_G = h_m - a_G$
Frich angle	$\gamma = \arctan \frac{N}{n} + \cos \Sigma$		1 = 2 ~ γ	Sum of dedendum		Σδ (See table 6)	
Outer cone distance		$A_o = \frac{0.5D}{\sin \Gamma}$		Dedendum angle	δ <sub>P</sub> (See table 7)		$\delta_{C}$ (See table 7)
Mean cone distance		$A_m = A_o - 0.5F$		Face angle	$\gamma_o = \gamma + \delta_G$		$\Gamma_o = \Gamma + \delta_P$
Depth factor		k <sub>1</sub> (See table 4)		Root angle	$\gamma_R = \gamma - \delta_P$		$\Gamma_R = \Gamma - \delta_G$ .
Mean working depth		$h = \frac{k_1}{m} \left( \frac{A_m}{m} \right) \cos \psi$		Outer addendum	$a_{oP} = a_P + 0.5F \tan \delta_G$		$a_{oG} = a_G + 0.5F \tan \delta_P$
		$P_d(A_o)$		Outer dedendum	$b_{oP} = b_P + 0.5F \tan \delta_P$		$b_{oG} = b_G + 0.5F \tan \delta_G$
(metric)		$\left(h = k_1 m_{et} \left(\frac{A_m}{A_m}\right) \cos \psi\right)$		Outer working depth		$h_k = a_{oP} + a_{oG}$	
Clearance factor		(See 7.5)		Outer whole depth	d = d + 2a over	$h_I = a_{OP} + b_{OP}$	$D = D + 2a$ cos $\Gamma$
Clearance		$c = k_0 h$		Pitch cone apex to	$a_0 = u + 2u_{oP} \cos \gamma$		$D_0 = D + 2a_{0G}\cos t$
Mean whole depth		$h_m = h + c$		crown	$x_o = A_o \cos \gamma - a_{oP} \sin \gamma$		$X_o = A_o \cos \Gamma - a_{oG} \sin \Gamma$
Equivalent 90° ratio		$m_{90} = \sqrt{\frac{N}{n} \frac{\cos \gamma}{\cos \Gamma}}$		Mean diametral pitch		$P_{dm} = P_d \left(\frac{A_o}{A_m}\right)$	
Mean addendum factor		$c_1$ (See table 5) $\pi (A_m)$		Mean pitch diameter	$d_m = \frac{n}{P_{dm}}$		$D_m = \frac{N}{P_{dm}}$
Mean circular pach		$P_m = \frac{H}{P_d} \left( \frac{M}{A_o} \right)$		Thickness factor		k <sub>3</sub> (See figure 21)	
				Mean normal circular thickness theoretical without backlash	$t_n = p_m \cos \psi - T_n$	$T_n = (0.5 p_m \cos \psi)$	$-(a_P-a_G)\tan\phi-rac{k_3\cos\psi}{P_{dm}}$
				Outer normal backlash allowance		B (See table 8)	
				Outer spiral angle (face milling)		$\sin\psi_o = \frac{2A_m r_c \sin\psi - A_m^2 + 2A_o r_c}{2A_o r_c}$	<u>A<sub>0</sub><sup>2</sup></u>
				Outer spiral angle (face hobbing)		$N_c = \frac{N}{\sin\Gamma}$	
						$\sin v = \frac{A_m N_s}{r_c N_c} \cos \psi$	
						$\lambda = 90^{\circ} - \psi + v$	
						$S_1 = \sqrt{A_m^2 + r_c^2 - 2A_m r_c \cos \lambda}$	
						$Q = \frac{S_1}{1 + \frac{N_s}{N_c}}$	
						$\cos \eta_o = \frac{A_o^2 + S_1^2 - r_c^2}{2A_o S_1}$	
						$\tan \psi_o = \frac{A_o - Q \cos \eta_o}{Q \sin \eta_o}$	
				Mean normal chordal thickness	$t_{nc} = t_n - \left(\frac{t_n^3}{6d_m^2}\right) - 0.5B \left[\frac{1}{\cos^2 t_n^2}\right]$	$\frac{\frac{A_m}{A_o}}{\frac{\cos\psi}{\cos\psi_o}} \qquad T_{nc} = T_n - \left($	$\left(\frac{T_n^3}{6D_m^2}\right) = 0.5B \left[\frac{\frac{A_m}{A_o}}{\cos\phi \frac{\cos\psi}{\cos\psi_o}}\right]$
				Mean chordal	$a_{nn} = a_n + 0.25 \frac{t_n^2 \cos \gamma}{t_n^2 \cos \gamma}$		$T_{\pi}^{2}\cos\Gamma$

# Creating a New Geometry

### Hypoid Gears ...

ltem	Pinion	Both pinion and gear	Gear	ltem	Pinion	Both pinion and gear	Gear
Pitch diameter			$D = \frac{N}{P_d}$	Spiral angle	$\tan \psi_P = \frac{K_1 + \Delta K - \cos \varepsilon'_1}{\sin \varepsilon'_1}$		$\psi_G = \psi_P - \mathfrak{c'}_i$
(metric)		N	$(D = Nm_{et})$	Gear pitch angle		tan F	$= \frac{\sin \varepsilon_1}{\cos \varepsilon_1 \cos \varepsilon_1} + \cos \varepsilon_1 \tan \varepsilon_2$
Gear ratio Desired pinion spiral		$m_G = \frac{m}{n}$		Mean cone distance			$a_{m(i)} = \frac{R}{\sin \Gamma}$
angle Shaft angle departure from 90°	$\Psi_{oP} = \Psi_P$	$\Delta\Sigma = \Sigma - 90$		Pinion mean radius increment	$\Delta R_P = \left(\frac{\Delta R_P}{R}\right) R$		
Approximate gear pitch			$\tan \Gamma_i = \frac{m_G(\cos \Delta \Sigma)}{10^{11}}$	Mean cone distance	$A_{mP} = \frac{R_{2P} + \Delta R_P}{\sin \gamma}$		
Gear mean pitch radius			$R = \frac{D - F \sin \Gamma}{D - F \sin \Gamma}$	Mean pinion radius	$R_P = A_{mP} \sin \gamma$	$\tan x \tan \Gamma (A = \sin w_0 = A)$	sinwa
Approximate pinion	E sin E		R = 2	Limit pressure angle	$(-\tan\phi_0) =$	$\frac{\tan \gamma \tan \gamma}{\cos \varepsilon'_1} \left( \frac{A_m \gamma \sin \gamma p}{A_m \gamma + A_m} \right)$	$\frac{1}{7} \tan \Gamma$
offset angle in pitch plane	$\sin \varepsilon'_i = \frac{E \sin \Gamma_i}{R}$			For face hobbed gears make the following		$N_c = \frac{N}{\sin\Gamma}$	
dimension factor		$K_1 = \tan \psi_{oP} \sin \varepsilon'_i + \cos \varepsilon'_i$		Calculations		AmGNs	
Approximate pinion mean radius	$R_{2P} = \frac{RK_1}{m_G}$					$\sin v = \frac{1}{r_c N_c} \cos \psi$ $\lambda = 90^\circ - \psi_c + v$	
		Start of iteration First trial			s <sub>1</sub>	$= \sqrt{A_{mG}^2 + r_c^2 - 2A_{mG}r_c\cos\lambda}$	
Gear offset angle in axial plane		$\tan \eta = \frac{1}{R(\tan \eta)}$	$\frac{E}{\Gamma_{1}\cos\Delta\Sigma - \sin\Delta\Sigma + R_{2P}}$		c0	$hs\eta_1 = \frac{A_{mG}\cos\psi_G}{S_*N_c}(N_c + N_s)$	
		Second trial	i 21			Г	٦
Intermediate pinion offset angle in axial	$\sin \varepsilon_2 = \frac{E - R_{2P} \sin \eta}{R}$			face hobbed gears	$\rho = A_{mG} \cos \eta$	$\psi_G \left[ \tan \psi_G + \frac{\tan \eta_1}{1 + \tan \nu (\tan \psi_G)} \right]$	$+ \tan \eta_1$
ntermediate pinion	$\tan \gamma_2 = \frac{\sin \eta}{1 + \tan \eta}$	$n \Delta \Sigma \cos \eta$		Mean tooth curvature face milled gears	$\rho = r_c$		
pitch angle	$t_2 = \tan \varepsilon_2 \cos \Delta \Sigma$				Calculate the following		
offset angle in pitch plane	$\sin \varepsilon'_2 = \frac{\sin \varepsilon_2 \cos \Delta \Sigma}{\cos \gamma_2}$			For Method 1	$r_{c1} = \frac{1}{(-\tan\phi_0)\left(\frac{\tan\phi_0}{1-\tan\phi_0}\right)}$	$\frac{\sec \phi_o \tan \psi_P - \tan \psi_G}{\tan \psi_P} + \frac{\tan \psi_G}{\cos \varphi_O} + \frac{1}{\cos \varphi_O}$	+
ntermediate pinion mean spiral angle	$\tan \psi_{2P} = \frac{K_1 - \cos \varepsilon'_2}{\sin \varepsilon'_2}$			Limit curvature radius	(A <sub>mi</sub>	$\frac{1}{2} \tan \gamma = A_{mG} \tan \Gamma = A_{mP} \cos \frac{1}{2}$	$s\psi_P  A_{mG}\cos\psi_G$
ncrement in hypoid		$\Delta K = \sin \epsilon'_2 (\tan \psi_{\alpha P} - \tan \psi_{2 A})$	)	For Method 2	Calculate the following		
Ratio of pinion mean radius increment to gear mean pitch		$\frac{\Delta R_P}{R} = \frac{\Delta K}{m_e}$	, 		$\Delta = \frac{r_c \cos(\psi_G - \nu)}{A_{mG} \sin \Gamma - r_c \sin \Gamma \sin(\psi_G - \nu)}$	$\frac{n\cos\psi_{G}\sin\psi_{G}}{N\cos\psi_{P}\sin\gamma - n\cos\psi_{G}}$	$\varepsilon'_1$ s $\psi_G \cos \varepsilon'_1$
radius		к <sup>"</sup> G			Change $\eta$ until $\Delta \leq 0.001$	End of iteration	
Pinion offset angle in axial plane	$\sin \varepsilon_1 = \sin \varepsilon_2 - \frac{\Delta R_P}{R} \sin \eta$			Pressure angle concave	$\phi_1 = \phi + \phi_o$		$\phi_2 = \phi - \phi_o$
Pinion pitch angle	$\tan \gamma = \frac{\sin \eta}{\tan \varepsilon_1 \cos \Delta \Sigma} + \tan z$	$\Delta\Sigma \cos \eta$		Pressure angle convex	$\phi_2 = \phi - \phi_o$		$\phi_1 = \phi + \phi_o$
Pinion offset angle in pitch plane	$\sin \varepsilon'_1 = \frac{\sin \varepsilon_1 \cos \Delta \Sigma}{\cos \gamma}$			point along pinion axis	$Z_P = A_m P \tan \gamma \sin \Gamma - \frac{E \tan \Lambda}{\tan \varepsilon_1}$	Σ	
				Gear pitch apex beyond crossing point			$Z = \frac{R}{\tan\Gamma} - Z_P$
				Outer cone distance			$A_{oG} = \frac{0.5D}{\sin \Gamma}$

Correction and RE



Corrective Machine Settings – i.e. Closed Loop - (like Gleason's GAGE) and Reverse Engineering

CMM data is used to calculate changes in machine settings needed for the actual tooth surface to match the theoretical tooth surface.

Corrective Machine Settings/RE support:

- 1<sup>st</sup> order errors: spiral angle, pressure angle, tooth taper;
- 2<sup>nd</sup> order errors: crowning and tooth warp (bias);
- Roughing and Finishing;
- All FM and FH cutting processes, Straight bevel, Coniflex, Spur, Helical and Face gears.

<sup>5</sup> Corrective Machine Settings	Pinion - [Finishing]	×	🖉 Corrective Machine Setting	ıs Pinion - [Finishing]		×
Tolerance Order Machine			Tolerance Order Machine			
Actual vs Actual Targets and Tolerances Tooth Thickness [mm] Pressure Angle [dd.mm.ss] Spiral Angle [dd.mm.ss] Crowning [mm] Profile Curvature [mm] Warp Factor [/10 mm] Tooth Taper [dd.mm.ss]	Concave-OB 0.0000 ± 0.0127 0.00.00 ± 0.00.10 0.00.00 ± 0.0015 0.0000 ± 0.0015 0.0000 ± 0.0010 0.00.00 ± 0.00.10 0.00.00 ± 0.00.25	Convex-IB 0.0000 ± 0.0127 0.00.00 ± 0.00.10 0.0000 ± 0.0015 0.0000 ± 0.0015 0.0000 ± 0.0010 0.00.00 ± 0.0010 0.00.00 ± 0.00.10 0.00.00 ± 0.00.25	Cutting Changes Order	Tooth Rank Con-OB Cvx-IB Con-OB + Cvx-IB Drop @ bottom: 0 Machine Gleason 116 Maintair Maintair Maintair Maintair	Selection All Spiral Angle Pressure Angle Tooth Taper Tooth Thickness Bias Crowning Profile Twist	
	Apply <u>R</u> eset	Print OK Cancel		Apply <u>R</u> eset	Print OK Ca	ancel

### CMM Output converted to HyGEARS common format

🗳 CMM-Simulati	on Comparison - Pinion Demo1441-116-Phoenix.HyG X
Geometry Displayed Tooth #	Pinion v 1 v
CMM File:	e:\vb\hygear25\demo\demo_p12.mes
	Apply OK Cancel

HyGEARS tests if the data file is of type:

- "Ram" / "Rfd";
- "Gleason-Zeiss";
- "Hoeffler";
- "MdM";
- "Klingelnberg-P";
- "GAGE";
- "Zeiss Gear Pro";
- "Mitutoyo";
- "HyGEARS".

RAM File Name:	e:\vb\hygear25\demo\demo_p.ram
	Create Nominal
	Mirror Image (Punch Mode)
	Overall Punch Height 0.0000
Thickness Error:	0.0000
RFD File Names:	e:\vb\hygear25\demo\demo_p.Rfd E:\VB\Demo\Demo_p1.rfdE:\VB \Demo\Demo_p2.rfd
Measured Tooth #s:	1.0
Medadred Toodi Ha.	1;6;
Output File Name:	e:\vb\hygear25\demo\demo_p1.mes

If <u>not</u> HyGEARS type, then the file must be converted to the HyGEARS format

Surface Match Algorithm for Correction / R.E.

The *Surface Match* algorithm (introduced in 1994) :

- Changes the machine settings of the selected member until the *measurement surface* statistics are within given tolerances;
- Uses the *sensitivity of the error surface* (difference between measurement and simulation) to chosen control parameters to iterate until the desired tolerances are met;



- Applies a Newton-Raphson based iterative process to solve objective functions.

## Surface Errors



### Surface Errors

### Warp (Bias) Error:





 $\zeta = \Phi_1 - \Phi_j$ 

### Taper Error:





$$\Delta \Psi = \Psi_{IB} - \Psi_{OB}$$

### Correction and RE

### Corrective Machine Settings (Closed Loop): 1st time -> identify the reference Nominal Summary

Corrective Machine Setting	s Pinion - [Finishing]	×
Tolerance Order Machine		
Cutting Changes Order Ord Ist 2nd Middle Row Middle Column # Iterations Max. # Iteratio 20	Tooth Flank Con-OB Cvx-IB Con-OB + Cvx-IB Drop @ bottom: 0 Machine Gleason 116	Selection All Spiral Angle Pressure Angle Tooth Taper Tooth Thickness Bias Crowning Profile Twist
✓ Auto Damping ☐ Recalc Jacobian each Itera	ation Maintai	n Point Width n Tooth Thickness n Tooth Depth <u>Print</u> OK Cancel



## Correction and RE

<sup>5</sup> Corrective Machine Settings	Pinion - [Finishing]	×	Corrective Machine Settings	Pinion - [Finishing]		х
Tolerance Order Machine			Tolerance Order Machine			
Actual vs Actual Targets and Tolerances Tooth Thickness [mm] Pressure Angle [dd.mm.ss] Spiral Angle [dd.mm.ss] Crowning [mm] Profile Curvature [mm] Warp Factor [/10 mm] Tooth Taper [dd.mm.ss]	Concave-OB 0.0000 ± 0.0127 0.00.00 ± 0.00.10 0.00.00 ± 0.0015 0.0000 ± 0.0015 0.0000 ± 0.0010 0.00.00 ± 0.00.10 0.00.00 ± 0.00.25	Convex-IB 0.0000 ± 0.0127 0.00.00 ± 0.00.10 0.00.00 ± 0.00.10 0.0000 ± 0.0015 0.0000 ± 0.0015 0.0000 ± 0.0010 0.00.00 ± 0.00.10 0.00.00 ± 0.00.25	Cutting Changes Order Ord Ist 2nd Middle Row Middle Column # Iterations Max. # Iteratio 20 Auto Damping Recalc Jacobian each Iteration	Tooth Flank Con-OB Cvx-IB Con-OB + Cvx-IB Drop @ bottom: Machine Gleason 116 Maintain Maintain Maintain	Selection All Spiral Angle Pressure Angle Tooth Taper Tooth Thickness Bias Crowning Profile Twist Point Width Tooth Thickness Tooth Depth	
	Apply <u>R</u> eset	Print OK Cancel		Apply Reset	Print OK Canc	cel

Tolerance Order Machine Correction Expected Stats Errors options on target values and tolerances; options on what is to be corrected; options on control parameters constraints; calculated changes in machine settings; what HyGEARS expects after correction; point by point differences

## Correction and RE

	Tolerance Orde	Machine	Correction	n [mm] Expected St	ats Errors
Machine Root Angle	lst Order	Changes		(O.B.)	(I.B.)
Cutter Spindle Angle	Machine Ro Eccentric	ot Angle Angle	:	0.00.00	0.00.00
Profile Curvature O Blade Curvature	Cradle Ang Swivel Ang Cutter Spi	le le ndle Angl	: e :	0.09.47 -0.02.45 0.00.00	0.15.41 -0.04.34 -0.00.00
Offset	Decimal Ra	tio	:	-0.00108	-0.0026
Crowning  Point Diameter  Machine Center To Back	Machine Ce Sliding Ba Blank Offs	nter To B se et	ack : : :	-0.0027 -0.1020 [Up] 0.0000	0.0000 0.0000 [Up] 0.0000
Blank Offset     Roll Ratio     Eccentric	Blade Angl Point Diam Tooth Thic	e eter kness	:	0.00.00 0.0000	0.00.00
	<				
	Machine Root Angle Fixed Free Cutter Spindle Angle Fixed      Free Profile Curvature Blade Curvature Offset Crowning Point Diameter Machine Center To Back Blank Offset Roll Ratio Eccentric	Machine Root Angle       Ist Order         Ist Order       Ist Order         Ist Order       Ist Order         Machine Root Angle       Machine Root         Cutter Spindle Angle       Ist Order         Fixed       Free         Profile Curvature       Cradle Angle         Blade Curvature       Cutter Spindle Angle         Offset       Decimal Rai         Machine Center To Back       Blank Offset         Blank Offset       Blade Angle         Point Diameter       Sliding Ba         Blank Offset       Blank Offset         Point Diameter       Sliding Ba         Court Diameter       Sliding Ba         Blank Offset       Blank Offset         Point Diameter       Sliding Ba         Court Diameter       Sliding Ba         Station       Station         Station       Station         Station       Station         Station       Station         Station       Station         Station       Station <td>Machine Root Angle       Ist Order Changes         Ist Order Changes       Ist Order Changes         Cutter Spindle Angle       Free         Profile Curvature       Blade Curvature         Blade Curvature       Blade Curvature         Offset       Octual Ratio         Crowning       Point Diameter         Machine Center To Back       Blade Angle         Blade Angle       Sliding Base         Blade Angle       Doint Diameter         Machine Center To Back       Blade Angle         Point Diameter       Coutter To Back         Blade Angle       Sliding Base         Blade Angle       Sliding Base         Blade Angle       Sliding Base         Blade Angle       Soint Diameter         Tooth Thickness       Stiding Base</td> <td>Machine Root Angle       Ist Order Changes         ● Fixed       ● Free         Cutter Spindle Angle       ○         ● Fixed       ● Free         Profile Curvature       ● Blade Curvature         ● Blade Curvature       ● Cutter Spindle Angle       ○         ● Offset       ○         Crowning       ● Point Diameter       ○         ● Machine Center To Back       ●         ● Blade Angle       ○         ● Point Diameter       ○         ● Roll Ratio       ○         ● Eccentric       ●</td> <td>Machine Root Angle       Free         Order       Machine       Correction [mm]       Expected State         Order       Fixed       Ist       Order       Correction [mm]       Expected State         Order       Fixed       Free       Ist       Order       Connection [mm]       Expected State         Cutter Spindle Angle       Ist       Order       Connection [mm]       Expected State         Profile Curvature       Free       Nachine       Counter       Counter       Swivel Angle       :       0.00.00         Blade Curvature       Blade Curvature       Swivel Angle       :       -0.02.45       Cutter       Spindle Angle       :       :       0.00.00         Order       Machine Center To Back       :       -0.00108       Machine Center To Back       :       -0.0027       Sliding Base       :       :       0.0000       Blank Offset       :       [Up] 0.0000       Blank Offset       :       0.00.000       Doint Diameter       :       0.00.000       :       :       .         Roll Ratio       Eccentric       :       :       :       0.00000       :       :       :       .</td>	Machine Root Angle       Ist Order Changes         Ist Order Changes       Ist Order Changes         Cutter Spindle Angle       Free         Profile Curvature       Blade Curvature         Blade Curvature       Blade Curvature         Offset       Octual Ratio         Crowning       Point Diameter         Machine Center To Back       Blade Angle         Blade Angle       Sliding Base         Blade Angle       Doint Diameter         Machine Center To Back       Blade Angle         Point Diameter       Coutter To Back         Blade Angle       Sliding Base         Blade Angle       Sliding Base         Blade Angle       Sliding Base         Blade Angle       Soint Diameter         Tooth Thickness       Stiding Base	Machine Root Angle       Ist Order Changes         ● Fixed       ● Free         Cutter Spindle Angle       ○         ● Fixed       ● Free         Profile Curvature       ● Blade Curvature         ● Blade Curvature       ● Cutter Spindle Angle       ○         ● Offset       ○         Crowning       ● Point Diameter       ○         ● Machine Center To Back       ●         ● Blade Angle       ○         ● Point Diameter       ○         ● Roll Ratio       ○         ● Eccentric       ●	Machine Root Angle       Free         Order       Machine       Correction [mm]       Expected State         Order       Fixed       Ist       Order       Correction [mm]       Expected State         Order       Fixed       Free       Ist       Order       Connection [mm]       Expected State         Cutter Spindle Angle       Ist       Order       Connection [mm]       Expected State         Profile Curvature       Free       Nachine       Counter       Counter       Swivel Angle       :       0.00.00         Blade Curvature       Blade Curvature       Swivel Angle       :       -0.02.45       Cutter       Spindle Angle       :       :       0.00.00         Order       Machine Center To Back       :       -0.00108       Machine Center To Back       :       -0.0027       Sliding Base       :       :       0.0000       Blank Offset       :       [Up] 0.0000       Blank Offset       :       0.00.000       Doint Diameter       :       0.00.000       :       :       .         Roll Ratio       Eccentric       :       :       :       0.00000       :       :       :       .

Tolerance Order Machine Correction Expected Stats Errors options on target values and tolerances; options on what is to be corrected; options on control parameters constraints; calculated changes in machine settings; what HyGEARS expects after correction; point by point differences Х

 $\wedge$ 

Cancel

OK

## Correction and RE

🎳 Correc	tive Ma	chine Setti	ngs Pinior	n - [Finishi	ing]			Х
Tolerance	Order	Machine	Correction	n [mm] Ex	pected Stat	s Errors		
				Concave	e-OB	Convex-	IB	
т	ooth Thia	ckness [mm]	1	-0.00	166			
P	ressure A	ngle (dd.mr	n.ss]	0.00.0	07	-0.00.	09	
S	piral Angl	le [dd.mm.s	s]	-0.00.	00	0.00.0	)4	
C	rowning	[mm]		0.001	70	-0.000	371	
P	rofile Cur	vature [mm]		0.001	29	0.002	04	
N	/arp Fact	tor [/10 mm]	l	0.02.1	13	0.00.2	29	
S	um Errors	s Squared [	um^2]	113.1		266.0		
Т	ooth Tap	er [dd.mm.s	s]	0.00.0	04			
				Apply	<u>R</u> eset	<u>P</u> rint	ОК	Cancel

olerar	nce	Ord	er	Ma	chir	ne	Co	rrect	tion	[mm	]	Expe	ecte	d St	tats	E	rors	J						
[a3\]	Iac	:	1			2			3			4			5	;		6	;		7		'	^
[Too	th I	Root	; C	onc	ave	-01	8]																-	
1	-0.	.000	050	0.	003	14	Ο.	.00	067	0.	.00	108	0	.00	212	-0	.00	004	0	.00	119	0.	С	
2	-0.	.001	170-	-0.	001	50-	-0.	00	180	-0.	. 00	163	-0	. 00	168	-0	.00	278	-0	.00	326	-0.	с	
3	0.	.002	231	0.	000	07-	-0.	.00	029	-0.	. 00	179	0	. 00	030	0	.00	065	-0	.00	125	0.	с	
4	0.	.003	807	0.	000	10	Ο.	00	152	-0.	.00	023	-0	. 00	040	-0	.00	078	0	.00	018	0.	c .	
5	0.	.002	241	Ο.	000	34-	-0.	00	048	-0.	.00	179	-0	. 00	138	0	.00	050	0	.00	060	Ο.	c	
[Too	th 1	[ip]																						
5	-0.	.004	168-	-0.	002	13	Ο.	.00	033	0.	.00	128	0	. 00	131	. 0	.00	262	0	.00	177	0.	C	
4	-0.	.004	153-	-0.	002	13-	-0.	.00	011	0.	.00	085	0	. 00	070	0	.00	115	-0	.00	091	0.	C	
3	-0.	.004	43-	-0.	002	69	-0.	00	117	-0.	.00	038	0	.00	000	-0	.00	007	-0	.00	185	-0.	C	
2	-0.	.003	321	-0.	002	03-	-0.	.00	140	-0.	.00	092	-0	.00	043	-0	.00	139	-0	.00	239	-0.	C	
1	0.	.002	240	0.	001	25	0.	.00	161	0.	.00	162	0	.00	099	0	.00	052	-0	.00	110	-0.	C	
[Too	th I	Root	; C	onv	ex-	IB	]																	
-																								Y
<																						2	ŀ	

Tolerance Order Machine Correction Expected Stats Errors

options on target values and tolerances; options on what is to be corrected; options on control parameters constraints; calculated changes in machine settings; what HyGEARS expects after correction; point by point differences

## **Reverse Engineering (RE)**

HyGEARS uses the Surface Match algorithm to Reverse Engineer existing tooth surfaces.

Reverse Engineering is useful to:

- identify the machine settings of existing gear sets for which the summaries are lost;
- *analyze existing gear sets* and identify the machine settings or provide a reference surface leading to quietness;
- *diagnose the reason for a failure* by simulating meshing and load sharing;
- optimize the Stock Distribution;
- use different cutters on a given geometry (Fixed Setting only);
- calibrate mechanical machines to pre-compensate for their inaccuracies;
- etc.



## **Starting HyGEARS: Registration**

45 HyGEARS V 5.0 (C) : Registration			×
User Name :	Please enter your NAME.		
User Company :	Involute Inc.		
User Address :	Please enter your ADDRESS.		
		ОК	Cancel



## Example: Start HyGEARS for the 1st time

Start HyGEARS

Fill in the Registration form: your name

your address

Watch the HyGEARS Copyright screen

Watch the HyGEARS Parent Window appear in the screen

## Example: Import a Gleason Spa file

Import the Spa file

File->Open

Navigate to the proper folder

Select "Gleason SPA (\*.Spa)"

Select "Summary for CNC.spa"

Look at the different display modes TCA, LTCA, Geometry, etc.

Save the imported geometry

File->Save As

Name: "Summary for CNC.HyG"

## **Example: Import a Gleason Spa file**



## **Example: Keyboard Shortcuts**

Start MS-Word; Experiment **^C** (select a Child window: Copy the Child Window contents to the clipboard) and then Paste it into Word (**^**V)

Experiment **^+** (Zoom In)

Experiment <sup>^</sup>Z (Center and Fit Display)

Experiment **^**R (Reference frames On/Off) and then Rotate/Zoom the Tooth Child Window display

Experiment **^F** (toggle tooth flank)

## Example: Open an existing geometry file

Open the Summary for CNC.HyG file

File->Open

Watch the CP-TCA Pre-Defined display

Create a Tooth Child Window

**Display** -> User

Graphics->Tooth->Tooth

Create a 2D Graph

**Graphics**->2D Graphs (Click on Ok)

# **HyGEARS Toolbar: Graphics Controls**





## **Example: Rotation With the Mouse**

Experiment the Rotation With the Mouse (left mouse button depressed) on the Tooth Child Window

## Parent Window: Mouse Behavior



Left mouse button over grey area:

File menu

Right mouse button over grey area:

Graphics menu

## **Example: Left and Right mouse buttons**

Experiment the Left Mouse Button - call the File menu

Experiment the Right Mouse Button - call the Graphics menu

## **Example: Establishing a Complex Blank**



## **Example: Establishing a Complex Blank**

Differences appear between the drawing and HyGEARS default tooth outlines.



**Default tooth – as created / imported** 

**Requested tooth** 

## **Example: Establishing a Complex Blank**



## **Example: Establishing a Turned OD**



## Example: Establishing a Turned OD – Method 1

Select the Gear Summary Editor: "Gea" function button

- 1- Set the Back Angle to 90 deg.
- 2- Click on "Apply"



## Example: Establishing a Turned OD – Method 1

- 3- Enter the requested OD: 52 [mm]
- 4- Click on "Apply"



# Example: Establishing a Tapered Toe OD – Method 1



# Example: Establishing a Tapered Toe OD- Method 2



Blank Editor: "Blank" function button (Gear Group)1- Enter the desired values2- Click on "Apply"



# Example: Establishing a Cropped Heel OD – Method 1

Pinion Summary Editor: "Pin" function button

- 1- Click on the check box to the right of the Outside Diameter input field;
- 2- Enter the desired Cropped OD;
- 3- Click on "Apply"



# Example: Establishing a Cropped Heel OD – Method 2



## **Example: Establishing the Correct Blank**

### Save your geometry under a different name to be able to compare

Fie       Ext       Graphic Mac       Window       Topping       User TCA LTCA Consisty Loads Stock CMM Correct Machine         Previous       ** Tooch - Princin (Convec-BB) (*)       ** Tooch - Gear (Concore-OB) (*)       ** Tooch - Gear (Concore-OB) (*)         ** Seve Geometry       ** Tooch - Sear (Concore-OB) (*)       ** Tooch - Gear (Concore-OB) (*)       ** Tooch - Gear (Concore-OB) (*)         ** Seve Geometry       ** Tooch - Sear (Concore-OB) (*)       ** Tooch - Sear (Concore-OB) (*)       ** Tooch - Gear (Concore-OB) (*)         ** MSDN8       Name       ** Seve Hare       ** Seve Hare       ** Seve Hare         ** MSDN8       Name       ** Seve Hare       ** Seve Hare       ** Seve Hare         ** Seve Score Hare       ** Seve Hare       ** Seve Hare       ** Seve Hare         ** Seve Score Hare       ** Seve Hare       ** Seve Hare       ** Seve Hare         ** Seve Score Hare       ** Seve Hare       ** Seve Hare       ** Seve Hare         ** Seve Store       ** Seve Hare       ** Seve Hare       ** Seve Hare         ** Seve Store       ** Seve Hare       ** Seve Hare       ** Seve Hare         ** Seve Hare       ** Seve Hare       ** Seve Hare       ** Seve Hare         ** Seve Hare       ** Seve Hare       ** Seve Hare       ** Seve Hare         ** Sev	HyGEARS V 4.0 © - e:\vb\minigears\11x39 spiralbevel dh\summary for cnc.hyg [v:4.0.405.10-0]			
Pro de	File Edit Graphics Misc Windo	ow Display Page Help		
Image: Provide Princip (Convex-UB) (*)       Image: Princip (Convex-UB) (*)         Image: Princip (Convex-UB) (*)       Image: Princip (*)         Image: Princip (*)		2.5 🖗 🌽 🏝 🗐 📼 🍲 User TCA LTCA Geometry Loads Stock CMM Corr-RE Machine		
Seve Geometry         ** Save Geometry         ** Save Geometry         ** miniGears + 11:39 SpiralBevel DH *         ** Save Geometry         ** New folder         ** New folder         ** SpiralBevel DH *         ** SpiralBevel Throm Spalry         ** SpiralBevel Normanion         ** Training         *** SpiralBevel Normanion	Depth 🖓 Tooth - Pinion [Convex-IB]	(*) 🖾 🙀 Tooth - Gear [Concave-OB] (*) 🖾		
Organize      New folder       MSDN98     Name       NRECIPES     CNC issues - GF Mikron       SpecialOperationsMedicalHandbook     11:339 SpiralBevel-190       SproA     11:339 SpiralBevel-FromSpa.hyg       MSDN9     Intropic SpiralBevel-FromSpa.hyg       SproA     11:339 SpiralBevel-FromSpa.hyg       MicroArgite SproA     11:339 SpiralBevel-FromSpa.hyg       MicroArgite SproA     11:339 SpiralBevel-FromSpa.hyg       MicroArgite SproA     11:339 SpiralBevel-FromSpa.hyg       SproAry     11:339 SpiralBevel-FromSpa.hyg       Save as type     HyGEARS 4.0 (*.HyG)       Save as type     HyGEARS 4.0 (*.HyG)	Sele STEP RemT Gea Fini Depth Sala	C 656(mm) C 556(mm) C 556(mm) C 550(mm) C 570(mm) C 570(mm)		
MSDN98 NRECIPES Repositories Special/OperationsMedicalHandbook SPRO4 Spro4drv Spro63 Spro63 Spro7 File game: 11x39-ActBlank.hyg File game: 11x39-ActBlank.hyg Save as type: HyGEARS 4.0 (".HyG) Save Cancel	Organize  New folder			
	MSDN98 NRECIPES Repositories SpecialOperationsMedicalHandbook SPRO4 Spro4 Spro63 SProDrv+ SuperPro - Soft System Volume Information Training File name: 11x39-ActBlank.hyg Save as type: HyGEARS 4.0 (*.HyG) Hide Folders	Name       Image: CNC issues - GF Mikron       Image: CNC issu		

## **Example: Establishing the Correct Blank**



Geometry as Created/Imported



### Geometry as Modified
### **Example: Establishing the Correct Blank**



TCA as Created/Imported

**TCA as Modified** 





Finishing Process	Roughing Process
Fixed Setting	Spread Blade
Duplex Helical	Spread Blade
Modified Roll	Spread Blade
Face Hobbing	Face Hobbing
Spread Blade	Spread Blade
Formate	Plunge cut
Helixform	Plunge cut
Simplex-T	Spread Blade

Gleason Machine Number			
16 22	Gear Pitch Diameter	Gear Pitch Diameter	Cutter Diameter
26	L		L1
102	3.000 - 5.250	75 - 135	3.500
106	3.875 - 6.750	100 - 170	4.500
108	4.250 - 7.500	110 - 190	5.000
116	5.125 - 9.000	130 - 230	6.000
Phoenix	5.375 - 9.375	135 - 240	6.250
607	6.500 - 11.250	165 - 285	7.500
613	7.750 - 13.500	195 - 345	9.000
631	10.250 - 18.000	260 - 455	12.000
641	13.750 - 24.000	350 - 610	16.000
Basic	18.000 - 31.500	455 - 800	21.000

Klingelnberg Machine
Number
K-ND (neutral data)
Other Machine Number
603 (no cutter tilt)



Example: 9x37 Generated Spiral Bevel gear set

Gear tooth type: Pinion tooth type: Pinion Tooth Hand: Gear Face Width: Speed ratio: Pinion Speed: Available diameter space: Power: Application: Generated Generated, Duplex Helical Left 30% of outer cone distance Approximately 4:1 2000 RPM About 70 mm (2.75 in) 1 kW (1.3 HP) Power tool

🎳 New Geometry Definition - [mm] [	[dd.mm.ss] X
General Cutter Units	
Names Geometry Name Directory	Test-1-Spiral-Bevel
Geometry Source File	SpirBevI.lst
Types Geometry Type Material	Spiral-Bevel
Pinion Tooth Hand Tooth Taper	Left ~ Duplex ~
Misc Power [Kw] / Torque [N-m]	1 4.77
Pinion Speed (RPM) Number of Teeth [Pinion - Gear] Module (Pitch Diameter	2000.00 9 4.111 37
Gear Tooth Face Width / mn Shaft Angle	0 0.266618 90.00.00
Depth Factor (Gear) Addendum Factor (Gear) Clearance Factor	0 AGMA / ISO 0 O AGMA 0 ISO

### Example: 9x37 Generated Spiral Bevel gear set

#### Cutter Data Section:

General Cutter Units		
	(OB) Pinion (IB)	(IB) Gear (OB)
Machine	Phoenix ~	Phoenix
Bias factor (-10 to +10)	0.00	
Spiral Angle	35.0000	
Sum Pressure Angles	40.0000	
Stock Allowance [in]	0.0060	0.0150
Cutter Diameter [in]		2.75
Blade Angle	0.0000 0.0000	0.0000 0.0000
Profile Curvature [in]	0.000 0.000	0.000 0.000
Ref. Height [mm]	0.000 0.000	0.000 0.000
Blade Edge Rad. [in]	0.0000 0.0000	0.0000 0.0000
Point Width [in]	0.0000	0.0000
Mounting Distance	0.0000	0.0000
	C	lear
Switches	Pinion Process	Gear Process
Bal. Strength	Fixed Setting	Generated
Sel. TopRem	Duplex Helical     Madified Dall	Duplex Helical
No Cutter Hit		
Auto Damping	Semi-compl.(Gen)	Fixed Setting
	O Cyclo-Palloid	Semi-compl.(Gen)
Use data as is	O Cyclo-Milling	Semi-compl.(NonGer

Click on Next >>

### Example: 9x37 Generated Spiral Bevel gear set

#### Units Data Section:

General Cutter Unit	s					<b></b>			
Blank Data		Pinion	Gear						Î
Backlash			0.050		Min. Bore to Ro	ot at Toe			
FCrown to	Хр	0.000	0.000				-		Bore Dia
Zero Fron	t Angle								
Outside D	iameter(Heel)	0.000	0.000						•
Face Ang	e	0.000	0.000						
Root Ang	e	0.000	0.000		vie				1
Dedendu	n Angle	0.000	0.000		a New Geometry Repo	rt		×	
Whole De	pth O @Mid-F	0	0		Item	Value	Suggested	Status	
Bore Dian	leter	0.000	0.000		Pinion M.D. [mm]	<= 0.000	> 0.000	Modify	
Min Bore	o Root @Toe	0.000	0.000		Gear M.D. [mm]	<= 0.000	> 0.000	Modify	
					Gear Process (mg > 3.5)	Spread Blade	Non Gen. (Formate)	Modify	
			Clear		Cutter Diameter [in]	2.750	< 2.736	Modify	
Units									
Linear Un	its	mm	~						
Angular U	nits	Deg Min Se	c v						
Cutter Un	ts	le le	· · ·						
			•						
		Import <	<back next="">&gt;</back>	Cancel			Ok Mod	ify Cancel	

### Example: 9x37 Generated Spiral Bevel gear set



### Example: 9x37 Generated Spiral Bevel gear set



Example: 9x37 Generated Spiral Bevel gear set

Press the **^S** (Save) keyboard combination and agree to the questions asked.



### Contact Pattern Display of the 9x37a.dat Geometry

### Example: 9x37 Generated Spiral Bevel gear set

#### Click on the **GSum** function button:



×

Cancel

🗳 Graphics Summary - Test-1-Spir	al-Bevel.hyg [mm] [deg] 🛛 🗙	Graphics Summary - Test-1	·Spiral-Bevel.hyg [mm] [deg]
Blank TCA LTCA unds WC	0.000	Blank TCA LTCA Grids E (Pinion Offset) P (Pinion Axial) G (Gear Axial) Shaft Angle Alignment Pinion Radial Gear Radial	0.000         Coast           0.000         LTCA           0.000         LTCA           0.000         0.000           0.000         0.000           0.000         0.000           0.000         0.000
	Apply OK Cancel		Apply OK

### Example: 9x37 Generated Spiral Bevel gear set

Duplex Helical Pinion [No pread Blade Gear [Nomi	iral-Bevel Geom ominal] inal]	etry Summary	Date / Time : 11/12/2021 / 8:01:18 FM General Units : [mm] [D.dec] Cutter Units : [mm] Frepared by : Claude Gosselin / Version : 5.0.500.00-464
GENERAL DATA	PINION	GEAR	TOOTH DATA FINION GEAR
Number of Teeth Hand of Spiral Bpeed Ratio Dismetal Fich Mean Normal Module Circular Fitch Face Width Angular Face Outer Cone Distance Outer Cone Distance Ratio Involute/Cone Dist Shaft Angle Fitch Dismeter Outside Disteter Colleater Addendm Factor Clearance Factor Dedendum Factor Cone Vidth & Cone Distance Mounting Distance Profile C.Ratio Total C.Ratio	: 9 . LEFT: 1 . 4.111: 13.8250 . 1.2707 . 2.777 . 3.7470 . 4.7470 . 4	37 RIGHT [speed Reducer] 334 1.2707 334 10.4241 31.0691 34.7470 29.3349 67.5250 67.7463 3.8839 0.1589 0.2088 0.9710 1.3710 1.3710 1.3710 1.3710 1.3710 1.3710 1.3710 1.4235 2.3509 2.5609	Calculated Tooth Depths (Chordal) Finion + Gear [Finishing] Form Bepth (Tce) : 2.1201 1.9448 Form Bepth (Tce) : 2.1205 1.9245 Whole Depth (Tce) : 2.5669 2.4539 Whole Depth (Wid-F) : 2.9998 2.4539 Form Depth (Wel) : 3.0380 2.8395 Form Depth (Weel) : 3.4685 3.2709 Calculated Tooth Depths (Circular) Form Depth (Weel) : 1.9603 Whole Depth (Tce) : 1.9603 Form Depth (Tce) : 2.3125 2.2889 Form Depth (Tce) : 2.3125 2.2889 Form Depth (Wid-F) : 2.4571 2.3885 Whole Depth (Wid-F) : 2.4641 2.7970 Form Depth (Wid-F) : 2.7641 2.7970 Form Depth (Wid-F) : 2.7641 2.7970 Form Depth (Wel) : 3.2611 3.2611 Fillet Radius @ Mid-Face Drive - Root Diameter : 0.4035 0.5283 Coast - Con Diameter : 0.4035 0.5283 Coast - Form Diameter : 0.4035 0.5283 Coast - Form Diameter : 0.4035 0.5283 Coast - Form Diameter : 0.4036 0.5283 Coast - Kord Diameter : 0.538 Kord Coast - Kord Diameter : 0.538 Kord Coast - Kord Diameter : 0.538 Kord - Kord Coast - Kord - K
BLANK DATA Face Apex Beyond XP Root Apex Beyond XP Root Apex Beyond XP Commto XP Front Crown to XP Addendum Dedendum	FINION : -0.7074 : -1.4024 : -1.4024 : 33.1768 : 23.2394 : 2.4783 : 0.8192	0EAR -0.0419 -0.1140 -0.1140 -7.7577 5.4423 0.4681 2.7913	Radial relation         :         0.99         26.0643           Angular Thick, [deg]         :         0.2028         30.034           Norran. Thick, [deg]         :         32.0238         30.034           Axial Fosition         :         33.7625         8.2125           Radial Position         :         8.2113         33.7625           Angular Thick, [deg]         :         27.0434         2.7863           Topland (Mid-Face - Normal Fl :         0.6115         0.9718           Topland (Hee - Normal Flane)         :         0.5527         0.9316           Topland (Hee - Normal Flane)         :         0.5527         0.9316           Topland (Hee - Normal Flane)         :         0.5527         0.9316           Topland (Hee - Tearw, Flane)         :         0.5527         0.9356
<pre>Ht [Act] Ht [Act] Dedendum Angle Dedendum Angle Face Angle (of Blank Ficth Angle (Actual) Front Angle Reference Yalues Back Angle Reference Yalues Freas. Angle (18) Freas. Angle (18) Outer Come Distance Distance Fire Width Freas. Angle (18) Outer Come Distance Fire Fi</pre>	: 3.205 : 4413 : 4413 : 0.8371 : 18.0713 : 13.6713 : 13.6713 : 35.0000 : 20.0000 : 20.0000 : 44.7471 : 0.4241	1 2596 3 6391 4 6148 77.1678 76.3287 76.3287 76.3287 76.3287 76.3287 76.3287 76.3287 10.000 20.0000 20.0000 34.7470 10.4241	OPERATING DATA         FINION         GEAR           Backlash (Max)         :         0.0762           Backlash (Max)         :         0.0762           Backlash (Max)         :         0.0967           Backlash (Max)         :         0.01762           Backlash (Max)         :         0.0967           Backlash (Max)         :         0.0314           Backlash (Max)         :         0.3126           Backlash (Generance (Max))         :         0.3126           Backlash (Beel)         :         0.3126           Gear Conceve=08 E=0.00 P=0.00 G=0.00 [mm])         0.3186
Spiral Angle-Toeter Spiral Angle-Center Spiral Angle-Keal Press Angle (IB) Spiral Press(Congles - Ro Spiral Angle-Center Press Angle (IB) Press Angle (Ob)	: 28.0697 : 35.0553 : 42.6835 : 20.0458 : 19.7267 ot Cone [Actual] : 35.0486 : 20.5218 : 19.2412	28.0820 35.0823 42.7699 19.7764 20.0176 34.9941 22.2873 17.4574	

### Example: Modifying the CP and TE 9x37 Generated Spiral Bevel gear set

🗳 C.Pattern Development - Gear Conv	vex-IB ×
BP Definition D-MSett [mm] LTCA E/	P Prop.
Mean Point / Convex-IB Horizontal Position 50.2 % Vertical Position 50.0 %	Mean Point / Concave-OB       Horizontal Position       51.2       %       Vertical Position       50.0
PoC Bias / Convex-IB       Image: Tree region       Fixed       -1.5	PoC Bias / Concave-OB Free Fixed -5.2 deg
T.E. ● Free ○ Fixed 133 ♀ [uRad] ☑ 2nd-3rd □ Curvature	T.E. ● Free ○ Fixed 129 ÷ [uRad]
Backlash O Free () Fixed (0.049) [mm]	Target Machine
Apply < <back next="">&gt;</back>	Reset Print OK Cancel







### Example: Modifying the CP and TE 9x37 Generated Spiral Bevel gear set

B.Pattern [	evelopment - Gea	r Convex	(-IB			×
BP Definition	D-MSett [mm] LT	CA E/P	Prop.	Links		
Mean Poi	nt / Convex-IB		Mean Point	/ Concav	e-OB	
Horizor	tal Position 50	%	Horizonta	al Position	50	%
Vertica	Position 50.0	%	Vertical F	osition	50.0	%
PoC Bias	/ Convex-IB		PoC Bias /	Concave-(	DB	
Free	•		Free			
Fixe	d 25 deg	3	Fixed	25	deg	
-T.E.			T.E.			
Free	•		Free			
Fixe	d 71 🚊 [uf	Rad	Fixed	53	÷ [uRa	d
$\checkmark$	2nd-3rd 📃 Curva	ature				
Backlash						
Free	•					
Fixe	d 0.052 [mr	n]				
Apply	<back ne<="" td=""><td>et&gt;&gt;</td><td>Reset F</td><td>rint</td><td>ок</td><td>Cancel</td></back>	et>>	Reset F	rint	ок	Cancel



💒 B.Pattern Development - Gear Convex-IB
BP Definition D-MSett [mm] LTCA E/P Prop. Links
Mean Point / Convex-IB Mean Point / Concave-OB
Horizontal Position         50         %         Horizontal Position         50         %           Vertical Position         50.0         %         Vertical Position         50.0         %
PoC Bias / Convex-IB PoC Bias / Concave-OB
○ Free         ○ Free           ● Fixed         25         deg         ● Fixed         25         deg
T.E. T.E. Free Fixed T.E. Free Fixed T.E. Free Fixed T.E. Free Pixed T.E.
Backlash © Free
Apply K <back next="">&gt; Reset Print OK Cancel</back>



### Example: Modifying the CP and TE 9x37 Generated Spiral Bevel gear set

n Development - Gear Convex D-MSett [mm] LTCA E/P ontrol izontal Position: 250 % tical Position: 50.0 %	<-IB
D-MSett [mm] LTCA E/P	
izontal Position: 250 %	
tical Position: 50.0 %	
izontal Position: 250 %	
izontal Position: 250 %	
tical Position: 50.0 %	
tical Position: 50.0 %	
tical Position: 50.0 %	
y < <back next="">&gt; Re</back>	ese
ly	< <back next="">&gt; R</back>

Gear Convex-IB

Gear Concave-OB

### IB O OB I Position: 25.0 Position: 50.0 % Reset <<Back Next>> Print OK Cancel ar [Convex-IB] [NoEr] [NoSep] [Finishing] mc=2:50 E=0:19 P=-0.7 G=0:00 [mm] B:0:011 [mm]/0:021 [deg.] Heel Heel Gear Convex-IB Gear Concave-OB

Prop.

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Example: Modifying the CP and TE 9x37 Generated Spiral Bevel gear set





### Example: Modifying the CP and TE 9x37 Generated Spiral Bevel gear set



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### Example: Modifying the CP and TE 9x37 Generated Spiral Bevel gear set

Definition	CA E/P	Prop.	
C.Pattern Development	;	(O.B.)	(I.B. 🔺
Radial Distance	:	-0.002	:5
Cutter Tilt	:	-2.808	5
Swivel Angle	:	-0.057	1
Blank Offset	:	0.000	0
Machine Root Angle	:	1.649	13
Machine Center To Bad	sk :	0.043	5
Sliding Base	:	0.868	9
Rate of Roll	:	-0.0155	2
Cradle Angle	:	-0.057	1
Blade Angle	:	0.0000	0.000
Average Diameter	:	0.000	0
Point Width	:	0.000	0
			~
<			>

🗳 C.Pattern Development - Gear Convex-IB 🛛 🕹 🗙			
BP Definition D-MSett [mm]	LTCA E/P	Prop.	
Rate of Roll	:	-0.01552	~
Cradle Angle	:	-0.0571	
Blade Angle	:	0.0000	0.000
Average Diameter	:	0.000	
Point Width	:	0.000	
Modified Roll			
2C	:	-0.002	
6D	:	-0.097	
24E	:	-0.198	
120F	:	0.990	
Helical Motion			
lst	:	-0.396	
×		$\sim$	
		(	
Apply < <back< th=""><th>Next&gt;&gt; Re</th><th>set Print OK</th><th>Cancel</th></back<>	Next>> Re	set Print OK	Cancel
			$\overline{}$

Click on Ok to keep the changes

Example: 9x37 Non-Generated Spiral Bevel gear set

Gear tooth type: Pinion tooth type: Pinion Tooth Hand: Gear Face Width: Speed ratio: Pinion Speed: Available diameter space: Power: Application: Non-Generated Generated, Duplex Helical Left 30% of outer cone distance Approximately 4:1 2000 RPM About 70mm (2.75 in) 1 kW (1.3 HP) Power tool

#### Example: 9x37 Non-Generated Spiral Bevel gear set

Call the File-> New Geometry menu entry – Spiral Bevel

General Cutter Units		
Names		
Geometry Name	Test-1-Spiral-Bevel	
Directory	E:\VB	
Geometry Source File	SpirBevI.lst	
Types		
Geometry Type	Spiral-Bevel 🗸	
Material	AGMA A-1 V	
Pinion Tooth Hand	Left ~	
Tooth Taper	Duplex 🗸	
Misc		
Power [Kw] / Torque [N-m]	1.00 4.77	
Pinion Speed (RPM)	2000.00	
Number of Teeth [Pinion - Gear]	9 4.111 37	
Module/Pitch Diameter	1.825000 / 67.5250	
Gear Tooth Face Width / mn	0.000 1.27071	
Shaft Angle	90.0000	
Depth Factor (Gear)	3.880 AGMA / ISO	
Addendum Factor (Gear)	0.159 O AGMA	
Clearance Factor	0.125 O ISO	
	Import < <back next="">&gt; Can</back>	cel

#### Example: 9x37 Non-Generated Spiral Bevel gear set <sup>55</sup> New Geometry Definition - [mm] [D.dec] X General Cutter Units (OB) Pinion (IB) (IB) Gear (OB) Machine Phoenix Phoenix $\sim$ $\sim$ Bias factor (-10 to +10) 0.00 Spiral Angle 35.0000 Sum Pressure Angles 40.0000 Stock Allowance [in] 0.0060 0.006 Cutter Diameter [in] 2.7500 Blade Angle 0.0000 0.0000 0.0000 0.0000 Profile Curvature [in] 0.000 0.000 0.000 0.000 Ref. Height [in] 0.000 0.000 0.000 0.000 🞳 New Geometry Report Blade Edge Rad. [in] 0.0000 0.0000 0.0000 0.0000 Point Width [in] 0.0000 0.0000 Item Value Suggested Mounting Distance 0.0000 0.0000 Pinion M.D. [mm] <= 0.000 > 0.000 Clear Gear M.D. [mm] <= 0.000 > 0.000 Switches Pinion Process Gear Process Cutter Diameter [in] 2,750 < 2.736 Bal. Strength Fixed Setting Generated Sel. TopRem Duplex Helical ) Duplex Helical Modified Roll Non Generated No Cutter Tilt ○ SimplexT Helixform VP No Gear Tilt Semi-compl.(Gen) Fixed Setting Auto Damping Cvclo-Palloid Semi-compl.(Gen) Use data as is O Cyclo-Milling Semi-compl (NonGen) Next>> Import <<Back Cancel Ok Modify Click on Next >> twice and Ok

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 $\times$ 

Status

Modify

Modify

Modify

Cancel

### Example: 9x37 Non-Generated Spiral Bevel gear set



### Example: 9x37 Non-Generated Spiral Bevel gear set



eneral Cutter Units			
Names			
Geometry Name	Test-1-Coniflex		
Directory	E:\VB		
Geometry Source File	Coniflex.lst		
Types			
Geometry Type	Coniflex 🗸 🗸		
Material	AGMA A-1 V		
Pinion Tooth Hand	Right ~		
Tooth Taper	Standard 🗸 🗸 🗸		
Misc		_	_ Speed ra
Power [Kw] / Torque [N-m]	1.00 2.12		
Pinion Speed (RPM)	4500.00		
Number of Teeth [Pinion - Gear]	32 1.000 32		
Module/Pitch Diameter	3.000000 / 96.0000		
Gear Tooth Face Width / mn	0.000 2.55000		
Shaft Angle	90.0000		
Depth Factor (Gear)	2.0000 AGMA / ISO		
Addendum Factor (Gear)	0.5000 AGMA		
Clearance Factor	0.1250		
TE [uRad]	0		



Pinion Tooth Number	Depth Factor
12 and +	2.000
11	1.995
10	1.975
9	1.940
8	1.900
7	1.835
6	1.752

🎳 New Geometry Defin	ition - [mm] [D.dec]	×
General Cutter Units		
	Pinion	Gear
Machine	Gleason 104 V	
Pressure Angle (Oper.) Pressure Angle Dish Angle (Beta) Point Diameter - [mm] Point Width Blade Edge Radius Back Angle Blade Thickness	20.000 20.0000 0.5000 125.0000 0.2000 0.1500 23.0000 4.0000	20.0000       0.2000       0.1500
Switches Bal. Strength Sel. TopRem	Pinion Process Generated Duplex Helical	Clear Gear Process Generated Duplex Helical
No Cutter Tilt No Gear Tilt Auto Damping Use data as is	SimplexT Semi-compl.(Gen) Cyclo-Palloid Cyclo-Milling	Helixform     Helixform     VP     Fixed Setting
	Import	< <back next="">&gt; Cancel</back>

















Name	\$				
Geo	ometry Name	Test-10-Conifl	ex		
Dire	ectory	E:\VB			
Geo	ometry Source File	Coniflex.lst			
Types	I				
Geo	ometry Type	Coniflex		~	
Mat	terial	AGMA A-1		~	
Pini	ion Tooth Hand	Right	<hr/>	~	
Тос	oth Taper	Standard		~	
Misc .		$\smile$			
Pov	ver [Kw] / Torque [N-m]	1.00		2.12	
Pini	ion Speed (RPM)	4500.00			
Nur	mber of Teeth [Pinion - Gear]	32	1.000	32	
Mod	dule/Pitch Diameter	3.000000	/	96.0000	
Gea	ar Tooth Face Width / mn	0.000		2.55000	
Sha	aft Angle	90.0000			
Dep	oth Factor (Gear)	2.0000	AGMA	/ ISO	
Add	lendum Factor (Gear)	0.5000	AGN	AМ	
Clea	arance Factor	0.1250	0 150		
TE	[uRad]	0			



🗳 New Geometry Definition - [mi	m] [D.dec]	×
General Cutter Units		
Names		
Geometry Name	Test-10-Coniflex	
Directory	E:\VB	
Geometry Source File	Coniflex.lst	
Types		
Geometry Type	Coniflex 🗸 🗸	
Material	AGMA A-1 🗸	
Pinion Tooth Hand	Right	
Tooth Taper	Tilted Root Line	
Misc		
Power [Kw] / Torque [N-m]	1.00 2.12	
Pinion Speed (RPM)	4500.00	
Number of Teeth [Pinion - Gear	] 32 1.000 32	
Module/Pitch Diameter	3.000000 / 96.0000	
Gear Tooth Face Width / mn	0.000 2.55000	
Shaft Angle	90.0000	
Depth Factor (Gear)	2.0000 AGMA / ISO	
Addendum Factor (Gear)	0.5000 AGMA	
Clearance Factor	0.1250	
TE [uRad]	0	
	Import < <back next="">&gt; Cano</back>	cel



# Creating a Spur gear set

🗳 New Geometry Definition - [mm] [de	d.mm.ss]	×	
General Cutter Units			
Names Geometry Name Directory Geometry Source File Types	Test-2-Spur-Helical [Ext] E:\VB ExtSpur.lst		
Geometry Type	Spur-Helical [Ext]		
Material	AGMA A-1 V		
Pinion Tooth Hand	Left 🗸 🗸		
Epicyclic Gear	No 🗸		
Misc	/		Gear ratio
Power [Kw] / Torque [N-m]	13.5 128.66		
Pinion Speed (RPM)	1000		
Number of Teeth [Pinion - Gear]	20 1.700 34		
	5.08 / 172.720		
Gear Tooth Face Width	25.4 Input Plane		
Number of Planets	0 Normal Plane		
Shaft Angle			
	0.000		
	Import < <back next="">&gt; Car</back>	ncel	

🎳 New Geometry Defin	iition - [mm] [dd.mm.ss]	×
General Cutter Units		
	Pinion	Gear
Crown Speed (RPM) Helix Angle Pressure Angle X Factor Addendum Factor Dedendum Factor Fillet Factor Root Diameter [mm] Tip Diameter [mm] TIF Diameter [mm] Center Distance [mm]	0 0 20.0000 0.0000 1.000 1.250 0.250 0.0000 0.0000 0.0000 0.0000	0.0000 1.000 1.250 0.250 0.0000 0.0000 0.0000 0.0000
Switches P. Len. Crown. G. Len. Crown. P. Profile Crown. G. Profile Crown.	Pinion Process Fixed Setting Duplex Helical Modified Roll Simplex T Semi-compl.(Gen) Cyclo-Palloid Cyclo-Milling	Gear Process Generated Duplex Helical Non Generated Helixform VP Fixed Setting
	Import	< <back next="">&gt; Cancel</back>

### Creating a Spur gear set / 2



### Creating a Spur gear set / 3



### Creating a Spur gear set / 4












# Creating a Spur gear set / 5



# Creating a Helical gear set

		Contraction of the second seco			
🞳 New Geometry Definition - [mm]	[dd.mm.ss] X	7	🗳 New Geometry Defin	ition - [mm] [dd.mm.ss]	×
General Cutter Units	/		General Cutter Units		
Names	/			Pinion	Gear
Directory Geometry Source File Types Geometry Type Material Pinion Tooth Hand Epicyclic Gear Misc Power [Kw] / Torque [N-m] Pinion Speed (RPM) Number of Teeth [Pinion - Gear] Module/Pitch Diameter	E:\VB ExtSpur.lst AGMA A-1 Left No 13.50 128.98 1000.00 20 .700 34 5.080000 / 199.440	Gear ratio	Comm Speed (RPM) Helix Angle Pressure Angle X Factor Addendum Factor Dedendum Factor Fillet Factor Root Diameter [mm] Tip Diameter [mm] TIF Diameter [mm] Center Distance [mm]	0 30.0000 20.0000 1.000 1.250 0.250 0.0000 0.0000 0.0000 0.0000	0.0000 1.000 1.250 0.250 0.0000 0.0000 0.0000 0.0000
Gear Tooth Face Width Number of Planets Backlash Shaft Angle	25.400 Input Plane Normal Plane Normal Plane Transv. Plane		Switches P. Len. Crown. G. Len. Crown. P. Profile Crown. G. P. Profile Crown.	Pinion Process Fixed Setting Duplex Helical Modified Roll SimplexT Semi-compl.(Gen) Cyclo-Palloid Cyclo-Milling	Gear Process          Generated         Duplex Helical         Non Generated         Helixform         VP         Fixed Setting

### Creating a Helical gear set / 2



# Creating a Face gear set

🞳 New Geometry Definition - [mm] [[	D.dec]	<	🞳 New Geometry Defin	nition - [mm] [D.dec	:]		×
General Cutter Units			General Cutter Units				
Names Geometry Name Directory	Test-5-Face Gear E:\VB			Pinion		Crown Gea	ar
Geometry Source File Types Geometry Type Material Pinion Tooth Hand	Face Gear  AGMA A-1		Shaft Angle Helix Angle Pressure Angle X Factor Addendum Factor Dedendum Factor	90.0000 0.0000 20.0000 0.4650 1.0000 1.2500		0.000 1.0000 1.2500	
Misc Power [Kw] / Torque [N-m] Pinion Speed (RPM) Number of Teeth [Pinion - Gear] Module/Pitch Diameter	375.00         2237.09           1600.00         14           3.857         54           5.000000         /	Gear ratio	Fillet Factor Minor Diameter [mm] Major Diameter [mm] Center Distance [mm] FC.Xp [mm]	0.2500 0.0000 0.0000 0.0000	Clea	0.2000 0.0000 ar	]
Gear Tooth Face Width Pinion Offset Backlash Number of Teeth (Shaper) X Factor (Shaper) Contact Position 0.25 -> 0.75	30.000 0.0000 0.0000 15.0 0.465 0.50		Switches Bal. Strength Sel. TopRem No Cutter Tilt No Gear Tilt Auto Damping Use data as is	Pinion Process Fixed Setting Duplex Helical Modified Roll SimplexT Semi-compl.(Ge Cyclo-Palloid Cyclo-Milling	en)	Gear Process Generated Duplex Helical Non Generated Helixform Fixed Setting	VP
	Import < <back next="">&gt; Cancel</back>				Import <<	Back Next>>	Cancel

### Creating a Face gear set / 2



### Creating a Face gear set / 3



# Creating a Beveloid gear set

🎳 New Geometry Definition - [mm] [D	.dec]	×	
General Cutter Units			
Names			
Geometry Name	Test-1-Reveloid (Evt)	7 1	
Directory		-	
Geometry Source File	Beveloid Ist		
-	Development		
Types			
Geometry Type	Beveloid [Ext]	~	
Material	AISI 4140	~	
Pinion Tooth Hand	Right	~	
Cutting Method	Plunging Tool	✓	
		Gear ratio	
Misc			
Power [Kw] / Torque [N-m]	747.620 89199.59		
Pinion Speed (RPM)	80.00		
Number of Teeth [Pinion - Gear]	35 0.886 31		
Module/Pitch Diameter	1.800000 / 55.8000		
Gear Tooth Face Width	20.000 Input Plane		
Number of Planets	0 Normal Plane		
Backlash	0.0000 O Transv. Plane		
Shaft Angle	0.0000		
Pitch Angle [Pinion - Gear]	0.0000 7.0000		
Offset	0.0000		
	Import < <back next="">&gt;</back>	Cancel	

🗳 New Geometry Definition - [mm] [D.dec]							
General Cutter Units							
	Planet	Gear					
Crown Speed (RPM) Helix Angle Pressure Angle X Factor Addendum Factor Dedendum Factor Fillet Factor Root Diameter [mm] Tip Diameter [mm] Center Distance [mm]	0 25.00000 20.0000 0.0000 1.000 1.250 0.250 0.0000 0.0000 0.0000 0.0000	0.0000 1.000 1.250 0.250 0.0000 0.0000					
Switches P. Len. Crown. G. Len. Crown. P. Profile Crown. G. Profile Crown.	Pinion Process Fixed Setting Duplex Helical Modified Roll SimplexT Semi-compl.(Gen) Cyclo-Palloid Cyclo-Milling	Clear Gear Process Generated Duplex Helical Non Generated Helixform VP Fixed Setting					
	Import	< <back next="">&gt; Cancel</back>					

### Creating a Beveloid gear set / 2



### Creating a Beveloid gear set / 3



# Creating a Beveloid gear set / 4

🎳 Pinion [Beveloid [Ext]] [Finishing][Nominal] Test-1-Beveloid [Ext].hyg - [mm] 🗙							
Blank Cutter Edge Machine	Other	Operating	Rim-Material	Bearings	A + +		
Helix Angle Blade Angle B.Edge Rad. Blade Thickness Addendum Dedendum Cutter Type # Teeth Pitch Diameter Outside Diameter X Factor	Left 25.0 23.0 0.49 2.92 1.92 1.80 Rac 17 33.7 37.6 0.00	659 805 65 743 330 000 k 634 100 00	C (in) Righ 24 17 0.4	) (i) (i) (i) (i) (i) (i) (i) (i) (i) (i	imm]		
<sup>55</sup> Pinion [Beveloid [Ext]] [Finishing][ Blank Cutter Cutter Edge Machine	Nomina Other	al] Test-1-Be Operating	Apply eveloid [Ext].h Rim-Material	OK nyg - [mm Bearings	Cancel		
Profile Relief Diameter + Value Edge + Angle P.Angle + Value Relief Order Tooth Addendum Relief Start Tooth Addendum Relief Angle	Left 0.0 0.	000	<ul> <li>[in]</li> <li>Rigit</li> <li>2</li> <li>0.</li> <li>0</li> </ul>	)  ()	imm]		
Relief Order Tooth Dedendum Relief Start Tooth Dedendum Relief Angle	2 0.0 0.	000	2	0000	~		



### Creating a Straight Bevel gear set

In HyGEARS, Straight-Bevel gear Blank shapes come in 2 flavors:

- "Differential" they usually forged or injection molded; the Front angle is zero degree; TE can be larger such as to be more tolerant.
- "Standard" where the Front angle equals the pitch angle; TE can be lesser, such as to be quieter.

Both variants can be cut on a 5 Axis CNC machine using:

- a Conical Side Milling Tool (or CoSIMT),
- an End Mill or
- a Ball Mill.

### Creating a Straight Bevel gear set





### Creating a "Differential" Straight Bevel gear set

eral Cutter Units						
Blank Data Backlash FCrown to Xp Zero Front Angle Outside Diameter(Heel) Face Angle Root Angle Dedendum Angle Whole Depth O @Mid O @Her	Pinion Gear 0.1 0.000					
Bore Diameter Min Bore to Root @Toe	0.000 0.000 0.000 0.000		🤋 New Geometry Report			
Units			ltem	Value	Suggested	Sta
Linear Units	mm v		#Teeth Pinion	13	> 18	Mod
Angular Units	Decimal ~		Face Width [mm]	10.000	< 9.095	Mod
Cutter Units	mm v					





Click on Next >> and Ok

New Geometry Definition	- [mm] [dd.m	m.ss]		×
General Cutter Units				
	Pinior	ı	Gear	
T. Error (uRad)	0			
Helix Angle	0.00.00			
Pressure Angle	20.00.0	0		
Thew Geometry Definition	- [mm] [dd.m	m.ss]		×
General Cutter Units				
Blank Data				
Dealdeach		Pinion	Gear	
Backlash			0.100	
FC.Xp		0.000	0.000	
Zero Front Angle				
Outside Diameter(	Heel)	0.000	0.000	
Face Angle		0.000	0.000	
Root Angle		0.000	0.000	
Dedendum Angle		0.000	0.000	
Whole Depth	) @Mid-F	0.000	0.000	
Bore Diameter	@Heel	0.000	0.000	
Min Bore to Root	@ Toe	0.000	0.000	
		0.000	0.000	
Units			Clear	
Units				
Linear Units		mm	<b>~</b>	
Angular Units		Deg.Min.Se	ec 🔻	
Cutter Units		In	•	
	r			
		Import <	<back next="">&gt;</back>	Cancel



Tooth – M/C -> Cutting Machine Child Window -> 5 Axis CNC manufacturing

### **Overview:**

HyGEARS integrates a **5Axis Post-Processor** that can generate CnC part programs to cut **any HyGEARS supported gear type on any 5 Axis CnC machine**.

The part programs, based on the exact tooth definition, **need no further intervention** and can be uploaded directly to any 5Axis CnC machine.

*Tool and machine movements are displayed in 3D*, *can be rotated in any direction for better viewing, and can be animated or single stepped to allow visualization and collision detection throughout the tool path.* 

The use of the Post-processor is easy, intuitive, and reflects the actual work done on the shop floor.

The Post-processor supports machine architectures of "BA", "BC", "AB" and "AC" types, where :

- the A axis rotates about the X axis
- the B axis rotates about the Y axis
- the C axis rotates about the Z axis

Specific machines with special kinematics can be created and saved for later use: the translation and rotation axes can be renamed, and their positive direction can be inverted.

Typical tools include Face Milling, Coniflex<sup>TM</sup> dish, CoSIMT (i.e. Conical Side Milling Tool), End Mill and Ball Mill cutters. A tool box for each tool type can be created by the users to suit their needs.

### Main features of the Post-Processor:

- *supports "AB", "AC", "BA" and "BC" architecture machines;*
- supports GCodes, Heidenhain, Siemens, Okuma, Mazak and Fanuc controllers;
- supports Traori (Siemens), TCPM (Heidenhain), TCP (Fanuc) and TCPC (Okuma);
- allows creation of specific 3, 4, 5 Axis machines from the 4 basic architectures; specific machines can be fully customized by the user to reproduce exactly the machine implementation;
- offers 10 pre-defined cutting cycles for CoSIMT, End Mill and Ball Mill tools; and 4 pre-defined cutting cycles for Face Mill tools (single roll/double roll);
- CoSIMT and End Mill cutting edges can be linear or circular (to cut a Face Gear for example);
- allows single pass roughing / multi-pass semi-finishing and finishing for CoSIMT, End Mill and Ball Mill tools;
- allows the generation of a protuberance in the fillet;
- the tool path is easily customized by the user in order to optimize both cycle time and product quality;
- allows automated / single stepping animation of the tool and work piece through the cutting cycle;
- allows the display of the supporting arbor and the machine head to detect potential collisions;
- allows the creation of "Operations" which define a given task; Operations can be re-used on different gears;
- allows the creation of "Processes" which are a series of "Operations" in a given order; Processes can thus generate a complete single file part program including roughing and semi-finishing of the tooth flank and fillet using different tools.

### Part Programs:

- *can be in CSV (comma separated values) format for import in Excel;*
- can include or exclude comments describing the operations performed;
- can be for Face Milling cutters (spiral bevel gears), Dish type cutters (Coniflex ™ The Gleason Works gears), CoSIMT (such as made by Ingersoll Rand, Sandvik, PTR-TEC), End Mill, Ball Mill cutters.

### <u>*A-C*</u> machine architecture:

- ➤ X, Y, Z translations (on the tool and/or work piece)
- Tilting Turntable about X axis: angle A
- Rotation about work axis: angle C



### <u>*A-B*</u> machine architecture:

- ➤ X, Y, Z translations (on the tool and/or work piece)
- Tilting Turntable about Y axis: angle B
- Rotation about work axis: angle A



### <u>*B-C*</u> machine architecture:

- ➤ X, Y, Z translations (on the tool and/or work piece)
- Tilting Tool about Y axis: angle B
- Rotation about work axis: angle C



### <u>*B-A</u> machine architecture*:</u>

- ➤ X, Y, Z translations (on the tool and/or work piece)
- Swiveling Tool about X axis: angle A
- Tilting Tool about Y axis: angle B



**Conversion:** To generate a part program, HyGEARS converts the movements of the conventional cutter in a conventional machine into movements of a Face Mill, Coniflex<sup>™</sup> dish, CoSIMT, End Mill or a Ball Mill tool in a 3, 4, 5 Axis CnC machine where:

- the relative orientation between the ref. frames of tool and work in the conventional machine are maintained in the CnC machine;
- the relative position between the ref. frames of tool and work in the conventional machine are maintained in the CnC machine.

The figure to the right shows a Face Mill cutter (pink) and a CoSIMT (green) with coincident cutting edges.

The HyGEARS Post Processor tracks the movements of the Face Mill cutter in the conventional machine and converts them to CoSIMT movements in a 5Axis CnC machine.

The same approach is applied to all tools and gear types.









Machine/Tool: The Apex Location is used in Machine coordinates to compensate for turntable tilt

















### Arbor: Blank supports on the machine.





*Tools:* Each tool type is described in a dedicated data page where the defining dimensions are entered by the user. The 30 character-long tool name is user defined.

The tools can be saved for re-use and are specific to users, i.e. they are not distributed with *HyGEARS*. Hence, proprietary information remains proprietary.



Ball Mill Definition: Tool dimensions, reference (tools are user defined).







**CoSIMT Definition**: Tool dimensions, reference (tools are user defined).


**CoSIMT Definition :** CoSIMT tools can have circular cutting edges which allow the generation of tooth profiles with concave curvature, such as Face Gears.



Face Mill Definition: Tool dimensions, reference (tools are user defined).

Machine/Tool Cycle	Cycling Time	/Power Arbor Face Mill Operation Process
Face Mill Details	Name Tool ID: TLU1D:	2.75"FM 16MnCr5 2.75"FM 16MnCr5 1 Clear Save Delete DXF 0
Body Height Blade Depth Cutter Gaging Number of Blades Tooth Depth Point Width Tool Length Cutter Holder	7.3069 7.3069 7.3069 0.0000 12 2.1762 0.4550 14.6138	Tool Length Body Diameter Body Diameter Body Height Blade Tip Blade Depth
		Feeds [mm/min]           RPM         1200.0           Rapid Move         1500.0         Plunge         500.0         Cutting         500.0

- the Face Mill cutter used on the 5Axis CnC machine can be defined and saved;
- *cutter Diameter, Blade angles, Edge Radii, and Point Width are those described in the Summary Editor (see below).*

Pinion [Hypoid] [Finishing][Nominal] Hypoid-N10x60x120-01-Test-452_Corr ×								
Blank	Cutter	TopRem	Machine	Hi Order	Other	Operating	Rim-Material	Bear 🔸 🕨
Ave Blac B.E Poir Cutt Rac Ref Nun Cutt	erage Diar de Angle dge Rad. ht Width ter Edge d. of Curv. . Height nber of Bl ter Gaging	ature ades g		Conca 50.9 17.5 0.20 0.45 Stra 0.00 0.53 20 0.00	ave-OB		(in) Convex-IB 23.5000 0.2000 Straight 0.0000 0.5350	) [mm]
						Apply	, ок	Cancel

Face Mill cutter definition

Face Mill Definition: Tool dimensions, reference (tools are user defined).



Coniflex Definition: Tool dimensions, reference (tools are user defined).



#### Coniflex Definition: DXF export.



**Probe Definition**: Tool dimensions, reference (tools are user defined).



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**Operation:** The Operations page allows saving combinations of Machine, Tool and Cutting Cycle selections, for the current geometry, under one identifier such as to be able to use the same combinations with different geometries, or when defining Processes.

° 5Axis Cn ∕lachine/Too	C - Pinion	[Fini	shing] 11) ics Cyclir	(39 SpiralBeve ng Time/Power	I-FromSp Arbor	a.hyg - [ End Mill	mm] Operatio	on Proces	s Stock	1
Operation										
Name Fir	nish-0.8 (mn	n] EM	[1-15/15]	Nork	Finis	h-0.8 [mm	) EM [1-1	5/15] Work	c	$\sim$
	ave D	elete	Import	STEP	Finis Finis Rou Rou	h <mark>-0.8 [mm</mark> h Fill-0.6   gh-MPass gh Fill-MP	) EM [1-1 [mm] EM [ s-0.8 [mm] ass-0.6 [r	5/15] Work [1-13/13] W [EM [1-29/ nm] EM [1-1	k /ork 29] Work 13/13] Wor	łk
Tool Cha	<b>ige</b> Tool	ID (	10	0	0	0	0		0	-
	TLU	ID	0	0	0	0	0		0	۲
	Gap	#	1	0	0	0	0		0	٦
		òpindle òpindle	CW CCW	Coolant Of	f Code 9	8000	Vc: 1 fz: 0 ae: 0	20.6 [m/ .0063 [mr .000 [mr	/min] n] <b>n]</b>	
Feeds (m	<b>n/min]</b> —	Return # Ste	Trip eps	11			- Kc: 1	800.0		
-	Rapio	d Mov	e	2000.0						
	Plung	je		500.0						
	Cuttir	g		IB Toe->Heel 1200.0	IB Heel-: 300.0	Toe O	B Toe->H 00.0	leel OB He 300.0	eel->Toe	
				Output	Apply	+/-	Ar	im C	)k Ca	anc
				Operatio	ons Tal	)				

- an Operation is specific to a geometry, i.e. it is saved in the "Operations.fil" file stored in the current geometry's folder;
- the *Save / Delete* buttons conserve and erase the selected operation;
- the **Import** button allows importing Operations from other geometries; thus, Operations can be re-used;
- the **Output** button generates the part program for the selected Operation;
- *Tool Changes* can be imposed at specified tooth gaps;
- Several *Switches* can be imposed to any given operation.

**Operations:** The STEP button displays a selection window where one Flank and one Fillet operation are selected, and then combines the selected operations in one STEP file which can be read by any CAD-CAM software, such that the actual shape of the tooth can be exported for assessment at any intermediate manufacturing step.







**Processes:** A Process is an ordered sequence of Operations in which a Main, or Calling, program is generated which calls the selected Operations in the requested order. For example, right column in the figure below, the Main program would call Operation "Rough-Mpass-0.8 [mm] ..." first, and then Operation "Rough-Fil-Mpass ..."

achine	Tool Cycle Metrics Cycling Time/Power Arbor End Mill Operation Process
Proce	sses
Name	186559 186559 ~
ID #:	559 Internal Subroutine
	Save Delete Import Summ Output Apex Loc. 0.000
	Available Operations
	.093 ROUGH FLANKS
	0.063 OD Test-LeftFlank
	0.063 OD Test-MPass -Radial [1-4/6] 0.035 ROU( 0.035 EINISH Root
	0.03 OD Test-RightFlank
	0.063 OD Test-WorkCoords 0.063 OD Test - Mazak
	Save Output Apply +/- Anim Ok Canc

- A Process is specific to a geometry, i.e. it is saved in the "Processes.fil" file stored in the current geometry's folder;
- A Process can contain any number of operations the controller's memory being the practical limit;
- the Save / Delete buttons conserve and erase the selected Process;
- the **Import** button allows importing Processes from other geometries;
- the **Output** button generates the complete part program for the selected Process;
- All *Switches* imposed in any given operation appear in each step of the *Process*.

*Machines*: 4 basic CnC machine architectures are available: BC, AC, AB and BA (bottom left figure); plus 3 and 4 Axis machines.

Any specific machine can be derived from the basic types using the HyGEARS machine editor (bottom right figure).

🔹 5Axis CnC - Pinion [Finishing] 11x39	9 SpiralBevel-FromSpa.hyg - [mm] X	
Machine/Tool Cycle Metrics Cycling	Time/Power Arbor CoSIMT Operation Process Stock	Mach Definition
Machine Selection	Cutting Tool	Mach. Preamble   Controller-Machine Head
3 Axis CnC     4 Axis CnC     5 Axis CnC	Face Mill Cutter I Hide Cutter Body	Machine Name     Mikron GF [Heidenain]     CoR-Wk.Spindl     24.400       Machine Type     "AB" Type P     3-Axis
<ul> <li>5 Axis CnC B-C [Type M]</li> <li>5 Axis CnC "A-C" [Type P]</li> <li>5 Axis CnC "A-B" [Type P]</li> </ul>	CoSIMT	O "BC" Type M     4+1-Axis     Rotation Offset     0.00       "BA" Type T     Work Rotation     • 357 363
5 Axis CnC "B-A" ]Type T]     Specific Machine		
Mikron GF [Heidenain] Mikron GF [Heidenain]	Probe [CMM]	ID Ref.Axis Sign Sync Out Oper. Offset     Z+
Com Mitsui HU63A-5X Mitsui HU63A-5X (Center)	Display	$\begin{array}{c c} \land & \mathbf{X} & \bigcirc + \textcircled{\bullet} - \\ \hline & & & \\ \hline & & \\ \hline & & & \\ \hline & & & \\ \hline \\ \hline$
Ape Mori NT3100-BC Mori NT4250 / C1 [B-]	Display Machine Head	Z Z • + O - 1 0.0000 C+ 7
Aligi Mori NT4250 / C1 [B+] 3Ax Multus B400	✓ Display Arbor ✓ Display T Table	A B C Signs X-
Multus B400 4Axis NMV 3000-AC	Display Target Grid	ID Ref Axis Sign Sync Out
NMV 3000-AC [Fanuc]	🗹 Display Tool Path	
Okuma MU-500VA [LH 0-360] Okuma MU-500VA [LH]	Display Section	
Okuma MU-500VA [RH 0-360] Okuma MU-500VA [RH]	Lock on Tool     Detect Gouging Display Warning	$ \begin{array}{c c} C & B & \textcircled{O} + O - \\ O & B+3, B+357 \end{array} $
Okuma MU-500VA [Univ] Okuma Multus [LH 0-360] Okuma Multus [RH 0-360] PAMA SPEEDRAM 2000	Workpiece is Fixed	C     C     · </td
ProX 1000 Rafaello R5A 6[A-] 4+1Axis Rafaello R5A.6	utput Apply +/- Anim Ok Cancel	Apply OK Cancel
1	Machine Selection	Machine Editor
		© Involute Simulation Softwares Inc. 202

**Display:** Several options allow selective information display. These include:

- the Machine Head,
- the Work Arbor and support,
- the Target Grid, where the target coordinates are displayed in wire frame mesh,
- the Target Volume which will be removed by the selected operation,
- the Tool Path.

🕷 5Axis CnC - Gear [Finishing] 11x39 Spi	iralBevel-52OD.hyg - [mm]	Cutting Machine
Machine/Tool Cycle Metrics Cycling T	Time Arbor End Mill Operation Process Stock	Cutting watchine Chill Liniversal SAds Art Jimhion (Finishing) (vomena
Machine Selection	Cutting Tool	
<ul> <li>3 Axis CnC</li> <li>4 Axis CnC</li> </ul>	Face Mill Cutter 🗸 Hide Cutter Body	
<ul> <li>5 Axis CnC "B-C" [Type M]</li> <li>5 Axis CnC "A-C" [Type P]</li> </ul>	CoSIMT Invert Arbor Outside Blade	
<ul> <li>5 Axis CnC "A-B" [Type P]</li> <li>5 Axis CnC "B-A" ]Type T]</li> </ul>		
Specific Machine	Ball Mill	
Mikron GF [Heidenain] - New Edit Delete	Probe [CMM]	
Compensation	Display	
Apex Location 37.4830	Display Machine Head	
Alignment Angle 0.0000	Display Arbor	
3Axis Tool Tilt 0.0000	Display Target Grid	
Tool Center Point [TCP]	✓ Display Tool Path	
Absolute	Display Section	80.792
Differential	Lock on Tool	
	Detect Gouging Display Warning	
	Workpiece is Fixed	x3
P		
	Output Apply +/- Anim Ok Cancel	
		Display of the Target Grid (beige) and Volume (light blue)

**Display:** Example of Tool Holder and Work Arbor with CoSIMT and 1.2 mm module hypoid pinion.



**Display:** Detection of Gouging interference (tool back side contact with opposite tooth flank): HyGEARS can determine, and display where, if any Gouging occurs such as to alert the user of potential profile mutilation; valid for CoSIMT, End Mill, Ball Mill tools.

📽 5Axis CnC - Pinion [Finishing] 11x39 Spir	alBevel-FromSpa.hyg - [mm] X	
Machine/Tool Cycle Metrics Cycling Time/	Power Arbor End Mill Operation Process Stock	Cutting Machine
Machine Selection 3 Axis CnC 4 Axis CnC 5 Axis CnC "B-C" [Type M] 5 Axis CnC "A-C" [Type P] 5 Axis CnC "A-B" [Type P] 5 Axis CnC "B-A" ]Type T] Specific Machine Mikron GF [Heidenain]	Cutting Tool	Cutting Machine ChC [MAZAK INTEGREX Siemens] Pinion [Finishing][Nominal]- Concave-OB
New     Edit     Delete     List       Compensation       Apex Location     0.0000       Alignment Angle     0.0000       3Axis Tool Tilt     0.0000       Image: Tool Center Point [TCP]     Absolute       Differential	Probe [CMM] Display Display Machine Head Display Arbor Display T.Table Display Target Grid Display Tool Path Display Section Lock on Tool Detect Gouging Display Warning Workpiece is Fixed	Current cutting point
Ou	tput Apply +/- Anim Ok Cancel	Display of Gouging points with Pink crosses

*Cycles: Cutting cycles can be extensively tailored to user preferences, depending on tool choice.* 

Cycle Options for CoSIMT, End Mill and Ball Mill tools

- Stock feed along the face width (#Facewidth Pts) and tooth depth (#Steps)
- Step# where cutting starts and ends (Start / End)
- Tool retraction at end of cycle (Retract Factor, based on Heel tooth depth)
- Whether the tooth is digitized with constant roll angle or constant radius increments (Constant D-Radius)
- Whether the contact point moves along the tool cutting edge (Moving Contact Pt)
- Roughing and Finishing cycles
- Toe and Heel clearances, to plunge the tool full speed
- Tip, Toe and Heel chamfering
- Indexing sequence in order to spread tool wear and thermal load over non sequential tooth Gaps (Skip#).

### Cycles: CoSIMT, End Mill, Ball Mill

🐇 5Axis CnC - Pinion [Finishing]	11x39 SpiralBevel-FromSpa.hyg - [mm]	×
Machine/Tool Cycle Metrics Cy Output Format	cling Time/Power Arbor CoSIMT Op	eration Process Stock
Use Actual Tooth CSV Format Line Numbers	# Steps 9 77	Actual Start 1 Steps
Include Operation Switches Include Short Header Include Start Positions Fixalicit Indexing	Retract Factor 2.0 A Moving Contact Pt — Over Ru	in 0.0000
No Comments Coordinates Only Work Coordinates	Clearance [mm]	tock 0.000 Stock 0.381
TCPM (Heidenhain) Haas Horizon	Toe         0.000         Skip #           Heel         0.000         Mirror	1     Start Gap     1        End Gap     11
Slot by Slot     Rank by Rank	Convex (I.B.) O None Toe -> Heel -> Toe	Concave (O.B.) O None Toe -> Heel -> Toe
Fillet-Root     Tool Tilt     Tool Flank     Combined     Tool Pivot	10         00         O         Heel -> Toe -> Heel           0.000         O         Toe -> Heel           Fixed         O         Heel -> Toe	<ul> <li>Heel -&gt; Toe -&gt; Heel</li> <li>Toe -&gt; Heel</li> <li>Heel -&gt; Toe</li> </ul>
Chamfer Tool Side Chamfer Tool End Chamfer Toe Chamfer Heel	0.000         O IB-OB OShape-Toe           0.000         IB-OB OShape-Heel           0.000         Rock Me [babe]           0.000         Plunge Generation	OB-IB OShape-Toe     OB-IB OShape-Heel     MultiPass     Plunge Generation
	Output Apply +/-	Anim Ok Cancel

Cycles for CoSIMT, End Mill and Ball Mill tools

- CoSIMT tools can rough tooth flanks and fillet;
- CoSIMT, End Mill and Ball Mill tools can finish tooth flanks;
- Bull Nose, End Mill and Ball Mill tools can finish the fillet, and a protuberance can be imposed in the form of negative Stock;
- End Mill can Chamfer (i.e. deburring) tooth Tip;
- *Positive and Negative stock can be used;*
- Toe and Heel clearances can be imposed;
- The Indexing Sequence can be selected.



Cycles:Constant D-Radius:checked:<br/>un-checked:constant radial steps; insensitive for Z > 25<br/>constant roll-angle steps – improved surface near fillet<br/>better for Z < 20







Constant D-Roll

Cycles:Moving Contact Pt:checked:contact point moves along End Mill edge; better Finishun-checked:un-checked:contact point always at End Mill tip: more tool wear





*Cycles: HyGEARS offers 7 cycles for Face Mill cutters and 1 cycle for the Coniflex™ dish cutter.* 

🐝 5Axis CnC - Gear [Finishing] 11:	1x39 SpiralBevel-FromSpa.hyg - [mm] X	🐝 5Axis CnC - Gear [Finishing] 11x39 SpiralBevel-FromSpa.hyg - [mm]	×
Machine/Tool Cycle Cycling Time	e/Power Arbor Face Mill Operation Process	Machine/Tool Cycle Cycling Time/Power Arbor Face Mill Operation Process	
Output Format	Stock-Feed	Output Format Stock-Feed	
Use Actual Tooth CSV Format Include Operation Switches Include Short Header Include Short Header Include Start Positions Explicit Indexing No Comments Coordinates Only Work Coordinates TCPM (Heidenhain) Haas Horizon	# Steps         201           # Bottomland Pts         0           # Facewidth Pts         11           Retract Factor         4.0           Moving Contact Pt         Over Run         0.0000           Constant D-Radius         Finish Stock         0.000           Roughing         Finish Stock         0.000           Rough Stock         0.381         Skip #           Toe         32         Skip #         1           Heel         1         Mirror         End Gap         33	Use Actual Tooth       # Steps       9         CSV Format       # Bottomland Pts       0         Line Numbers       Include Operation Switches       # Facewidth Pts       11         Include Short Header       Include Start Positions       Moving Contact Pt       - Over Run       0.0000         Explicit Indexing       Constant D-Radius       - Finish Stock       0.000       0.381         Work Coordinates       Clearance [mm]       Indexing Sequence       Skip # 1       Start Gap 1         TCPM (Heidenhain)       Heel       0.000       Mirror       End Gap 39	]
Cutting Cycle Face Mill Cycle Single Roll - Toe to Heel Single Roll - Heel to Toe Plunge Roll - Heel to Toe Plunge Roll - Heel to Toe Double Roll - Heel to Toe Non Gen. Plunge Cut	Depth Fact         Feed         RPM         Dwell (Rot)           Rapid         1500         1000         250           Z1:         1.050         1000         250           Z2:         0.250         200         23:           Z3:         0.300         250         1.2	Cutting Cycle         Face Mill Cycle       Depth Fact       Feed       RPM       Dwell (Rot)         Toe -Heel/ Toe -Heel       Depth Fact       Feed       RPM       Dwell (Rot)         Heel-Toe / Heel-Toe       Fapid       1500       1000       250         Heel-Toe / Toe -Heel       Z1:       1.050       1000       250       200         Double Roll - Toe to Heel       Z2:       0.250       200       23:       0.300       0.300         Non Gen. Plunge Cut       74:       0.000       100       250       1.2	
	Output Apply +/- Anim Ok Cancel	Output Apply +/- Anim Ok Cano	:el

Cycles for Face Mill cutters / Completing

Cycles for Face Mill cutters / Semi-Completing

### *Cycles:* Face Mill Cutter – Completing cutting processes

🐇 5Axis CnC - Gear [Finishing] 11x39 S	SpiralBevel-FromSpa.hyg - [mm] X
Machine/Tool Cycle Cycling Time/Pow	wer Arbor Face Mill Operation Process
Output Format St	tock-Feed
□ Use Actual Tooth       #         □ CSV Format       #         □ Line Numbers       #         □ Include Operation Switches       #         □ Include Short Header       R         □ Include Start Positions       M         □ Explicit Indexing       Co         □ No Comments       R         □ Coordinates Only       Work Coordinates         □ TCPM (Heidenhain)       To         □ Haas Horizon       Heidenhain	Steps       9         Bottomland Pts       0         Facewidth Pts       25         Ideract Factor       4.0         Ioving Contact Pt       Over Run       0.0000         onstant D-Radius          Ioughing       Finish Stock       0.000         Rough Stock       0.0         Idearance [mm]       Indexing Sequence         Skip #       1       Start Gap       1         Mirror       End Gap       39
Face Mill Cycle	
Toe -Heel/ Toe -Heel     Toe -Heel/ Heel-Toe	Depth Fact Feed RPM Dwell (Rot)
Heel-Toe / Heel-Toe Fapi     Heel-Toe / Toe -Heel     Z1:	id 1500 1.050 1000 250
O Double Roll - Toe to Heel     Z2:     Double Roll - Heel to Toe     Z3:	0.250 200
◯ Non Gen. Plunge Cut74:	0.000 100 250 1.2
	Output Apply +/- Anim Ok Cancel

Cycles for Face Mill cutters

- can be Single Roll/Double Roll;
- Double Roll plunges the cutter to full depth between the start and end of the 1<sup>st</sup> roll, and then generates full depth on the 2<sup>nd</sup> roll;
- can be Toe to Heel or Heel to Toe;
- the use of Toe/Heel clearances allows progressive cutter entry/retract for better tool life (see the Target Volume in light blue below);
- the Indexing Sequence allows spreading tool wear and thermal load over non-consecutive tooth slots.



### *Cycles:* Face Mill Cutter – Fixed Setting / Semi-Completing cutting processes

5Axis CnC - Gear [Finishing] 11x	89 SpiralBevel-FromSpa.hyg - [mm]	×
Output Format	Stock-Feed	
<ul> <li>Use Actual Tooth</li> <li>CSV Format</li> <li>Line Numbers</li> <li>Include Operation Switches</li> <li>Include Short Header</li> <li>Include Start Positions</li> <li>Explicit Indexing</li> <li>No Comments</li> <li>Coordinates Only</li> <li>Work Coordinates</li> <li>TCPM (Heidenhain)</li> </ul>	# Steps         9           # Bottomland Pts         0           # Facewidth Pts         11           Retract Factor         4.0           Moving Contact Pt         - Over Run         0.0000           Constant D-Radius Roughing         - Finish Stock         0.000           Clearance [mm] Toe         Indexing Sequence         5kip #	
Cutting Cycle	Heel 0.000 Mirror End Gap 39	]
Face Mill Cycle		
Single Roll - Toe to Heel     Single Roll - Heel to Toe     Plunge Roll - Toe to Heel     Plunge Roll - Toe to Heel     Plunge Roll - Heel to Toe     Double Roll - Toe to Heel     Double Roll - Heel to Toe     Neg Con Rhome Cot	Depth Fact         Feed         RPM         Dwell (Rot)           apid         1500         1         1         1         1         1         1         1         1         1000         250         200         2         0         2         0         3         0         3         0         3         1         0         2         0         2         0         2         0         2         0         3         1         0         3         1         0         0         0         0         0         0         0         0         0         0         0         0         0	
O Ivon Gen. Plunge Cut - 2	Output         Apply         +/-         Anim         Ok         Can	cel

Cycles for Face Mill cutters

- xx / yy: 1<sup>st</sup> part is Convex flank; 2<sup>nd</sup> part is Concave flank
- the use of Toe/Heel clearances allows progressive cutter entry/retract for better tool life (see the Target Volume in light blue below);
- Negative Finish stock pushes the cutter In such as to compensate for tool wear;
- the Indexing Sequence allows spreading tool wear and thermal load over non-consecutive tooth slots.



*Cycles: HyGEARS offers* 14+ *different cutting cycles for CoSIMT, End Mill and Ball Mill tools.* 

🐝 5Axis CnC - Gear [Finishing] 11	1x39 SpiralBevel-FromSpa.hyg - [mm] X
Machine/Tool Cycle Metrics Cy	cling Time/Power Arbor End Mill Operation Process Stock
Output Format Use Actual Tooth CSV Format Line Numbers Include Operation Switches	Stock-Feed       Reqd. Sugg.       Actual       Positive Tool Pivot         # Steps       9       [7]       Start       1       Steps         # Bottomland Pts       0       End       9       Tgt.Pts         # Facewidth Pts       25       Bottom Up       Positive Tool Pivot
Include Short Header Include Start Positions Explicit Indexing No Comments Coordinates Only	Retract Factor       4.0         Moving Contact Pt       - Over Run       0.0000         Constant D-Radius       Image: Constant D-Radius       Image: Constant D-Radius         Roughing       Image: Constant D-Radius       Image: Constant D-Radius         Roughing       Image: Constant D-Radius       Image: Constant D-Radius         Roughing       Image: Constant D-Radius       Image: Constant D-Radius         Rough Stock       0.2000       0.381
Work Coordinates TCPM (Heidenhain) Haas Horizon	Clearance [mm]     Indexing Sequence       Toe     10       Heel     10       Mirror     End Gap       39
Slot by Slot     Flank by Flank     Fillet-Root     Tool Tilt     Tool Tilt     Tool Pivo     Combined	Convex (I.B.)         Concave (0.B.)           None         None           Toe -> Heel         Toe -> Heel           10.00         Heel -> Toe -> Heel           Toe -> Heel         Toe -> Heel
Chamfer Tool Side Chamfer Tool End Chamfer Toe Chamfer Heel	Fixed       O       Heel -> Toe       O         0.000       O       IB-OB OShape-Toe       O       OB-IB OShape-Toe         0.000       O       IB-OB OShape-Heel       O       OB-IB OShape-Heel         0.000       Rock Me [babe]       MultiPass       MultiPass         0.000       Plunge Generation       Plunge Generation
	Output Apply +/- Anim Ok Cancel

Cycles for CoSIMT, End Mill and Ball Mill tools

### Cycles: Finishing cycles for CoSIMT, End Mill and Ball Mill tools.

🔹 5Axis CnC - Gear [Finishing] 11	x39 SpiralBevel-FromSpa.hyg - [mm]	×
Machine/Tool Cycle Metrics Cyc	cling Time/Power Arbor End Mill Operation Process Stock	
Output Format         Use Actual Tooth         CSV Format         Line Numbers         Include Operation Switches         Include Short Header         Include Start Positions         Explicit Indexing         No Comments         Coordinates Only         Work Coordinates	Stock-Feed       Reqd.       Sugg.       Actual         # Steps       9       [7]       Start       1       Steps         # Bottomland Pts       0       End       9       Tgt.Pt         # Facewidth Pts       25       Bottom Up       Bottom Up         Retract Factor       4.0       Over Run       0.0000         Constant D-Radius       Image: Finish Stock       0.2000       0.381         Clearance [mm]       Indexing Sequence       Stock Image: Finish Stock Image: Finis	5
TCPM (Heidenhain)	loe 10 Skip # 1 Start Gap 1	-11
		_
Cutting Cycle  Slot by Slot  Rank by Flank  Cutlet Back  Cutlet Back	Convex (I.B.) O None Toe -> Heel -> Toe O None O Toe -> Heel -> Toe	
Tooth Flank     Combined	(0.000         O         Toe -> Heel         O         Toe -> Heel           Fixed         O         Heel -> Toe         O         Heel -> Toe	1
<ul> <li>Chamfer Tool Side</li> <li>Chamfer Tool End</li> <li>Chamfer Toe</li> <li>Chamfer Toe</li> <li>Chamfer Heel</li> <li>Pivot A.</li> </ul>	0.000         O IB-08 OShape-Toe         O OB-IB OShape-Toe           0.000         O IB-08 OShape-Heel         O OB-IB OShape-Heel           0.000         Rock Me [babe]         MultiPass           0.000         Plunge Generation         Plunge Generation	, 1
	Output Apply +/- Anim Ok C	ancel
Finishing Cycles fo	or CoSIMT, End Mill and Ball Mill tools	7

- Fillet/Root, Tooth Flank, Combined, Toe, Heel and Tip Chamfer (Deburring) are different operations;
- They can be cut Slot by Slot or Flank by Flank, depending on machine selection, work size, and how much travel is required by the machine or tool between tooth flanks;
- Finishing cycles need not be the same on both tooth flanks;



Cycles: Example: End Mill tool, Toe-Heel-Toe (IB-Side) / Heel-Toe-Heel (OB-Side)

achine/Tool Cycle Metrics	Cycling Time/Power Arbor End Mill Operation	ion Process Stock
Output Format Use Actual Tooth CSV Format Line Numbers Include Operation Switches Include Short Header Include Start Positions Explicit Indexing No Comments Coordinates Only Work Coordinates	Stock-Feed       Reqd. Sugg.         # Steps       15       [6]       Steps         # Bottomland Pts       0       Ei         # Facewidth Pts       51       B         Retract Factor       4.0       Ver Run         Constant D-Radius	Actual           tart         1         ✓ Steps           nd         15         ✓ Tgt.Pts           ottom Up         □           0.0000         □           k         0.000           ck         0.050           Sequence         □
ICPM (Heidenhain)     Haas Horizon Cutting Cycle	Heel 3.000 Mirror	Start Gap     I     End Gap     39
Slot by Slot     Fank by Flank     Fillet-Root     Tool T     Tool T     O Tooth Flank     Combined	Convex         (I.B.)         C           None         Image: Convex         Image: Convex	_oncave (0.8.) ○ None ④ Toe -> Heel -> Toe ○ Heel -> Toe -> Heel ○ Toe -> Heel ○ Heel -> Toe
Chamfer Tool Side     Chamfer Tool End     Chamfer Toe     Chamfer Heel     Pivot A	0.000       O       IB-OB OShape-Toe         0.000       O       IB-OB OShape-Heel         0.000       O       Rock Me [babe]         0.000       Plunge Generation	OB-IB OShape-Toe     OB-IB OShape-Heel     MultiPass     Plunge Generation

End Mill cycles

• Cutting cycles can be different for each tooth flank (IB-OB, Left-Right);

- a cutting cycle may start on the IB and finish on the OB (Left-Right for non spiral-bevels);
- for example, with the selections made in the left figure, given the IB cycle ends at Heel, unless otherwise dictated it could make sense to start the OB cycle at Heel to reduce cycle time (the tool path is the red line in the figure below).



### Cycles: Example: End Mill tool, Fillet

achine/Tool Cycle Metrics Cy	cling Time/Power Art	oor End Mill	Operation	Process	Stock
Output Format	Stock-Feed	Read Suga		Actual	
Use Actual Tooth	# Steps	6 [6]	J Start		Stene
CSV Format	# Bottomland Pts	0	End		Tot Pte
Line Numbers	# Facewidth Pts	11	Botto	m Un	rgunta
Include Operation Switches	Retract Factor	4.0	Dotto		
✓ Include Short Header	Maying Contact Pt	<b>4.0</b> → 0v	er Run	0.000	
Include Start Positions	Constant D Dadius		or Hull	0.0000	
No Commonto	Constant D-Radius	⊢ ∐ Filk	et Stock	0.000	
	Roughing	Fla	nk Stock	0.000	
Work Coordinates	Clearance [mm]	In	dexing Sec	Juence	
TCPM (Heidenhain)	Toe 2.500	S	kip # 1	- Start G	ap 1
Haas Horizon	Heel 3.000	M	lirror 🗌	End Ga	ap 39
utting Cycle					
	Convex	(I.B.)	Cond	cave (O.B.)	
Slot by Slot     Eack by Elank	O Nor	e	۲	None	
		-> Heel -> Toe	0	Toe -> Hee	l -> Toe
Fillet-Root     Tool Tilt	10.00 O Hee	I -> Toe -> Hee		Heel -> Toe	-> Heel
Combined		-> Heel	0	Toe -> Hee	l
	Fixed O Hee	I-> loe		Heel -> Toe	
Chamfer Tool Side Depth	0.000	D OShape-Toe		OB-IB OShi	ape-roe
Chamfer Toe Chamf A.	0.000 O Boo	k Me [babe]		MultiPass	ape-neel
O Chamfer Heel Pivot A.	0.000 O Plur	nge Generation	ĬŎ	Plunge Gen	eration
		-			

*Fillet cycles* 

- Fillet finishing is integral to tooth flank finishing when using a Face Mill cutter since the tool sweeping movement generates the fillet;
- Fillet finishing is done in a distinct operation when using an End Mill or Ball Mill tool;
- *negative Stock can be imposed to produce a protuberance;*
- *the tool can be tilted away from the tooth to avoid interference;*
- Fillet finishing uses the same cycles as for Flank finishing.



Cycles: Example: tapered End Mill tool, IB-OB O-Shaped / OB-IB O-Shaped

Machine/Tool Cycle Metrics Cycling Time/Power Arbor End Mill Operation Process Stock
Output Format       Stock-Feed         Use Actual Tooth       # Steps         CSV Format       15         Line Numbers       15         Include Operation Switches       # Bottomland Pts         Include Short Header       # Facewidth Pts         Include Start Positions       Retract Factor         Explicit Indexing       Constant D-Radius         No Comments       Roughing         Coordinates       Clearance [mm]         TCPM (Heidenhain)       Toe         Heal 3000       Mirror
Cutting Cycle       Convex (I.B.)       Concave (0.B.)         Slot by Slot       None       None         Rank by Rank       Tool Tilt       10.00         Fillet-Root       Tool Tilt       10.00         Tool Flank       Tool Pivot 0.000       Toe -> Heel         Combined       Fixed       Heel -> Toe         Chamfer Tool Side       Depth       0.000         Chamfer Tool End       Depth       0.000         Chamfer Toe       IBOB OShape-Toe       OB-IB OShape-Toe         Chamfer Toe       Pivot A.       0.000       Plunge Generation         Output       Apply       +/-       Anim       Ok

IB-OB O-Shaped cycle

- only one starting flank can be selected, the other being slave;
- for IB-OB, the cutting cycle takes a pass along the face width on the IB and switches to the OB for return; the cycle then switches back to the IB and takes one step depth wise before starting over again;
- can be a real time saver when used with a Tapered End Mill or a CoSIMT.



### Cycles: Example: CoSIMT tool, Rock-Me (Babe)

chine/Tool	Cycle	Metrics	Cycling Time	/Power A	rbor	CoSIMT	Operation	Process	Stock
Output For Use Actu CSV Fon Line Nun Include ( Include ( Include ( Explicit In No Comr	mat ual Tooth mat Dperation Short Hea Start Posi ndexing ments	Switches ader tions	Stock # Step # Botte # Face Retrac Moving Consta Rough	Feed s omland Pts width Pts t Factor contact P nt D-Radiu ing	Reqc 15 0 51 4.0 t s C	1. Sugg [12] ] Ove	- Start End Botto er Run [ sh Stock [	Actual 1 15 m Up 0.0000 0.000	] Steps ] Tgt.Pts
Coordina Coordina Work Co TCPM (F Haas Ho Utting Cycl	ites Only oordinates Heidenhai orizon I <b>e</b>	n)	<b>Cleara</b> Toe Heel	nce [mm] 2.500 3.000		Inc Sł M	lexing Sec kip # 1 irror	quence Start G End G	iap 1 ap 39
Slot by Slo	Slot v Flank				((I.B.)− )ne )e -> He	el -> Toe	Conc	cave (O.B.) None Toe -> Hee	-> Toe
<ul> <li>Fillet-Roo</li> <li>Tooth Fillet</li> <li>Combine</li> </ul>	ot ank ed	Tool Ti Tool Pi	t 10.00 vot 0.000 Fixed		el -> To e -> He el -> To	e -> Heel el e	000	Heel -> Too Toe -> Hee Heel -> Too	e -> Heel e
Chamfer Chamfer Chamfer Chamfer	Tool Side Tool End Toe Heel	e Depth Chamf Pivot A	0.000           A.         0.000           0.000         0.000		OBOSH OBOSH ock Me	nape-Toe hape Hee [babe] [ neration		OB-IB OSh OB-IB OSh MultiPass Plunge Ger	ape-Toe ape-Heel neration

Rock Me (babe) cycle

- the cycle starts at IB Toe-Tip, generates depth wise to the Fillet, switches to the OB and generates from Fillet to Tip, advances along the OB face width, generates depth wise along the OB side to the Fillet, switches to the IB and generates till Tip, advances along the IB face width, and starts over until Heel is reached;
- this process is well suited to CoSIMT and finishing in one operation.



### Cycles: Roughing cycles for End Mill and Ball Mill tools.

Machine/Tool Cycle Metrics	Cycling Time/Power Arbor End	d Mill Operation Process Stock			
Output Format         Use Actual Tooth         CSV Format         Line Numbers         Include Operation Switcher         Include Short Header         Include Start Positions         Explicit Indexing         No Comments         Coordinates         TCPM (Heidenhain)         Haas Horizon	Stock-Feed Reqd. # Steps 9 # Bottomland Pts 0 # Facewidth Pts 25 Retract Factor 4.0 Moving Contact Pt Constant D-Radius Roughing 2 Clearance [mm] Toe 10 Heel 10	Sugg.         Actual           [7]         Start         1         Steps           End         9         Tgt.Pts           Bottom Up         Over Run         0.0000           Finish Stock         0.000           Rough Stock         0.381           Indexing Sequence         Skip #           Skip #         1         Start Gap           Mimm         End Gap         29			
Image: Starting Cycle         Image: Starting Cycle <td< th=""><th>Convex (I.B.)           O None           O Toe -&gt; Heel -           O Heel -&gt; Toe -           Pivot 0.000           Fixed           O Heel -&gt; Toe -&gt; Heel           O Heel -&gt; Toe -&gt; Heel           O Heel -&gt; Toe           IB-OB OShap           O IB-OB OShap           O Center Slot           Plunge Gene</th><th>Concave (O.B.) None Toe Heel Heel Toe -&gt; Heel -&gt; Toe Heel -&gt; Toe -&gt; Heel Toe -&gt; Heel Toe -&gt; Heel OB-IB OShape-Toe OB-IB OShape-Toe OB-IB OShape-Heel MultiPass Plunge Generation</th></td<>	Convex (I.B.)           O None           O Toe -> Heel -           O Heel -> Toe -           Pivot 0.000           Fixed           O Heel -> Toe -> Heel           O Heel -> Toe -> Heel           O Heel -> Toe           IB-OB OShap           O IB-OB OShap           O Center Slot           Plunge Gene	Concave (O.B.) None Toe Heel Heel Toe -> Heel -> Toe Heel -> Toe -> Heel Toe -> Heel Toe -> Heel OB-IB OShape-Toe OB-IB OShape-Toe OB-IB OShape-Heel MultiPass Plunge Generation			
Output Apply +/- Anim Ok Cancel					

- *Fillet/Root and Tooth Flank are different operations;*
- They can be cut Slot by Slot or Flank by Flank, depending on machine selection, work size, and how much travel is required by the machine or tool between tooth flanks;
- Roughing cycles need not be the same on both tooth flanks;
- Center Slot cuts a through in the center of the gap;
- MultiPass is a Slot by Slot operation; it makes an even number of passes per Step, based on slot width and tool diameter; the number of passes is calculated at each Step; allows greater tool feeds over Center Slot because the tool is never captive in a through.

### Cycles: Roughing cycles for CoSIMT tools.

Machine/Tool Cycle Metrics Cycl  Output Format Use Actual Tooth CSV Format Line Numbers Include Operation Switches Include Start Positions Explicit Indexing No Comments Coordinates Only Work Coordinates TCPM (Heidenhain) Haas Horizon	Ing Time/Power Arbor CoSIMT C Stock-Feed # Steps # Bottomland Pts # Facewidth Pts Retract Factor Moving Contact Pt Constant D-Radius Roughing Clearance [mm] Toe 10 Heel 10	Actual Actual Start 1 Steps End 9 Tgt.Pts Bottom Up Run 0.0000 Stock 0.00 a Stock 0.00 ting Sequence # 1 Start Gap 1 r End Gap 39
Image: Starting Cycle         Image: Starting System         Image: Starting Syste	Convex (I.B.)           None           Toe -> Heel -> Toe           Heel -> Toe -> Heel           Toe -> Heel           Toe -> Heel           B-OB OShape-Toe           B-OB OShape-Heel           Center Slot           Plunge Center Slot	Concave (O.B.) None Toe -> Heel -> Toe Heel -> Toe -> Heel Toe -> Heel Heel -> Toe OB-IB OShape-Toe OB-IB OShape-Toe OB-IB OShape-Heel MultiPass Plunge Generation
Roughi	Output Apply +/-	Anim Ok Cancel

- *Fillet/Root and Tooth Flank are different operations;*
- They can be cut Slot by Slot or Flank by Flank, depending on machine selection, work size, and how much travel is required by the machine or tool between tooth flanks;
- Roughing cycles need not be the same on both tooth flanks;
- Center Slot cuts a through in the center of the gap;
- MultiPass is a Slot by Slot operation; it makes an even number of passes per Step, based on slot width and tool diameter, the number of passes is calculated at each Step; allows greater tool feeds when compared to Center Slot;
- For Fillet roughing, only Center Slot is available;

**Tool Reference Point:** the Tool Length to be entered in the 5Axis machine controller depends on the location of the Tool Center Point (TCP), as follows.



CoSIMT : TCP (located @, mid P.Width)



Face Mill Cutter: TCP (in the plane of blade tips)

*Tool Reference Point:* End Mill / Ball Mill tools: reference can be given at TCP or Tip.





Ball Mill : TCP and Tip

End Mill: TCP and Tip

**Tool Reference Point:** Coniflex<sup>TM</sup> dish type cutter: TCP.



Coniflex Dish Reference Point

*Part Reference Point:* The reference point on the work piece changes with geometry type; it is tool independent.



Spur/Helical/Beveloid/Herringbone gears: BC type machines

*Part Reference Point:* The reference point on the work piece changes with geometry type; it is tool independent.



Spur/Helical/Beveloid/Herringbone gears: AC-AB type machines

### *Part Reference Point:* Straight Bevel / Spiral Bevel / Zerol / Coniflex gears.


Part Reference Point: Hypoid gears.



### Part Reference Point: Face gears.



*Output:* The Output button instructs HyGEARS to read the selected user choices, generate the part program and send the output to a Text Results window.

SAxis CnC - Pinion [Finishing]     Machine/Tool Cycle Metrics Cy	11x39 SpiralBevel-FromSpa.hyg - [mm ycling Time/Power Arbor End Mill Op	] X veration Process Stock
Output Format         Use Actual Tooth         CSV Format         Line Numbers         Include Operation Switches         Include Short Header         Include Start Positions         Explicit Indexing         No Comments         Coordinates Only         Work Coordinates         TCPM (Heidenhain)         Haas Horizon	Stock-Feed       Reqd. Sugg.         # Steps       15       [6]         # Bottomland Pts       0         # Facewidth Pts       51         Retract Factor       4.0         Moving Contact Pt       — Over R         Constant D-Radius       — Finish S         Roughing       — Finish S         Toe       2.500         Heel       3.000	Actual Start 1 Steps End 15 Tgt.Pts Bottom Up un 0.0000 Stock 0.000 Stock 0.000 Stock 0.050 ing Sequence # 1 Start Gap 1 End Gap 39
Cutting Cycle <ul> <li>Slot by Slot</li> <li>Rank by Flank</li> </ul> Fillet-Root <ul> <li>Tool Tilt</li> <li>Tool Tilt</li> <li>Tool Pivo</li> <li>Combined</li> <li>Chamfer Tool Side</li> <li>Chamfer Tool End</li> <li>Chamfer Toe</li> <li>Chamfer Heel</li> </ul>	Convex (I.B.)           None           Toe -> Heel -> Toe           Heel -> Toe -> Heel           Toe -> Heel           Fixed           0.000           0.000           0.000           0.000           0.000           0.000           0.000           0.000           0.000           0.000           0.000           Output           Apply	Concave (0.B.)         None         Toe -> Heel -> Toe         Heel -> Toe -> Heel         Toe -> Heel         Heel -> Toe         OB-IB OShape-Toe         OB-IB OShape-Heel         MultiPass         Plunge Generation
	Part program Output	

A part program comprises:

- a Header, in which user selections, machine settings and tool definition are listed; this is optional at output time using the "No comment lines" switch;
- a Preamble, specific to the selected machine, where machine code desired by the operator is added automatically;
- the Indexing Sequence, where each tooth slot calls the actual cutting program in the specified sequence order;
- *the actual cutting program with tool path coordinates;*
- Work Coordinates indicate that X, Y and Z are in work piece coordinates, and that angles A, B, C are machine angles;
- Traori, TCPM, TCP and TCPC indicate that the unit vector of the tool axis is provided along with X, Y and Z in work piece coordinates.

### **Output:** the Header lists user selections, machine settings and tool definition.

e Edit		File Edit			
					_
DOCDIM NIME . #2 Finiah	Mowing Contage [1-10/10]		; GEAR [FINISHING]		
ROGRAM NAME : #2 FINISH	Moving Concace [1-10/10]	ada	; CUTTER SPECIFICATIONS	[I.B.]	[O.B.
ROGRAM DAIL : 0/-21-201	5	lees.	;		
SUMMARI VERSION : [NOMINAI]	500.007				
100L ID : 120121 2/	588 36/	=	; Average Diameter :	304.8	000
COL DIAMETER : 6.00[mm]			; Blade Angle :	28.4178	11.4156
COL LENGIH : 40.00[mm]			; Blade Edge Radius :	4.1	910
	******		; Point Width :	6.1	112
; Date / Time	: 21/07/2015 / 6:13:44 PM		; Rad. of Curvature :	6350.0000	6350.0000
; General Units	: [mm] [dd.mm.ss]		; Rad. of Curvature-Ref. Height :	0.0000	0.0000
; Cutter Units	: [mm]		; TopRem Depth :	0.0000	0.0000
; Prepared by	: Claude Gosselin		; TopRem Radius :	88.9000	0.0000
; Version	: 4.0.404.60-457		; Cutter Gaging :	0.0000	0.0000
;					
;	Start Header				
; Hygears V 4.0 © 👁			; GEAR [FINISHING] :Spread Blade		
;			; MACHINE SETTINGS - #175-S		
; Part Program	: 13x33d400_final_REG.hyg		;		
;					
; Machine	: CnC [Ultrix] - [Finishing][Nominal]		; Radial Distance :	148.9870	
;			; Cutter Tilt ;	6.1644	
; Operation	: #2 Finish Moving Contace [1-10/10]		: Swivel Angle :	197.3272	
;			: Blank Offset :	0.000	
; Member	: Gear		: Machine Root Angle :	64.5626	
; Controller	: Siemens		: Machine Center To Back	0.0947	
; Coordinates	: Work Piece		· Sliding Base	13 7400	
; Indexing	: Controller code		, Bate of Boll	1 07255	
; Contact Point	: Fixed		, Rate of Roll :	1.07255	
: Tooth line sep.	: Cat D-Roll		; Cradie Angle :	54.5272	
: Stock left	-0.5000				
. Tool Length	40.000		; WORKPIECE DIMENSIONS		
· Anex Location	. 0.000		;		
. # Gane			; # Teeth :		33
· Start			; Module :	12	.121
, Start			; Face Angle :	69	.746
· Increment	. 55		; Face Width :	78	.749
, increment			; Front Crown to Xp :	49	.047
; = Steps	. 6		; OD Toe :	266	.512
; Start	. 1		; OD Heel :	400	.036
; Ella	. 6		;		
; # Points Width	: 11		; END MILL TOOL DEFINITION		
; TOOL TILL Angle	: 10.000		;		
; Retract factor	: 2.0		; Name :		
; Toe Clear. [#pts]	: 50.000[3]		; Diameter :	6	.000
; Heel Clear. [#pts]	: 20.000[3]		; Edge Radius :	3	.000
; Compensation	: Tool Center Point		; Cone Angle :	0	.000
; Cutting Cycle	: Slot by Slot		; Cutting Length :	30	.000
; Target	: Fillet Area		; Cutting Length in Use:	30	.000
; IB/Left Cycle	: Toe-Heel-Toe		: Tool Length :	40	.000
; OB/Right Cycle	: Toe-Heel-Toe		: Stem Diameter :	10	.000
;			· Holder Diameter	0	000
		·	, norder Drameter :	U	.000

Output: Header – 1<sup>st</sup> part

*Output: Header – 2<sup>nd</sup> part* 

**Output:** Indexing Sequence: indexes the work piece axis in the specified sequence.

🖉 Part Program for : Gear [Finishing] 13x33d400_final_REG.hyg	x
File Edit	
: Start of Program	T
SEQINDEX[1] = 1	۲
SEQINDEX[2] = 2	
SEQINDEX[3] = 3	
SEQINDEX[4] = 4	
SEQINDEX[5] = 5	
SECINDEX[6] = 6	
SEQINDEX[7] = 7	
SECINDEX[8] = 8	
SECINDEX[9] = 9	
SEQINDEX[10] = 10	
SEQINDEX[11] = 11	
SFOINDFX[12] = 12	
SFOINDFY[13] = 13	
SECTION $FY[14] = 14$	
SECTION (1) = 15	
SECTIONEY[15] = 16	
SECINDEV[10] = 17	L.
SECINDEV[10] = 10	
SEQUINDER [19] = 19	
SEQUINDER (20) = 20	1
SEQUINDER [21] = 21	
SEQINDER(22) = 22	
SEQINDEX[23] = 23	
SEQINDEX[24] = 24	
SEQINDER(25) = 25	
SEQUNDER [26] = 26	
SEQUNDER[27] = 27	
SEQINDEX [28] = 28	
SEQINDEX[29] = 29	
SEQINDEX[30] = 30	
SEQINDEX [31] = 31	
SEQINDEX[32] = 32	
SEQINDEX[33] = 33	
TEETH ANGLE = (360/TOTAL TEETH)	
TEETH ANGLE = (ROUND (TEETH ANGLE*100000) /100000)	
TRAORI	
ORTAXES	
: Start of Cycle	
Section 1	
,	
T120121 M6	
; Tooth Space # 1	
RESTART_TEETH=1	
TRANS C=(TEETH_ANGLE*SEQINDEX[(RESTART_TEETH)])	
STOPRE	
EXTCALL "PROC1"	
; Tooth Space # 2	H
RESTART TEETH=2	Ľ

*Output: Header – Indexing Sequence* 

### **Output:** Tool path coordinates: the actual tooth flank cutting commands.

Fait Program for . Gear (Emissiong) 15/05/0400_mma_kco.nyg	
File Edit	
; Cutting Cycle	V4
SIAKII:	444
TANS C=(ILLIN_ANGLE"SEQINDEX[(RESIAKI_ILLIN)])	leec.
STOPRE	
Convex	
; Top	
F=HYG RMOVE FEED	
G1 X43,53071 Y110,61900 Z-3,74949 A35,756273 C=DC(400,152521)	
F=HYG PLUNGE FEED	
G1 X26.06661 Y89.91821 Z-41.36221 A35.756273 C=DC(400.152521)	
F=HYG CUT FEED	
G1 X25.26790 Y103.03668 Z-47.52692 A36.029326 C=DC(397.961522)	
G1 X22.55098 Y116.12572 Z-53.68882 A36.265516 C=DC(395.416752)	
G1 X17.92101 Y129.18801 Z-59.84734 A36.460072 C=DC(392.519123)	
G1 X14.29067 Y136.78683 Z-63.44583 A36.550894 C=DC(390.645807)	
G1 X10.10552 Y144.30330 Z-66.99599 A36.625650 C=DC(388.695267)	
G1 X5.34714 Y151.70683 Z-70.49853 A36.680815 C=DC(386.646779)	
G1 X-0.00629 Y158.96533 Z-73.95076 A36.716033 C=DC(384.496324)	
G1 X-5.97993 Y166.04370 Z-77.34803 A36.731920 C=DC(382.244733)	
G1 X-12.60486 Y172.90406 Z-80.68036 A36.732909 C=DC(379.913287)	
G1 X-19.90/85 Y1/9.49/89 Z-83.95180 A36./09655 C=DC(3//.44/298)	
GI X-2/.931/9 1185.//62/ 2-8/.1460/ A36.6/0126 C=DC(3/4.886054)	
GI X-46 31630 V107 12535 7-03 28604 336 523252 C=DC(372.109100)	
G1 X-54 77268 V201 37500 7-05 73668 336 434804 C=DC(365.330240)	
G1 X-63.87406 Y205.45836 Z-98.18585 A36.327558 C=DC(364.320003)	
G1 X-73.61161 Y209.37427 Z-100.63336 A36.199903 C=DC(361.595406)	
; Heel	
G1 X-73.08370 Y209.26241 Z-100.84835 A34.528885 C=DC(360.289059)	
G1 X-63.34294 Y205.30060 Z-98.40175 A34.664243 C=DC(362.902380)	
G1 X-54.24202 Y201.17677 Z-95.95369 A34.780279 C=DC(365.378343)	
G1 X-45.78994 Y196.88897 Z-93.50434 A34.878262 C=DC(367.718440)	
G1 X-36.23343 Y191.41968 Z-90.49238 A34.975347 C=DC(370.418916)	
G1 X-27.48794 Y185.50425 Z-87.38904 A35.051837 C=DC(372.984634)	
G1 X-19.50004 Y179.21428 Z-84.20582 A35.106547 C=DC(375.413710)	
G1 X-12.23398 Y172.61331 Z-80.94058 A35.150797 C=DC(377.779319)	
G1 X-5.64100 Y165.74836 Z-77.61518 A35.169069 C=DC(379.990188)	
G1 XU.29936 Y158.66957 Z-74.21937 A35.178710 C=DC(382.154580)	
GI X5.62145 II51.41360 Z-70.76635 A35.171167 C=DC(384.222515)	
GI XIU.33029 II44.01533 2-67.20063 A35.146073 CEDC(386.193376)	
GI XIR 11027 VI20 01074 7_60 00716 N26 061006 C=DC(388.U/1190)	
G1 X22 66829 V115 94751 7-53 94874 334 929071 C=DC(309.902034)	
G1 X25.31506 V102.97743 7-47.79827 A34.774315 C=DC(392.726020)	
G1 X26.04511 Y90.00484 Z-41.64624 A34.591863 C=DC(395.2501/4)	
; Toe	
C1 ¥26 12023 ¥80 08651 7_41 01066 %33 485440 C=DC/304 572160)	

*Output: Tool path coordinates (with comments)* 

**Closed Loop:** Integral to HyGEARS

A) Corrective Machine Settings must have been applied to the desired part;



A: Calculating Corrective Machine Settings

### Closed Loop: B) Select the desired Correction iteration



### Closed Loop: C) Work in 5Axis as usual



C: Working in 5Axis with 1<sup>st</sup> Correction "[Corr #1]"

Example:

Create a sequence of Operations to:

- *Rough the Flanks* 0.040 mm Stock
- *Rough the Fillet* 0.020 mm Stock
- *Finish the Fillet* 0 *Stock*
- Finish the Flanks 0 Stock

### Use the imported 11x39 spiral-bevel gear set

💒 Open Geometry			<b></b>
MiniGears > 11x39 SpiralBev	el DH	<b>▼</b> 4j	Search 11x39 SpiralBevel DH 👂
Organize 🔻 New folder			i 🕶 🕇 🚺 🔞
🌗 found.000	^	Name	Date modified
퉬 found.001		11x39 DH ActBlank HvG	3/15/2016 2·59 AM
퉬 found.002		11x39 DH GleasonSummar	x HyG 3/15/2016 2:05 AM
퉬 found.003			, , , , , , , , , , , , , , , , , , ,
퉬 Garmin			
JE2KAP			
HYGEARS4Data			
HYGEARS30Data			
HyGEARS40Data			
HyGEARS40			
MiniGears	_		
11x38	Ξ		
11x39 SpiralBevel DH	-		
	-	✓ III	•
File <u>n</u> ame: 11x39 DH Act	lank.	HyG 🔻	Нубеакъ 4.0 (^.Нуб) 🔹
			Open 🔻 Cancel
			jh.

*Example:* Go into Machine mode:

- Click on "5Axis", Gear group
- "Machine/Tool" tab
- In "Specific Machine", select "Mikron GF [Heidenhain]"
- Select "End Mill" tool
- Select the "Display" options
- Click on "Apply"

<sup>w</sup> 5Axis CnC - Gear [Finishing] 11x39 DH A	ctBlank.HyG - [mm]
Machine/Tool Cycle Metrics Cycling Tin	ne Arbor End Mill Operation Process Stock
Machine Selection	Cutting Tool
<ul> <li>3 Axis CnC</li> <li>4 Axis CnC</li> </ul>	Face Mill Cutter I Hide Cutter Body
<ul> <li>5 Axis CnC "B-C" [Type M]</li> <li>5 Axis CnC "A-C" [Type P]</li> </ul>	CoSIMT Invert Arbor V Outside Blade
<ul> <li>5 Axis CnC "A-B" [Type P]</li> <li>5 Axis CnC "B-A" ]Type T]</li> </ul>	End Mill      Invert work
Specific Machine	Ball Mill
Mikron GF [Heidenain]   New Edit Delete	Probe [CMM]
Compensation	Display
Apex Location         0.0000           Alignment Angle         0.0000           3Axis Tool Tilt         0.0000	<ul> <li>Display Machine Head</li> <li>Display Arbor</li> <li>Display Target Grid</li> </ul>
Tool Center Point [TCP]	<ul> <li>Display Target Volume</li> <li>Display Tool Path</li> </ul>
<ul> <li>Absolute</li> <li>Differential</li> </ul>	<ul> <li>Display Section</li> <li>Lock on Tool</li> </ul>
	Detect Gouging Display Warning     Workpiece is Fixed
	Output Apply +/- Anim Ok Cancel

*Example:* Go into Machine mode:

- Click on "5Axis", Gear group
- Select "Machine/Tool" tab
- In "Specific Machine", select "Mikron GF [Heidenhain]"
- Select "End Mill" tool
- Select the "Display" options
- Click on "Apply"



### Example:

- Select "End Mill" Tab
- Enter the data for the X6562060 tool (below)
- Click on "Apply", click on "Save"



### Example:

- Enter the data for the M45713080 tool (below)
- Click on "Apply", click on "Save"



Example:

1<sup>st</sup> Operation: Rough the Flanks – 0.040 [mm] Stock with M45713080 tool

- Select the "Cycle" Tab
- *Maximum Step depth is 0.1 [mm] (from tool manufacturer)*
- Make the selections as below, Click on "Apply"
- Check the Metrics for Step Depth: too large => Increase #Steps

💕 5Axis CnC - Gear [Finishing] 11x	39 DH ActBlank.HyG - [mm]		🕷 5Axis CnC - G	iear [Finishing]	11x39 DH ActB	lank.HyG - [mm]		×
Machine/Tool Cycle Metrics Cyr	cling Time Arbor End Mill Opera	tion Process Stock	Machine/Tool (	Cycle Metrics	Cycling Time	Arbor End Mill (	Operation Process Stock	
Output Format	Stock-Feed	Artical	Stepping Dim	ensions				
CSV Format	# Steps 15 [15]	J. Actual Start 0. Display	1>2	1.6948	0.0845	0.1690		*
Line Numbers	# Facewidth Pts 51	End 15 Display	2>3	1.6282	0.0844	0.2534		
Include Operation Switches	Petroet Exeter 4.0	Life 15 Display	4>5	1.5625	0.0844	0.3378		
Include Short Header			5>6	1.4333	0.0844	0.5067		
Include Chat Pacificas	Constant D-Radius		6>7	1.3700	0.0845	0.5912		_
Include Start Positions	Moving Contact Pt		7>8	1.3076	0.0846	0.6758		
Explicit Indexing	Roughing 🔍 —	Finish Stock 0.000	8>9	1.2460	0.0847	0.7604		
No Comments		Rough Stock 0.040	9>10	1.1853	0.0847	0.8451		
Coordinates Only		<b>C</b>	11>12	1.0666	0.0848	1.0148		
Weds Coordinates		ng Sequence	12>13	1.0086	0.0848	1.0996		
VVOR Coordinates	Toe 2 Skip #	# /3 Start Gap 1	13>14	0.9516	0.0848	1.1844		
TCPM (Heidenhain)	Heel 2 Mirror	End Gap 39	14>15	0.8955	0.0847	1.2691		=
C			Total :		1.2691			
	Convex (LB)	Concave (O.B.)	Ending Dep	th :	1.2691			
Slot by Slot	Convex (i.b.)	Nees	Roughing []	Heell [mm]				
Flank by Flank	() None	Inone	Step# Sl	ot-Width Ste	ep-Depth To	t.Depth Flat-W	idth Flat-Prof. Ramp-	Ang.
	Toe -> Heel -> Toe	e 💿 Toe -> Heel -> Toe				-	-	-
Fillet-Root Tool Tilt Tool Tilt Tool Tilt	10.00 (in Heel -> Toe -> Heel	el 💿 Heel -> Toe -> Heel	[Tooth Tip 0>1	Diameter] 2.6510	0.1647	0.1647		
Combined	© Toe -> Heel	Toe -> Heel	1>2	2.5253	0.1645	0.3293		
Combined			2>3	2.4006	0.1644	0.4937		
Chamfer Tool Side Depth	0.000 Heel -> Toe	Heel -> Toe	3>4	2.2769	0.1644	0.6581		
Chamfer Tool End	0 000 O IB-OB O-Shaped	OB-IB O-Shaped	4>5	2.1542	0.1661	0.8242		
Chamfer Toe	0.000 Center Slot	MultiPase	5>6	2.0322	0.1648	1 1538		
Chamfer Heel Pivot A.		Multir dss	0.27	1.1117	0.1040	1,1000		Ψ.
<u></u>			· · · · · · · · · · · · · · · · · · ·	$\sim$				
	Output Apply +/-	Anim Ok Can			Outp	put Apply	+/- Anim Ok	Cancel

### Example:

1<sup>st</sup> Operation: Rough the Flanks – 0.040 [mm] Stock

- Select the "Cycle" Tab
- Increase #Steps to 25; Click on "Apply"
- Check the Metrics for Step Depth: Ok this time

Dutput Format         Stock-Feed           CSV Format         Include Stock Feed           Include Operation Switches         # Steps           Include Operation Switches         # Facewidth Pts           Include Stock Feed         # Steps           Include Stock Feed         # Steps           Include Store Roughing         # Steps           Include Store Roughing         # Fracewidth Pts           Stock Feed         # Steps           Include Store Roughing         # Steps           Include Store Roughing         # Fracewidth Pts           No Comments         Coordinates Only           Coordinates Only         Work Coordinates           Y Work Coordinates         Nore           TCPM (Heiderhain)         Indexing Sequence           Skip # /3         Stat Gap 1           Mirror         End Gap 33           Atting Cycle         Oorth Tip Diameter]           Onther Rough Park         None           Tool Tk 10.000         Tool Tk 10.000           Priest Stock         Ood Tk 10.000           Y Stock Stole         Tool Tk 10.000           Y Stock Stole         Tool Tk 10.000           Priest Stock W Stole         Tool Tk 10.000           Priest Stock Heel > Toe	achine/Tool Cycle Metrics Cycling Time	Arbor End Mill Operation	Process Stock	hine/Tool	Cycle Metrics	Cycling Time	e Arbor I	End Mill Operat	ion Process	Stock
CSV Format       # Steps       25       15       Statt       0       Display         Line Numbers       # Facewidth Pts       51       Find       25       Display         Include Operation Switches       # Facewidth Pts       51       Find       25       Display         Include Short Header       1.0       0.0509       0.0508       0.7096       0.0546       0.0000       -         Include Short Header       1.0       0.0509       0.9610       0.0544       0.0000       -         Include Short Header       1.0       0.0509       0.9610       0.0544       0.0000       -         Include Short Header       1.0       0.0509       0.9610       0.0544       0.0000       -         Include Short Header       1.0       0.0509       0.9610       0.0544       0.0000       -         Include Short Header       1.0       0.0509       0.9120       0.0543       0.0000       -         Include Short Header       1.0       0.0000       0.0509       1.0614       0.0509       0.0542       0.0000       -         Include Short Machines       Image Sequence       1.0000       1.0657       0.0509       1.1657       0.0509       1.2651       0.0	Output Format Stock-	Feed		epping Dir	nensions					
TCPM (Heidenhain)       Heel       2       Mirror       End Gap 39         atting Cycle       Convex (I.B.)       Concave (O.B.)       1.2691         Slot by Slot       Fank by Flank       O Toe -> Heel -> Toe       O Toe -> Heel -> Toe       O Toe -> Heel         Tool Tilt       10.00       Too -> Heel       O Toe -> Heel       O Toe -> Heel       O Toe -> Heel         Tool Fix Tool Fix Tool Fix Tool Fix Tool Otto       Too -> Heel       Toe -> Heel       Toe -> Heel       O Toe -> Heel         Combined       Tool Fix Tool Fix Tool Otto       Toe -> Heel       Toe -> Heel       Toe -> Heel       O Toe -> Heel         Charfer Tool Side       Depth       0.000       Heel -> Toe       Heel -> Toe       Heel -> Toe         Heel -> Too       Heel -> Toe       Heel -> Toe       O theel -> Toe       O theel -> Toe         Other Tool Side       Depth       0.000       0.0000       0.1466         S>4       2.4255       0.0987       0.3921       0.1139       0.0000       0.1466         S>4       2.4255       0.0987       0.5933       0.1136       0.0000       0.1465	CSV Format       # Step         Line Numbers       # Face         Include Operation Switches       Retract         Include Short Header       Consta         Include Start Positions       Movin         Explicit Indexing       Rough         No Comments       Cleara         V Work Coordinates       Toe	Reqd.     Sugg.       is     25     [15]       ewidth Pts     51       it Factor     4.0       ant D-Radius     Image: Contact Pt       ing     Image: Contact Pt       ing     Image: Contact Pt       2     Skip #	Actual Start 0 Display End 25 Display Finish Stock 0.000 Rough Stock 0.040 Sequence /3 Start Gap 1	12>13 13>14 14>15 15>16 16>17 17>18 18>19 19>20 20>21 21>22 22>23 23>24	1.2952 1.2583 1.2216 1.1853 1.1493 1.1136 1.0783 1.0433 1.0086 0.9743 0.9403 0.9403	0.0507 0.0508 0.0508 0.0509 0.0509 0.0509 0.0509 0.0509 0.0509 0.0509 0.0509 0.0509	0.6588 0.7096 0.7604 0.8112 0.9130 0.9639 1.0148 1.0657 1.1166 1.1675 1.2133	0.0546 0.0545 0.0545 0.0544 0.0543 0.0543 0.0543 0.0542 0.0542 0.0541 0.0540 0.0538		
Tool Tilt       Tool Tilt       10.00       Toe -> Heel -> Toe       Toe -> Heel -> Toe       Toe -> Heel -> Toe         Fillet-Root       Tool Tilt       10.00       Heel -> Toe -> Heel       Heel -> Toe -> Heel       0>1       2.6\$10       0.0989       0.0989       0.0989       0.0000       0.1469         Tool Pivot       0.000       Toe -> Heel       Toe -> Heel       Toe -> Heel       0>1       2.6\$10       0.0989       0.0989       0.0000       0.1467         Chamfer Tool Side       Depth       0.000       Heel -> Toe       Heel -> Toe       Heel -> Toe       4>5       2.3\$10       0.0987       0.2964       0.1139       0.0000       0.1466         Chamfer Tool Side       Depth       0.000       0.1465       4>5       2.3\$10       0.0987       0.4933       0.1138       0.0000       0.1465	TCPM (Heidenhain) Heel  Utting Cycle  Slot by Slot	2 Mirror Convex (I.B.)	End Gap 39 Concave (0.B.)	24>25 otal : nding Dep inishing Step# S:	0.8734 pth Concave-OB Lot-Width St	0.0508 1.2691 1.2691 [Heel] [mm ep-Depth ]	1.2691 m] Iot.Depth	0.0537 Flat-Width	0.0000 Flat-Prof.	- Ramp-Ang
	Filet-Root     Tool Tilt     10.00       Tooth Rank     Tool Pivot     0.000       Combined     Chamfer Tool Side     Depth     0.000	<ul> <li>Toe -&gt; Heel -&gt; Toe</li> <li>Heel -&gt; Toe -&gt; Heel</li> <li>Toe -&gt; Heel</li> <li>Heel -&gt; Toe</li> <li>Heel -&gt; Toe</li> </ul>	<ul> <li>Toe -&gt; Heel -&gt; Toe</li> <li>Heel -&gt; Toe -&gt; Heel</li> <li>Toe -&gt; Heel</li> <li>Heel -&gt; Toe</li> <li>Heel -&gt; Toe</li> </ul>	Footh Tip 0>1 1>2 2>3 3>4 4>5 5>6	<pre>Diameter] 2.6510 2.5755 2.5003 2.4255 2.3510 2.2769</pre>	0.0989 0.0988 0.0987 0.0987 0.0987 0.0987	0.0989 0.1977 0.2964 0.3951 0.4937 0.5923	0.0000 0.1143 0.1141 0.1139 0.1138 0.1136	0.0000 0.0000 0.0000 0.0000 0.0000 0.0000	0.1469 0.1467 0.1466 0.1466 0.1465 0.1465

Example:

1<sup>st</sup> Operation: Rough the Flanks – 0.040 [mm] Stock

- Select the "Cycling Time" Tab
- *Operation time ~ 36 min.*

achine/Tool Cycle Metrics	Cycling Time Arbor End Mill (	Operation Process Stock	
Cycle Times			
 I	Cycling Time	 I	*
Concave-OB			
Line:	0.59 [sec]		
Face:	49.28 [sec]		
Plunge/Retract:	1.00 [sec]		
Return:	0.56 [sec]		
Flank:	53.85 [see]		
(			
Total/Slot:	53.85 [sec]		
Indexing:	1.67 [sec]		
# Slots:	39		
Operation:	36.09 [min]		
Cutting Feed:	1920.00 [mm/min]		
Plunge Feed:	500.00 [mm/min]		
Rapid Move Feed:	2000.00 [mm/min]		
TOOL RPM: -	48000.00		
			Ŧ

Example:

1<sup>st</sup> Operation: Rough the Flanks – 0.040 [mm] Stock

- Select the "Operation" Tab
- Enter the data as shown below
- Click on "Apply"; click on "Save"

💒 5Axis CnC - Gear [Finishing] 11x39 DH	ActBlank.HyG - [mm]	🛫 5Axis CnC - Gear [Finishing] 11x39 DH ActBlank.HyG - [mm]
Machine/Tool Cycle Metrics Cycling T	Time Arbor End Mill Operation Process Stock	Machine/Tool Cycle Metrics Cycling Time Arbor End Mill Operation Process Stock
Operation           Name         1) R Flank-0.8 EM-[1-25/25]           ID #:         TEST01A           Save         Delete           Import         C	Subroutine V Dutput STEP	Operation           Name         1) R Flank-0.8 EM-[1-25/25]           ID #:         TEST01A           Save         Delete           Import         Output           STEP
Tool Change		Tool Change
Tool ID 10 0	0 0 0	Tool ID 10 0 0 0 0 0
Gap # 1 0	0 0 0	Gap # 7 0 0 0 0 0
Switches Coolant On	Coolant On Code 8 Coolant Off Code 9	Switches Coolant On Coolant On Code 8 Coolant Off Code 9
Spindle CW Spindle CCW	Spindle RPM 48000.0	Spindle CW Spindle CCW Spindle CCW
Return Trip # Steps	11	Retum Trip # Steps 11
Rapid Move [mm/min]	2000.0	Rapid Move [mm/min] 2000.0
Plunge [mm/min]	500.0	Plunge [mm/min] 500.0
	1920.0	
	Output Apply +/- Anim Ok Can	Output Apply +/- Anim Ok Cancel

*Example:* 1<sup>st</sup> Operation: Rough the Flanks – 0.040 [mm] Stock

- Visualize your Operation;
- "Anim" and / or "+/-"; Zoom in / out for better view



Example:

- 1<sup>st</sup> Operation: Rough the Flanks 0.040 [mm] Stock
- *Click on "Output" to generate the part program*
- Click on File->Save to save your program

🖋 Part Program for : Gear [Finishing] 11x39 DH ActBlank.HyG	- • •				
File Edit					
BEGIN PGM TESTOIA MM ;***********************************	Part Program	or : Gear [Finishir	ng] 11x39 DH ActBlank.Hy	G	×
;TOOL ID : 10 ;TOOL DIAMETER : 0.80[mm]	Save įn:	퉬 11x39 SpiralB	Bevel DH	- 🕝 🤌 🛛	"
;TOOL LENGTH : 16.90[mm];***********************************	Cia.	Name	*	Date mod	lified Type
FN 0: Q1600 = +2000.0000 FN 0: Q1601 = +500.0000	Recent Places		No items mat	ch your search.	
FN 0: Q1602 = +1200.0000 FN 0: Q1603 = +48000 FN 0: Q1604 = +3					
FN 0: Q1605 = +10 FN 0: Q1606 = +8	Desktop				
FN 0: Q1607 = +0 ; End Feed Strings TOOL CALL 10 Z S01603					
M3 M8	Libraries				
; Start Preamble M129					
CYCL DEF 7.1 X+0 CYCL DEF 7.1 X+0	Computer				
CYCL DEF 7.3 Z+0 CYCL DEF 7.4 B+0		•			4
CYCL DEF 7.5 C+0 M140 MB MAX F5000	Network	File <u>n</u> ame:	TEST01A.h		▼ <u>S</u> ave
L X+0 Y+0 F2000 L Z+120 F2000 PLANE RESET MOVE F5000		Save as type:	(*.h)		Cancel
M11 M16	<b>.</b>				
<	E. I				

Example:

- $2^{nd}$  Operation: Rough the Fillet -0.030 [mm] Stock with X6562060 tool
  - Select the "End Mill" Tab; select the X6562060 tool
  - *Maximum Step depth is 0.03 [mm] (from tool manufacturer)*
  - Make the selections as below, Click on "Apply"
  - Check the Metrics for Step Depth: too large => Increase #Steps

Dutput Format         Stock-Feed           CSV Format         # Steps         9         13         - Start         1         Display           Line Numbers         # Steps         9         13         - Start         1         Display           In Include Operation Switches         # Facewidth Pts         51         Find         9         Display           Include Start Positions         Moving Contact Pt         Finish Stock         0.000         -         1.3130         1.3532         0.0452         0.0005         -           No Comments         Constant D-Radius         Work Coordinates         0.0311         1.4232         0.0452         0.0006         -           Work Coordinates         Toe         2000         Skip # / 3         Statt Gap 1         -					-,	-,,				
CSV Format       # Steps       9	output Format	Stock-Feed		epping D	imensions					
Une Numbers       in code       g       j       g       j       g       j       g       j       g       j       g       j       g       j       g       j       g       j       g       j       g       j       g       j       g       j       g       j       g       j       g       j       j       g       j       j       g       j       j       g       j       j       j       g       j	CSV Format	# Steps 0 [9]	Actual Stat 1	inishin	g Concave-OB	[Toe] [mm]	1			
Include Operation Switches       Include Start Postions         Include Shot Header       Include Shot Header         Include Start Postions       Explicit Indexing         No comments       Image Start Postions         Depicit Indexing       Moving Contact P         No comments       Rough Stock 0.002         Coordinates Only       Image Start Gap 1         Work Coordinates       Indexing Sequence         Toce       2000         Start Start Post       Image Start Gap 1         Wing Cordet       Image Start Gap 1         Work Coordinates       Convex (I.B.)         Toce       2.000         Mimor       End Gap 39         Mimor       End Gap 39         Intell You Start Post       Concave (O.B.)         None       Toce > Heel         Toce > Heel       Toce > Heel         Otom Flank       Toce > Heel         Commert Tool Start De The None       Toce > Heel         Toce > Heel       Toce > Heel         Commert A       0.000         Chamfer Tool Start Post       Depth         Chamfer Tool Start Post       Depth         Depth       Heel > Toe         Depth       Depth         Chamfer Tool Stard	Line Numbers	# Escewidth Pte 51	End 0 Display	Step#	Slot Width	Step Dept	h Tot.Dept	h Flat Wid	ith Peak-	-Fill.
Period radiu       4,0         Include Start Positions       Constant D-Radius         Explicit Indexing       Noving Contact Pt         Roughing       Finish Stock       0.000         No Comments       Constant D-Radius       Induce Start Positions         Constant D-Radius       Induce Start Positions       Induce Start Positions         Explicit Indexing       Roughing       Finish Stock       0.000         No Comments       Constant D-Radius       Indexing Sequence         Constantes       Indexing Sequence       Skip # /3       Start Gap 1         TCPM (Heidenhain)       Indexing Sequence       Skip # /3       Start Gap 1         Minor       End Gap 39       Indexing Sequence       Indexing Sequence         Skip Stot       None       Indexing Sequence       Indexing Sequence         TCPM (Heidenhain)       Indexing Sequence       Indexing Sequence       Indexing Sequence         Skip Stot       None       Indexing Sequence       Indexing Sequence       Indexing Sequence         Skip Stot       None       Indexing Sequence       India Gap 39       India Gap 39         Intig Cycle       Interver (I.B.)       None       Insining Concave (O.B.)       Intig Sequence         Filet-Root       Toe > Heel<	Include Operation Switches	Primet France		Footh F	orm Diameter	1				
Include Start Pestions         Explicit Indexing         Include Start Postions         Explicit Indexing         No Comments         Coordinates Only         Cearance Imm)         Toe         Toe         Work Coordinates         Toe         Toe         Stap #         Mirror         Stap #         Stap #         Stap #         Toe         Stap #         Stap #         Toe         Stap #         Stap #         Toe         Stap #         Toe         Park by Stat         Park by Stat         Park by Stat         Park by Rank         Filet-Root         Tool Tht         Toot Thank         Toot Proct         O.0000         Charmfer Tool Stad         Depth         Proot A         On BBO Shaped         Order Filed         Order Filed         Order Filed         Order Filed         Opeth         Indexing Sequence         Too Thank </th <th>7 Include Short Header</th> <th>Retract Factor 4.0</th> <th></th> <th>tarting</th> <th>Depth:</th> <th>1.3130</th> <th></th> <th></th> <th></th> <th></th>	7 Include Short Header	Retract Factor 4.0		tarting	Depth:	1.3130				
Include Start Positions       Moving Contact Pt       Princh Stock       0.000         Explicit Indexing       Roughing       Princh Stock       0.000         No comments       Coordinates Only       Cearance [mm]       Indexing Sequence         Work Coordinates       Skip # /3       Start Gap 1         Toc P2 (000)       Kip # /3       Start Gap 1         Heel       2.000       Mirror       End Gap 39         tting Cycle       Convex (I.B.)       Concave (0.B.)         Stot by Slot       None       Toc >> Heel       Toc >> Heel         Toch Flank       Toc >> Heel       Toc >> Heel       Toc >> Heel         Toc >> Heel       Toc >> Heel       Toc >> Heel       Toc >> Heel         Toch Flank       Toc >> Heel       Toc >> Heel       Toc >> Heel         Toc >> Heel       Toc >> Heel       Toc >> Heel       Toc >> Heel         Toc >> Heel       Toc >> Heel       Toc >> Heel       Toc >> Heel         Charmfer Tool Side       Depth       0.000       Center Slot         Charmfer Tool End       Depth       0.000       OB-BB O-Shaped         Charmfer Tool End       Depth       0.0000       OB-BB O-Shaped         Charmfer Tool End       Depth       0.0007		Constant D-Radius 🔍		1>2	0.8507	0.0402	1.3532	0.0452	0.0005	-
Explicit Indexing       Roughing       Finish Stock       0.000       3>4       0.7735       0.0331       1.4232       0.0428       0.0006       -         No Comments       Coordinates Only       Indexing Sequence       Skip #       3       Stat Gap 1       4>5       0.7269       0.0231       1.4523       0.0418       0.0006       -         Work Coordinates       Toe       2.000       Skip #       /3       Stat Gap 1       0.6755       0.0231       1.4523       0.0418       0.0006       -         Work Coordinates       Toe       2.000       Mirror       End Gap 39       0.4989       0.0294       1.5422       0.03125       0.0016       -         TCPM (Heidenhain)       Toe       2.000       Mirror       End Gap 39       0.4989       0.0294       1.5422       0.3125       0.0216       -         titing Cycle       Concave (0.B)       None       Toe > Heel > Toe       None       Toe > Heel > Toe       None       Toe > Heel > Toe       Heel > Toe > Heel       Toe > Heel > Toe <th>Include Start Positions</th> <th>Moving Contact Pt</th> <th></th> <th>2&gt;3</th> <th>0.8149</th> <th>0.0368</th> <th>1.3901</th> <th>0.0440</th> <th>0.0005</th> <th>-</th>	Include Start Positions	Moving Contact Pt		2>3	0.8149	0.0368	1.3901	0.0440	0.0005	-
No Comments       Rough Stock 0.02         Coordinates Only       Clearance [mm]       Indexing Sequence         Work Coordinates       Toe 2.000       Skip # /3       Start Gap 1         Mirror       End Gap 39         atting Cycle       Convex (I.B.)       Concave (O.B.)         Slot by Slot       None         Rank by Rank       Toe > Heel       One > Heel         Toe > Heel       Toe > Heel         Chamfer Tool Side       O.000         Chamfer Tool End       Depth         Chamfer Tool End       O.000         Chamfer Tool End       O.000         Chamfer Heel       O.000         Chamfer Heel       Conotot Gas         Ch	Explicit Indexing	Boughing 🔍 —	Finish Stock 0.000	3>4	0.7735	0.0331	1.4232	0.0428	0.0006	-
Coordinates Only       Coordinates Only       Indexing Sequence       0.0248       1.4771       0.0408       0.0006       -         Work Coordinates       Toe       2.000       Skip # /3       Start Gap 1       - <th>No Comments</th> <th>i loogining</th> <th>Rough Stock 0.02</th> <th>4&gt;5</th> <th>0.7269</th> <th>0.0291</th> <th>1.4523</th> <th>0.0418</th> <th>0.0006</th> <th>-</th>	No Comments	i loogining	Rough Stock 0.02	4>5	0.7269	0.0291	1.4523	0.0418	0.0006	-
Coordinates Only       Clearance [mm]       Indexing Sequence         Work Coordinates       Toe       2000       Skip #       3       Start Gap 1         TCPM (Heidenhain)       Heel       2000       Mirror       End Gap 39         atting Cycle       Image: Convex (I.B.)       Concave (O.B.)       Image: Convex (I.B.)       Image: Convex (I.B.)         Slot by Slot       Image: Convex (I.B.)       Concave (O.B.)       Image: Convex (I.B.)       Image: Convex (I.B.)         Fillet-Root       Toe > Heel > Toe       None       Toe > Heel > Toe       Toe > Heel       Toe > Heel         Toot Flank       Tool Tit       10.00       Toe > Heel       Toe > Heel       Toe > Heel       Toe > Heel         Constreed       Toe > Heel       Toe > Heel > Toe       Toe > Heel > Toe	Coordinates Only			5>6	0.6755	0.0248	1.4771	0.0408	0.0006	-
V Work Coordinates       Toe       2000       Skip # /3       Start Gap       1         T CPM (Heidenhain)       Heel       2000       Mirror       End Gap       1         #ting Cycle       Convex (I.B.)       Image: Convex (I.B.)	Coordinates Only	Clearance [mm] Indexing	Sequence	6>7	0.6200	0.0203	1.4973	0.0401	0.0006	_
TCPM (Heidenhain)       Heel       2.000       Mirror       End Gap       39         atting Cycle       Onvex (I.B.)       Concave (O.B.)       None         Slot by Slot       None       Toe -> Heel -> Toe       None         Fillet-Root       Tool Tit       10.00       Toe -> Heel       Toe -> Heel         Tooth Flank       Tool Pivot       0.000       None       Toe -> Heel         Tooth Flank       Toe -> Heel       Toe -> Heel       Toe -> Heel       Toe -> Heel         Toot Flor       Toe -> Heel       Toe -> Heel       Toe -> Heel       Toe -> Heel         Combined       Toe -> Heel       Toe -> Heel       Toe -> Heel       Toe -> Heel         Chamfer Tool Side       Depth       0.000       0.0111       2.5257         Chamfer Toe       Heel -> Toe       Heel -> Toe       Heel -> Toe       0.0324       2.6428       0.0544       0.0006       0.010         Chamfer Toe       IB-OB O-Shaped       O B-IB O-Shaped       O B-IB O-Shaped       O B-IB O-Shaped       0.0171       2.7483       0.0535       0.0007       0.006         Chamfer Heel       Pivot A.       0.000       Center Slot       MultiPass       0.0111       2.7483       0.0535       0.0007       0.005<	Work Coordinates	Toe 2.000 Skip #	/3 Start Gap 1	8>9	0.3609	0.0135	1 5422	0.0394	0.0008	-
Atting Cycle       Convex (I.B.)       Concave (O.B.)            Slot by Slot Rank by Flank           Convex (I.B.) None           Concave (O.B.) None           None             Fillet-Root Tool Tit Tool Tit Cond Pivot 0.000           Toe -> Heel           Depth           Dotsta            Dotsta	TCPM (Heidenhain)	Heel 2,000 Mirror	End Gap 39	btal :	0.4505	0.2292	1.0122	0.0120	0.0210	
atting Cycle         Slot by Slot         Rank by Flank         Fillet-Root         Tool Tilt         Tool Pivot         0.000         Chamfer Tool Side         Chamfer Tool Side         Depth       0.000         Name         Ibox         Toot Tilt         10.000         Chamfer Tool Side         Depth       0.000         Chamfer Tool Side         Chamfer Sidt         Chamfer Heel </th <th></th> <th>2.000</th> <th></th> <th>nding D</th> <th>epth :</th> <th>1.5422</th> <th></th> <th></th> <th></th> <th></th>		2.000		nding D	epth :	1.5422				
Slot by Slot       Convex (I.B.)       Concave (O.B.)         Flank by Flank       None         Fillet-Root       Toe -> Heel -> Toe         Tooth Flank       Toe -> Heel         Combined       Toe -> Heel         Tooth Flank       Toe -> Heel         Chamfer Tool Side       Depth       0.000         Chamfer Tool End       Depth       0.000         Chamfer Toe       IB-OB O-Shaped       OB-IB O-Shaped         O Chamfer Heel       Outh Heel -> Toe       MultiPass	Itting Cycle		· · · · · ·							
Stot by Stot       None       None         Flank by Flank       None       None         Flank by Flank       Toe -> Heel -> Toe       Toe -> Heel       Toe -> Heel         Flot Flat       Toe -> Heel       Toe -> Heel       Toe -> Heel         Flot Flat       Toe -> Heel       Toe -> Heel       Toe -> Heel         Flot Flat       Toe -> Heel       Toe -> Heel       Toe -> Heel         Flot Flat       Toe -> Heel       Toe -> Heel       Toe -> Heel         Flot Flat       Toe -> Heel       Toe -> Heel       Toe -> Heel         Flot Flat       Toe -> Heel       Toe -> Heel       Toe -> Heel         Flot Flat       Toe -> Heel       Toe -> Heel       Toe -> Heel         Flot Flat       Toe -> Heel       Toe -> Heel       Toe -> Heel         Flot Flat       Toe -> Heel       Toe -> Heel       Toe -> Heel         Flot Flat       Image: Store Flat Flat       Image: Store Flat Flat Flat         Flat Flat       Image: Store Flat Flat Flat Flat Flat Flat Flat Flat	Slat by Slat	Convex (I.B.)	Concave (O.B.)	inishin	g Concave OB	[Heel] [ma				
Hank by Hank       Toe -> Heel -> Toe       Toe -> Heel -> Toe         Fillet-Root       Tool Tit       10.00         Tooth Flank       Tool Pivot 0.000       Heel -> Toe -> Heel         Combined       Toe -> Heel         Chamfer Tool Side       Depth       0.000         Chamfer Tool End       Depth       0.000         Chamfer Toe       IB-OB O-Shaped       OB-IB O-Shaped         O Chamfer Heel       Pivot A.       0.000	Balaka Bala	None	None	Step#	Slot Width	Step Dept	h Tot Dept	h Flat Wid	ith Peak-	-Fill.
Fillet-Root       Tool Tilt       10.00       Image: Constraint of the constrain	Hank by Hank	Toe -> Heel -> Toe	Toe -> Heel -> Toe	Footh F	orm Diameter	1				
Tool Flank         Tool Pivot         0.000         Toe -> Heel         Toe -> Heel           Combined         Toe -> Heel         Toe -> Heel         Toe -> Heel         Toe -> Heel           Chamfer Tool Side         Depth         0.000         IB-OB O-Shaped         O B-IB O-Shaped         O B-IB O-Shaped           Chamfer Heel         Pivot A.         0.000         Center Slot         MultiPass         O MultiPass	Billet-Boot	10.00		tarting	Depth	2 5257				
1001 Prior [0.000]       Toe -> Heel       Toe -> Heel       Toe -> Heel       Image: Combined for the combined fore combined for the combined for the combined		Heel -> Toe -> Heel	Heel -> Toe -> Heel	1>2	0.8789	0.0450	2.5707	0.0552	0.0005	0.0147
Commend       Image: Comme	Combined	0.000   Toe -> Heel	Toe -> Heel	2>3	0.8391	0.0411	2.6119	0.0547	0.0006	0.0132
Chamfer Tool Side       Depth       0.000       Image: Heel -> Tool       Image: Heel ->		0 H I I T		3>4	0.7938	0.0369	2.6488	0.0544	0.0006	0.0116
Chamfer Tool End       Chamf A.       0.000       IB-OB O-Shaped       O OB-IB O-Shaped       5>6       0.6889       0.0275       2.7087       0.0538       0.0007       0.008         Chamfer Toe       Pivot A.       0.000       Center Slot       MultiPass       5>6       0.6889       0.0275       2.7087       0.0538       0.0007       0.008         Chamfer Heel       Pivot A.       0.000       Center Slot       MultiPass       7>8       0.5682       0.0171       2.7483       0.0535       0.0007       0.008	Chamfer Tool Side Depth	0.000	Heel -> Toe	4>5	0.7436	0.0324	2.6812	0.0540	0.0006	0.0100
Chamfer Toe         Could         Center Slot         MultiPass           Chamfer Heel         Pivot A.         0.000         Center Slot         MultiPass	Chamfer Tool End	0 000 O IB-OB O-Shaped	OB-IB O-Shaped	5>6	0.6889	0.0275	2.7087	0.0538	0.0007	0.0084
Chamfer Heel Pivot A. U.UUU Center Siot MultiPass 758 0.5082 0.0171 2.7483 0.0535 0.0007 0.005	Chamfer Toe	Carter Cat	A MakiPasa	6>7	0.6303	0.0224	2.7312	0.0536	0.0007	0.0067
	Chamfer Heel Pivot A.	0.000 Center Slot	<ul> <li>MultiPass</li> </ul>	/>8	0.5682	0.0171	2.7483	0.0535	0.0007	0.0050

### Example:

 $2^{nd}$  Operation: Rough the Fillet – 0.020 [mm] Stock

- Select the "Cycle" Tab
- Increase #Steps to 15; Click on "Apply"
- Check the Metrics for Step Depth: Ok this time

				0,00	oyoung in				Acourt .
Output Format	Stock-Feed	Antoni	epping D	imensions					
CSV Format	Heqd. Sugg.		tarting	Depth:	1.2961				
Line Numbers		Start I Display	1>2	0.8634	0.0252	1.3213	0.0276	0.0002	-
Include Operation Switches	# Facewidth Pts 51	End 15 Display	2>3	0.8440	0.0241	1.3454	0.0271	0.0002	-
Include Operation Switches	Retract Factor 4.0		3>4	0.8226	0.0229	1.3684	0.0267	0.0002	-
Include Short Header	Constant D-Radius		5>6	0.735	0.0217	1 4104	0.0263	0.0002	-
Include Start Positions	Moving Contact Pt		6>7	0.7461	0.0189	1.4293	0.0254	0.0002	-
Explicit Indexing	Pavahiaa III	Finish Stock 0.000	7>8	0.7170	0.0175	1.4468	0.0251	0.0002	-
	Rougning	Bough Stock 0.02	8>9	0.6861	0.0159	1.4627	0.0247	0.0002	-
		Hough Stock 0.02	9>10	0.6538	0.0143	1.4771	0.0244	0.0002	-
Coordinates Only	Clearance [mm] Indexing	Sequence	10>11	0.6200	0.0127	1 4898	0.0241	0.0002	-
Work Coordinates	Toe 2.000 Skip #	/3 Start Gap 1	11>12	0.5849	0.0110	1.5008	0.0239	0.0002	-
TCPM (Heidenhain)	Heel 2,000 Mirror	End Gap 29	13>14	0.5115	0 0075	1 5177	0.0235	0.0002	_
	11661 2.000 Million	55	14>15	0.4735	0.0246	1.5422	0.2972	0.0185	-
utting Cycle		· · · · ·	otal :		0.2462	2			
Clat bu Clat	Convex (I.B.)	Concave (O.B.)	nding D	epth	1.5422	2			
	None	None		~ ~ ~					
Hank by Hank	Toe -> Heel -> Toe	Toe -> Heel -> Toe	Step#	g Concave-OF	Step Dept	mij b Tot Dev	oth Flat Wi	dth Deak-	- 11 1
Fillet-Root     Tool Tit	10.00		DCEP+	DIOC MIGHT	Dieb pebi	. 100.Dej	pon riac wi	util Feak	
Tooth Flank	○ Heel -> Toe -> Heel	Heel -> Ioe -> Heel	footh Fe	orm Diameter	:]				
Combined	© Toe -> Heel	Toe -> Heel	tarting	Depth	2.5067				
		Heal > Tea	1>2	0.8932	0.0283	2.5350	0.0333	0.0002	0.0094
Chamfer Tool Side Depth	0.000	Heel-> Toe	2>3	0.8713	0.0270	2.5620	0.0331	0.0002	0.0088
Chamfer Tool End Chamf A.	0.000 O IB-OB O-Shaped	OB-IB O-Shaped	3>4	0.8475	0.0257	2.5877	0.0330	0.0002	0.0083
Chamfer Toe	0.000 Center Slot	MultiPass	5>6	0 7938	0.0242	2 6346	0.0328	0.0002	0.0072
Chamfer Heel			0.0		0.0227		0.0027	0.0002	0.0072
				$\sim$					

Example:

2<sup>nd</sup> Operation: Rough the Fillet – 0.020 [mm] Stock

- Select the "Cycling Time" Tab
- Operation time ~ 16 min.

hine/Tool Cycle Metrics Cycling Time Arbor End Mill Operation Process Stock  ycle Times	
ycle Times	
Concave-OB Line: 0.59 [sec] Face: 17.58 [sec] Plunge/Retract: 1.00 [sec] Return: 0.56 [sec] Flenk: 22.15 [sec] Total/Slot: 22.15 [sec] Indexing: 1.67 [sec] ‡ Slots: 39 Operation: 15.48 [min] Cutting Feed: 1920.00 [mm/min] Plunge Feed: 500.00 [mm/min]	
Line: 0.59 [sec] Face: 17.58 [sec] Plunge/Retract: 1.00 [sec] Return: 0.56 [sec] Flank: 22.15 [sec] Total/Slot: 22.15 [sec] Indexing: 1.67 [sec] ‡ Slots: 39 Operation: 15.48 [min] Cutting Feed: 1920.00 [mm/min] Plunge Feed: 500.00 [mm/min]	
Face: 17.58 [sec] Plunge/Retract: 1.00 [sec] Return: 0.56 [sec] Flenk: 22.15 [sec] Total/Slot: 22.15 [sec] Indexing: 1.67 [sec] ‡ Slots: 39 Operation: 15.48 [min] Cutting Feed: 1920.00 [mm/min] Plunge Feed: 500.00 [mm/min]	
Plunge/Retract: 1.00 [sec] Return: 0.56 [sec] Flenk: 22.15 [sec] Total/Slot: 22.15 [sec] Indexing: 1.67 [sec] # Slots: 39 Operation: 15.48 [min] Cutting Feed: 1920.00 [mm/min] Plunge Feed: 500.00 [mm/min]	
Return: 0.56 [sec] Flank: 22.15 [sec] Total/Slot: 22.15 [sec] Indexing: 1.67 [sec] # Slots: 39 Operation: 15.48 [min] Cutting Feed: 1920.00 [mm/min] Plunge Feed: 500.00 [mm/min]	
Flank:       22.15 [sec]         Total/Slot:       22.15 [sec]         Indexing:       1.67 [sec]         # Slots:       39         Operation:       15.48 [min]         Cutting Feed:       1920.00 [mm/min]         Plunge Feed:       500.00 [mm/min]	
Total/Slot: 22.15 [sec] Indexing: 1.67 [sec] # Slots: 39 Operation: 15.48 [min] Cutting Feed: 1920.00 [mm/min] Plunge Feed: 500.00 [mm/min]	
Total/Slot: 22.15 [sec] Indexing: 1.67 [sec] # Slots: 39 Operation: 15.48 [min] Cutting Feed: 1920.00 [mm/min] Plunge Feed: 500.00 [mm/min]	
Indexing: 1.67 [sec] # Slots: 39 Operation: 15.48 [min] Cutting Feed: 1920.00 [mm/min] Plunge Feed: 500.00 [mm/min]	
<pre># Slots: 39 Operation: 15.48 [min] Cutting Feed: 1920.00 [mm/min] Plunge Feed: 500.00 [mm/min]</pre>	
Operation: 15.48 [min] Cutting Feed: 1920.00 [mm/min] Plunge Feed: 500.00 [mm/min]	
Cutting Feed: 1920.00 [mm/min] Plunge Feed: 500.00 [mm/min]	
Plunge Feed: 500.00 [mm/min]	
Plange Feed: S00.00 [mm/min]	
Banid Moura Food: 2000 00 [mm/min]	
Tool DDM: 48000 00	
1001 KM. 4000000	
-	
	_
Output Apply +/- Anim Ok Canc	cel

### Example:

2<sup>nd</sup> Operation: Rough the Fillet – 0.020 [mm] Stock

- Select the "Operation" Tab
- Enter the data as shown below
- Click on "Apply"; click on "Save"

👷 🕈 5Axis CnC - Gear [Finishing] 11x39 DH ActBlank.HyG - [mm]	😴 5Axis CnC - Gear [Finishing] 11x39 DH ActBlank.HyG - [mm]
Machine/Tool Cycle Metrics Cycling Time Arbor End Mill Operation Process Stock	Machine/Tool Cycle Metrics Cycling Time Arbor End Mill Operation Process Stock
Operation	Operation
Name         2) R Fillet-0.6 BM-[1-15/15]         1) R Flank-0.8 EM-[1-25/25]	Name 2) R Fillet-0.6 BM-[1-15/15]
ID #: TEST01B Internal Subroutine	ID #: TEST01B Internal Subroutine V 1) R Flank-0.8 EM-[1-25/25]
Save Delete Import Output STEP	Save Delete Import Output STEP
Tool Change	Tasl Change
Tool ID 11 0 0 0 0 0	Tool ID 11 0 0 0 0 0
Gap # 1 0 0 0 0 0	Gap # 1 0 0 0 0 0
Switches	Switches
Coolant Off Code 9	Coolant Off Code 9
Spindle CW Spindle RPM 48000.0	Spindle CW Spindle RPM 48000
Betum Trip	Betum Trip
# Steps 11	# Steps 11
Rapid Move [mm/min] 2000.0	Rapid Move [mm/min] 2000.0
Plunge [mm/min] 500.0	Plunge [mm/min] 500.0
Cutting [mm/min] 1920.0	Cutting [mm/min] 1920.0
Output Apply +/- Anim Ok Can	Output Apply +/- Anim Ok Cancel

*Example:* 2<sup>nd</sup> Operation: Rough the Fillet – 0.020 [mm] Stock

- Visualize your Operation;
- "Anim" and / or "+/-"; Zoom in / out for better view



### Example:

- 2<sup>nd</sup> Operation: Rough the Fillet 0.020 [mm] Stock
- *Click on "Output" to generate the part program*
- Click on File->Save to save your program

🖋 Part Program for : Gear [Finishing] 11x39 DH ActBlank.HyG				
File Edit				
BEGIN PGM TEST01B MM ;***********************************	<b>*</b> 4			
TOOL ID : 11	🚀 Part Program	or : Gear [Finishing] 11x39 DH ActBlank.HyG		×
; TOOL LENGTH : 16.90 [mm];	Save in:	↓ 11x39 SpiralBevel DH	G 🦻 📂 🛄 -	
; Begin Feed Strings		Name	Date modified	Type
FN 0: Q1601 = +500.0000 FN 0: Q1602 = +1920.0000 FN 0: Q1603 = +48000	Recent Places	TEST01A.h	3/17/2016 7:48 PM	H File
FN 0: Q1604 = +3 FN 0: Q1605 = +11 FN 0: Q1606 = +8	Desktor			
FN 0: Q1607 = +0 ; End Feed Strings TOOL CALL 11 Z SQ1603 M3 M8	Libraries			
; Start Preamble M129 CYCL DEF 7.0 NULLPUNKT CYCL DEF 7.1 X+0	Computer			
CYCL DEF 7.2 Y+0 CYCL DEF 7.3 Z+0 CYCL DEF 7.4 B+0				
CYCL DEF 7.5 C+0 M140 MB MAX F5000 L X+0 Y+0 F2000	Network	File name: TEST01B.h	-	<u>S</u> ave
L Z+120 F2000 PLANE RESET MOVE F5000 M11		Save as type: (*.h)	-	Cancel
M16				

Example:

- $3^{rd}$  Operation: Finish the Fillet -0.0 [mm] Stock with X6562060 tool
  - Select the "End Mill" Tab; select the X6562060 tool
  - Maximum Step depth is 0.03 [mm] (from tool manufacturer)
  - Make the selections as below, Click on "Apply"
  - Check the step depth in the "Metrics" tab; Ok

<sup>4</sup> 5Axis CnC - Gear [Finishing] 11x3	9 DH ActBlank.HyG - [mm]		Axis CnC -	Gear [Finishing	g] 11x39 DH A	ctBlank.HyG	i - [mm]			
Machine/Tool Cycle Metrics Cyc	ling Time Arbor End Mill Operation	Process Stock	hine/Tool	Cycle Metric	s Cycling Tim	e Arbor I	End Mill Operatio	n Process St	ock	
Output Format	Stock-Feed	Antonia	epping Di	mensions						
<ul> <li>CSV Fomat</li> <li>Line Numbers</li> <li>Include Operation Switches</li> <li>Include Short Header</li> <li>Include Start Positions</li> <li>Explicit Indexing</li> <li>No Comments</li> <li>Coordinates Only</li> <li>Work Coordinates</li> <li>TCPM (Heidenhain)</li> </ul>	# Steps     15     [15]       # Facewidth Pts     51       Retract Factor     4.0       Constant D-Radius     Image: Constant D-Radius       Moving Contact Pt     Image: Constant D-Radius       Roughing     Image: Constant D-Radius       Toe     2.000       Hading     Skip #	Actual Start 1 Display End 15 Display Finish Stock 0.000 Rough Stock 0.020 Sequence 73 Start Gap 1 Finish Gap 200	tarting 1>2 2>3 3>4 4>5 5>6 6>7 7>8 8>9 9>10 10>11 11>12 12>13	Depth: 0.9034 0.8840 0.8626 0.8390 0.8135 0.7861 0.7570 0.7261 0.6938 0.6600 0.6249 0.5887 0.5887	1.2961 0.0252 0.0241 0.0229 0.0217 0.0203 0.0189 0.0175 0.0159 0.0143 0.0127 0.0143 0.0127 0.0110 0.0093 0.0075	1.3213 1.3454 1.3684 1.4104 1.4293 1.4468 1.4627 1.4771 1.4898 1.5008 1.5101	0.0276 0.0271 0.0267 0.0263 0.0258 0.0254 0.0251 0.0247 0.0244 0.0241 0.0241 0.0237 0.0237	0.0002 0.0002 0.0002 0.0002 0.0002 0.0002 0.0002 0.0002 0.0002 0.0002 0.0002 0.0002 0.0002 0.0002	-	* E
Cutting Cycle  Slot by Slot Flank by Flank  Fillet-Root Tool Tilt Tool Pivot	Convex (I.B.)           O None           O Toe -> Heel -> Toe           0.000           Toe -> Heel	Concave (0.B.) None Toe -> Heel -> Toe Heel -> Toe -> Heel Toe -> Heel	14>15 btal : hding De inishing Step# Footh Fo	0.5135 pth : Conceve-OB Slot Width vrm Diameter Depth	0.0246 0.2462 1.5422 (Heel] [mm Step Dept] 2.5067	1.5422 m] h Tot.De	0.2972 pth Flat Wi	0.0185	-	
<ul> <li>Combined</li> <li>Chamfer Tool Side</li> <li>Chamfer Tool End</li> <li>Chamfer Toe</li> <li>Chamfer Heel</li> <li>Depth</li> <li>Chamf A.</li> <li>Pivot A.</li> </ul>	0.000 0.000 0.000 0.000 0 Heel -> Toe 0 IB-OB O-Shaped 0.000 0 Rock Me [babe]	Heel -> Toe     OB-IB O-Shaped     MultiPass	1>2 2>3 3>4 4>5 5>6	0.9332 0.9113 0.8875 0.8616 0.838	0.0283 0.0270 0.0257 0.0242 0.0227	2.5350 2.5620 2.5877 2.6119 2.6346	0.0333 0.0331 0.0330 0.0328 0.0327	0.0002 0.0002 0.0002 0.0002 0.0002	0.0094 0.0088 0.0083 0.0077 0.0072	*
							ppiy +/-			

Example:

*3<sup>rd</sup> Operation: Finish the Fillet* – 0.0 [*mm*] *Stock* 

- Select the "Cycling Time" Tab
- Operation time ~ 16 min.

chine/Tool Cycle Metrics	Cycling Tim	e Arbor End	Mill Operation	Process Sto	ck
vole Times					
 I	Сус	ling Time			*
Concave-OB					
Line:	0.59	[sec]			
Face:	8.79	[sec]			
Plunge/Retract:	1.00	[sec]			
Return:	0.56	[sec]			
Flank:	11.36	[sec]			
Convex-IB					
Line:	0.60	[sec]			
Face:	9.00	[sec]			
Plunge/Retract:	1.00	[sec]			
Return:	0.58	[sec]			
Flank:	11.58	[sec]			
Total/Slot:	22.94	[sec]			
Indexing:	1.67	[sec]			
# Slots:	39				
Operation:	16.00	[min]			
Cutting Feed:	1920.00	[mm/min]			
Plunge Feed:	500.00	[mm/min]			
Rapid Move Feed:	2000.00	[mm/min]			
Tool RPM:	48000.00				
					-

Example:

*3<sup>rd</sup> Operation: Finish the Fillet* – 0.0 [*mm*] *Stock* 

- Select the "Operation" Tab
- Enter the data as shown below
- Click on "Apply"; click on "Save"

🕷 5Axis C	nC - Ge	ar (Finish	ing] 11x3	9 DH Act	Blank.HyG	[mm]			<b>—</b> ×	Axis CnC ·	- Gear [Finishing] 11x39	DH ActBlank.	HyG - [mm]			<b></b>
Machine/1	Tool C	ycle Me	trics Cyc	cling Time	Arbor Er	nd Mill Ope	eration Proc	cess Stor	ck	hine/Tool	Cycle Metrics Cycli	ing Time Arbor	End Mill Or	peration P	rocess Stoc	k
Operati	ion				C					peration						
Name	3) F Fille	et-0.6 BM-[	[1-15/15]			2) R Fillet-0	.6 BM-[1-15/	15]	-	ame 3) F	Fillet-0.6 BM [1 15/15]		3) F Fillet-0	).6 BM-[1-1	5/15]	-
ID #:	TEST0	10	In	temal Sub	routine 🔽					#: TES	ST01C Inte	mal Subroutine	1) R Flank 2) R Fillet-	-0.8 EM-[1-) 0.6 BM-[1-1	25/25] 5/15]	
[	Save	Delete		rt Outp	ut	STEP				Sa	ve Delete Import	Output	3) F Fillet-0	).6 BM-[1-1	5/15]	
-																
Tool Cr	hange	Tool ID	11	0	0	0	0	0		pol Chan	ge Tool ID 11	0 0	0	0	0	
		Gap #	1	0	0	0	0	0			Gap # 1	0 0	0	0	0	
Switche	es		10	0						witches		6.1.10	C to D			
			int Un	Coc	lant On Code	8 9	_				Coolant On	Coolant Off	Code 9	_		
				1				-				1				
		Spind	lle CVV lle CCW		Spindle RPN	48000					Spindle CW	Spindle	RPM 48000			
			<b>T</b> .					-								
		Retur # S	n Inp iteps	11							# Steps	11				
		Rapid Mo	ove [mm/r	min] 20	00.0			-/			Rapid Move [mm/mi	n] 2000.0	-			
		Plunge (n	nm/min]	50	0.0						Plunge [mm/min]	500.0	-			
		Cutting [n	nm/min]	19	20.0						Cutting [mm/min]	1920.0	Ĭ			
								-								
				0ι	itput Ap	oly +	/- Anii	m 0	k Cancel	]		Output	Apply	+/- A	Nim Ol	c Cancel

*Example:*  $3^{rd}$  Operation: Finish the Fillet -0.0 [mm] Stock

- Visualize your Operation;
- "Anim" and / or "+/-"; Zoom in / out for better view



Example:

- 3<sup>rd</sup> Operation: Finish the Fillet 0.0 [mm] Stock
- *Click on "Output" to generate the part program*
- Click on File->Save to save your program

Part Program for : Gear [Finishing] 11x39 DH ActBlank.HyG				
File Edit				
BEGIN PGM TESTOIC MM ;***********************************	<b>*4</b>			
TOOL ID : 11 TOOL DIAMETER : 0.60[mm]	💣 Part Program f	or : Gear [Finishing] 11x39 DH ActBlank.HyG		×
;TOOL LENGTH : 16.90 [mm]	,			
***************************************	Save in:	📔 11x39 SpiralBevel DH 🔹 👻	🎯 🦻 📂 🛄 🔻	
; Begin Feed Strings	-	Name	Data modified	Tune
FN 0: $Q1601 = +500.0000$		Iname .	Date modified	туре
FN 0: Q1602 = +1920.0000		TEST01A.h	3/17/2016 7:48 PM	H File
FN 0: Q1603 = +48000	Recent Places	TEST01B.h	3/17/2016 7:52 PM	H File
FN 0: $Q1604 = +3$				
FN 0: $Q1605 = +11$				
FN 0: 01607 = 10	Deskton			
: End Feed Strings	Desktop			
TOOL CALL 11 Z SQ1603	<u> </u>			
M3	6			
M8	Libraries			
; Start Preamble	cioraries			
M129				
CYCL DEF 7.1 YLO				
CYCL DEF 7.2 Y+0	Computer			
CYCL DEF 7.3 Z+0				
CYCL DEF 7.4 B+0				
CYCL DEF 7.5 C+0		•		Þ
M140 MB MAX F5000	Network			
L X+0 Y+0 F2000		File name: TEST01C.h		Save
T 7+T50 L5000		-		
M11		Save as type: (*.h)	▼	Cancel
M16				
M126	-			
<	► at			

Example:

4<sup>th</sup> Operation: Finish the Flank – 0.0 [mm] Stock with M45713080 tool

- Select the "End Mill" Tab; select the M45713080 tool
- *Flat-Prof deviation < 2 um*
- Make the selections as below, Click on "Apply"
- Check the "Flat-Prof" in the "Metrics" tab;  $\sim 0.1 \text{ um} \rightarrow Ok$

Varpet Format         Stock-Feed           CSV Format         # Steps         15	nine/Tool Cycle Metrics Cyc	aing time   Arbor   End M	III   Operation	Process Stock	thine/ I ool	Cycle Wether	S Cycling Time	e Arbor	End Mill   Operati	on   Process   S	tock
CSV Format       # Steps       15       100       1000       10000       10000       0.1035         Line Numbers       # Steps       15       15       1000       10000       0.2041       0.1094       0.0001       -         Include Operation Switches       # Facewidth Pts       10       1000       0.2041       0.1035       0.0001       -         Include Operation Switches       # Exact Factor       4.0       -	Output Format	Stock-Feed			epping D	imensions					
Work Coordinates       Toe       2.000       Skip # /3       Statt Gap 1         TCPM (Heidenhain)       Heel       2.000       Mirror       End Gap 39         Itting Cycle       Image: Convex (I.B.)       Convex (I.B.)       Concave (O.B.)       0.00673       1.2698       0.0710       0.0000       -         Statt Gap 1       Image: Convex (I.B.)       Convex (I.B.)       Concave (O.B.)       0.11663       0.0000       -         Statt S fand Gap 39       Image: Convex (I.B.)       Concave (O.B.)       0.0000       -       1.1663         Statt Gap 1       Image: Convex (I.B.)       Concave (O.B.)       0.000       -       1.1663         Statt Gap 1       Image: Convex (I.B.)       Concave (O.B.)       0.000       -       1.1663         Mired Park       Tool Tit 10.00       None       Image: Concave -OB [Heel] [mm]       -       -         Tool Flank       Tool Pivot 0.000       Toe -> Heel       Toe -> Heel       -       -       -         Combined       Depth       0.000       IB-OB O-Shaped       -       Heel -> Toe       -       -       -         Chamfer Tool Side       Depth       0.000       IB-OB O-Shaped       OB-IB O-Shaped       OB-IB O-Shaped       0.001       0.	CSV Format Line Numbers Include Operation Switches Include Short Header Include Start Positions Explicit Indexing No Comments Coordinates Only	# Steps 15 # Facewidth Pts 51 Retract Factor 4.0 Constant D-Radius Moving Contact Pt Roughing Clearance [mm]	d. Sugg.	Actual Start 1 Display End 15 Display Finish Stock 0.000 Rough Stock 0.020 Sequence	tarting 1>2 2>3 3>4 4>5 5>6 6>7 7>8 8>9 9>10 10>11 11>12	Depth: 1.7681 1.6960 1.6261 1.5580 1.4918 1.4274 1.3648 1.3037 1.2442 1.1863 1.1300	0.1035 0.0973 0.0954 0.0920 0.0894 0.0868 0.0842 0.0816 0.0791 0.0768 0.0740	0.2041 0.3014 0.3968 0.4888 0.5782 0.6650 0.7492 0.8309 0.9100 0.9868 1.0608	0.1094 0.1056 0.1032 0.0994 0.0964 0.0934 0.0934 0.0874 0.0874 0.0846 0.0819 0.0786	0.0001 0.0001 0.0001 0.0001 0.0001 0.0001 0.0001 0.0001 0.0001 0.0001	
Image Cycle       Convex (I.B.)       Concave (O.B.)         Slot by Slot       None       None         Flank by Flank       Tool Tilt       10.00         Fillet-Root       Tool Tilt       10.00         Tool Tilt       10.00       Tool -> Heel -> Toe         Tool Flank       Tool Tilt       10.00         Combined       Tool -> Heel       Toe -> Heel         Tool Flank       Tool -> Heel       Toe -> Heel         Combined       Tool -> Heel       Toe -> Heel         Tool Flank       Tool -> Heel       Toe -> Heel         Chamfer Tool Side       Depth       0.000         Chamfer Tool End       Chamfer A.       0.000         Chamfer Heel       0.000       NublPass	Work Coordinates TCPM (Heidenhain)	Toe 2.000 Heel 2.000	Skip # Mirror	/3 Start Gap 1 End Gap 39	11>12 12>13 13>14 14>15	1.0752 1.0218 0.9703	0.0721 0.0696 0.0673	1.1329 1.2025 1.2698	0.0786 0.0765 0.0736 0.0710	0.0000 0.0000 0.0000	
Tool Pivot 0.000       Tool Pivot 0.000       Toe -> Heel       Toe ->	Slot by Slot Rank by Flank Fillet-Root Tool Titt	Convex (I.B.) None Toe -> H None None None None None	eel -> Toe	Concave (O.B.) © None © Toe -> Heel -> Toe	nding De inishino Step‡ S	epth : g Concave-OB Slot-Width S	1.1663 1.2698 [Heel] [mm tep-Depth ]	m] Tot.Depth	. Flat-Width	Flat-Prof.	Ramp-Ang.
	Tooth Flank     Tool Pivot       Combined     Depth       Chamfer Tool Side     Depth       Chamfer Tool End     Chamf A.       Chamfer Heel     Pivot A.	0.000 Toe -> H 0.000 Heel -> T 0.000 IB-OB O- 0.000 Rock Me	eel oe Shaped : [babe]	<ul> <li>Heel -&gt; Toe</li> <li>Toe -&gt; Heel</li> <li>Heel -&gt; Toe</li> <li>OB-IB O-Shaped</li> <li>MultiPass</li> </ul>	Tooth T: tarting 1>2 2>3 3>4 4>5 5>6	<pre>p Diameter] Depth:     2.5984     2.4684     2.3407     2.2153     2.0920</pre>	0.1986 0.1941 0.1886 0.1836 0.1786 0.1738	0.3927 0.5813 0.7649 0.9435 1.1173	0.2236 0.2170 0.2109 0.2048 0.1989	0.0001 0.0001 0.0001 0.0001 0.0001	0.2867 0.2796 0.2703 0.2654 0.2584

Example:

4<sup>th</sup> Operation: Finish the Flank – 0.0 [mm] Stock

- Select the "Cycling Time" Tab
- Operation time ~ 23 min.

chine/Tool Cycle Metrics		e Arbor   End Mill	Operation	Process Stock	
Cycle Times					
	Cve	ling Time		 I	~
Congava-OP					
Concave-ob	0 93	[sec]			
Face:	14 02	[sec]			
Plunge/Retract:	1 00	[sec]			
Return:	0.56	[sec]			
Flank:	16.59	[sec]			
Convex-IB					
Line:	0.96	[sec]			
Face:	14.47	[sec]			
Plunge/Retract:	1.00	[sec]			
Return:	0.58	[sec]			
Flank:	17.05	[sec]			
Total/Slot:	33.64	[sec]			
Indexing:	1.67	[sec]			
# Slots:	39				
Operation:	22.95	[min]			
Cutting Feed:	1200.00	[mm/min]			
Plunge Feed:	500.00	[mm/min]			
Rapid Move Feed:	2000.00	[mm/min]			
Tool RPM:	48000.00				
					-

### Example:

4<sup>th</sup> Operation: Finish the Flank – 0.0 [mm] Stock

- Select the "Operation" Tab
- Enter the data as shown below
- Click on "Apply"; click on "Save"

👾 5Axis CnC - Gear [Finishing] 11x39 DH ActBlank.HyG - [mm]	xis CnC - Gear [Finishing] 11x39 DH ActBlank.HyG - [mm]
Machine/Tool Cycle Metrics Cycling Time Arbor End Mill Operation Process Stock	thine/Tool Cycle Metrics Cycling Time Arbor End Mill Operation Process Stock
Operation	peration
Name 4) F Flankt-0.8 BM-[1-15/15] 3) F Fillet-0.6 BM-[1-15/15] -	4) F Rankt 0.0 BM [1 15/15]
ID #: TEST01D Internal Subroutine	#: TEST01D Internal Subroutine 1) R Flank-0.8 EM-[1-25/25] 2) R Fillet-0.6 BM-[1-15/15]
Save Delete Import Output STEP	Save         Delete         Import         Output         3) F Fillet-0.6 BM-[1-15/15]           4) F Flankt-0.8 BM-[1-15/15]         4) F Flankt-0.8 BM-[1-15/15]
	val Change
Tool ID 10 0 0 0 0	Tool ID 10 0 0 0 0
Gap # 1 0 0 0 0 0	Gap # 1 0 0 0 0 0
Switches V Coolant On Coolant On Code 8	witches Coolant On Coolant On Code 8
Coolant Off Code 9	Coolant Off Code 9
Spindle CW	Spindle CW Spindle DBM
Spindle CCW 48000.0	Spindle CCW
Return Trip	Return Trip
# Steps 11	# Steps 11
Rapid Move [mm/min] 2000.0	Rapid Move [mm/min] 2000.0
	Plunge [mm/min] 500.0
	1200.0
Output Apply +/- Anim Ok Cancel	Output Apply +/- Anim Ok Cancel

*Example:* 4<sup>th</sup> Operation: Finish the Flank – 0.0 [mm] Stock

- Visualize your Operation;
- "Anim" and / or "+/-"; Zoom in / out for better view



Example:

- 4<sup>th</sup> Operation: Finish the Flank 0.0 [mm] Stock
- *Click on "Output" to generate the part program*
- Click on File->Save to save your program

🖋 Part Program for : Gear [Finishing] 11x39 DH ActBlank.HyG							
File Edit							
BEGIN PGM TESTOID MM ;***********************************	<b>1</b>						
;TOOL DIAMETER : 0.80[mm]	👾 * Part Program for : Gear [Finishing] 11x39 DH ActBlank.HyG						
;TOOL LENGTH : 16.90 [mm]	Save in:	Devel DH ▼	G 🤌 📂 🛄 -				
FN 0: Q1600 = +2000.0000	æ	Name	Date modified	Туре			
FN 0: Q1601 = +300.0000 FN 0: Q1602 = +1200.0000 FN 0: Q1603 = +48000 FN 0: Q1604 = +3	Recent Places	TEST01A.h	3/17/2016 7:48 PM 3/17/2016 7:52 PM	H File H File			
FN 0: Q1605 = +10 FN 0: Q1606 = +8 FN 0: Q1607 = +0	Desktop	TESTOLC.n	3/1//2016 8:08 PM	HFIIE			
TOOL CALL 10 Z SQ1603 M3 M8							
; Start Preamble	Libraries						
CYCL DEF 7.0 NULLPUNKT CYCL DEF 7.1 X+0							
CYCL DEF 7.2 Y+0 CYCL DEF 7.3 Z+0	Computer						
CYCL DEF 7.4 B+0 CYCL DEF 7.5 C+0		< III		•			
L X+0 Y+0 F2000 L Z+120 F2000	Network	File name: TEST01D.h		<u>S</u> ave			
PLANE RESET MOVE F5000 M11		Save as type: (*.h)	•	Cancel			
M16 M126	+						
			~ ~ ~				
Example:	Save the Geometry to include the name of the current Operation						
----------	---	----------------------------	--	--	--	--	
	Total Process time:						
	<ul><li>1) Rough Flank:</li><li>2) Rough Fillet:</li></ul>	~ 26 min ~ 16 min					
	<ul> <li>3) Finish Fillet:</li> <li>4) Finish Flank:</li> </ul>	~ 16 min ~ 23 min					
	Total:	~ 1.35 Hour					
	Effect:	~ 2.03 Hour (Total x ~1.5)					

**Example:** Create a Process

- Select the "Process" tab
- Select each Operation in the desired sequence and move to Process Content
- Ensure "Internal Subroutine"
- Give a Name and ID to the Process
- Click on "Apply" and "Save"

🕷 5Axis C	CnC - Gear [Finishing] 11x39 DH ActBlank.HyG - [mm]	💒 5Axis Cr	nC - Gear [Finishing] 11x39 DH ActBlank.HyG - [mm]
Machine/	Tool Cycle Metrics Cycling Time Arbor End Mill Operation Process Stock	Machine/T	Tool Cycle Metrics Cycling Time Arbor End Mill Operation Process Stock
Proces	ises	Process	ses
Name	Copper Electrode	Name	Copper Electrode
ID #:	TEST01E Internal Subroutine 🔽	ID #:	TEST01E Internal Subroutine Copper Electrode
	Save Delete Import Output	(	Save Delete Import Output
	Available Operations $\leftarrow$ $\rightarrow$ Process Content $\downarrow$ $\uparrow$		Available Operations $\overleftarrow{\leftarrow} $ Process Content $\overleftarrow{\downarrow} \uparrow$
	1) R Hank-0.8 EM-[1-25/25] 2) R Fillet-0.6 BM-[1-15/15] 2) R Fillet-0.6 BM-[1-15/15] 2) R Fillet-0.6 BM-[1-15/15]		1) R Flank-0.8 EM-11-25/25] 2) R Filet-0.6 BM-11-15/15] 2) R Filet-0.6 BM-11-15/15] 2) R Filet-0.6 BM-11-15/15]
	2) F Inter 0.6 BM-[1-15/15]         3) F Fillet-0.6 BM-[1-15/15]           3) F Fillet-0.6 BM-[1-15/15]         4) F Fillet-0.6 BM-[1-15/15]		3) F Fillet-0.6 BM-[1-15/15] 3) F Fillet-0.6 BM-[1-15/15] 4) F Flankt-0.8 BM-[1-15/15] 4) F Bankt-0.8 BM-[1-15/15]
	Output Apply +/- Anim Ok Cancel		Output Apply +/- Anim Ok Cancel

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Example:

Create a Process

- Click on "Output" to get a complete Process in 1 file
- Click on "File->Save" to save the Process file

💒 Program for : Copper Electrode						
File Edit						
BEGIN PGM TESTO1E MM; **********************************	; Start Process TEST01E	7	<b>V4</b> ^			
; PROCESS NAME : Copper Electr	ode	1	the			
; PROCESS DATE : 03-17-2016						
; SUMMARY VERSION : [Nominal]		Pi Pi	rogram for : C	Copper Electrode		×
; Data / Tima . 2/17/2016 / 9.	20.47 DM		-			
General Unite : [mm] [dd mm ee	25.17 PM		Save in:	11x29 CoirolPoyol DU	🔗 🏤 📂 📩 -	
: Cutter Units : [in]	1		oave in.	I IX35 Spiralbever DH	• • • • • • • • • • • • • • • • • • • •	
; Prepared by : Claude Gosseli	n			A		
; Version : 4.0.405.10-458			(Here)	Name	Date modified	Type
; GEAR [FINISHING]				····		
; CUTTER SPECIFICATIONS	[I.B.] [O.B.]			TEST01A.h	3/17/2016 7:48 PM	H File
;		Rec	ent Places	TEST01B h	3/17/2016 7:52 PM	H File
; Average Diameter :	1.5000				5/17/2010 7:52 1 10	
; Blade Edge Padius :	20.0000 20.0000			TEST01C.h	3/17/2016 8:08 PM	H File
: Point Width :	0.0280				2/17/2016 9.17 DM	LI Ella
; TopRem Letter :	NO			TESTOID.n	5/17/2010 6:17 PIM	ri rile
; TopRem Length :	0.0000 0.0000	[	Desktop			
; TopRem Angle :	0.00.00 0.00.00					
; Cutter Gaging :	0.0000 0.0000					
; GEAR [FINISHING] :Spread Blade			<u></u>			
; MACHINE SETTINGS - #Phoenix						
;	19 0967	L	libraries			
, Cutter Tilt	2 5511					
: Swivel Angle :	24.8047					
; Blank Offset :	0.0000					
; Machine Root Angle :	69.7203		- Col			
; Machine Center To Back :	0.0000	C	omputer			
; Sliding Base :	-0.7468					
; Rate of Roll :	1.03577					
; Cradle Angle :	59.8047					
, WORKPIECE DIMENSIONS				III		•
: # Teeth :	39	1	Network			
; Module :	1.150			File name: TEST01E b		Covo
; Face Angle :	75.711				·	Jave
; Face Width :	10.805			Courses to an		Connel
; Front Crown to Xp :	5.602			Save as type: (".h)	▼	Cancel
; OD Toe :	31.750					
; OD Heel :	52.000	. 11-20 PU 3-+Plank				
TPP IEDIOIEI		; IIX39 DH ACCBIANK				
PROGRAM NAME : 1) R Flank-0.8	EM-[1-25/25]					
; PROGRAM DATE : 03-17-2016	(1 20, 20)					
;SUMMARY VERSION : [Nominal]						
;TOOL ID : 10						
;TOOL DIAMETER : 0.80[mm]						
;TOOL LENGTH : 16.90[mm]						
; = = = = = = = = = = = = = = = = = = =			-			
< III						
				© Involute Simulat	10n Softwares I	nc. $20^{7}$

*Sample Result 1:* 13x37 6.5 mm module, hypoid gear set: *soft-finish*. Contact Pattern checks show perfect agreement with HyGEARS' prediction.



Sample Result 1:

13x37 6.5 mm module, hypoid gear set: hard-finish. Contact Pattern check shows perfect agreement with HyGEARS' prediction.



13x37 hypoid gear pair on the VH tester

- Pinion Fixed Setting Generated
- Gear Spread Blade Generated
- Cut on DMU65 Monoblock (AC type machine)
- Roughing : CoSIMT
- Pre-Finishing : Bull Nose End Mill
- Hard finish : Tapered End Mill

Actual Contact Pattern Pinion OB



HyGEARS' Predicted Contact Pattern Pinion OB



*Sample Result 1:* 13x37 6.5 mm module, hypoid gear set: Pinion CMM output after hard-finish shows negligible deviations between actual and HyGEARS' theoretical.



*Sample Result 1:* 13x37 6.5 mm module, hypoid gear set: Gear CMM output after hard-finish shows negligible deviations between actual and HyGEARS' theoretical.



Sample Result 2: 26x26, 1.5 mm module, duplex helical spiral-bevel pinion cut using a Face Mill cutter.

Pinion CMM output after soft cut show a combination of pressure and spiral angle errors, plus some surface bias and lengthwise crowning.







Sample Result 2:CMM results after the 1st corrective cycle appear below. As expected,<br/>crowning remains in the GAGE corrected tooth while it is not visible in the<br/>HyGEARS corrected tooth.<br/>In both the GAGE and HyGEARS corrected teeth, spiral and pressure angle<br/>errors have been eliminated.



GAGE correction

HyGEARS correction

- 1. HyGEARS' tooth flank generation and TCA calculations match Gleason's CAGE and Klingelnberg's KIMoS; therefore, the **reference topography** in HyGEARS is the **exact tooth** *definition*;
- 2. *HyGEARS designs gear set geometries*, i.e. the machine settings for all HyGEARS supported geometries are calculated and a Summary is created;
- 3. Geometries can be imported from Gleason SPA, KIMoS ND and BECAL ND files;
- 4. Spiral bevel cutting processes such as Face Milling and Face Hobbing are integral to HyGEARS;
- 5. Geometries can be analyzed unloaded and loaded for contact and tooth fillet stresses;
- 6. **5Axis CnC machine Post-Processing**, i.e. the generation of a part program "machine ready", is integral to HyGEARS;
- 7. Part programs are **generated in reference to the exact tooth surface** definition (rather than an interpolated surface as is the case with the many other CAM softwares);
- 8. Part program generation is based on a wide range of user selected cycle features;
- 9. Any **5Axis CnC machine architecture** can be accommodated; current architectures include "AB", "AC", "BA" and "BC"; any controller can be accommodated; current controllers include GCodes, Siemens, Heidenhain and Fanuc;
- 10. Part programs can be in *Machine coordinates, Work piece coordinates* with axis angles, or Work piece coordinates with tool axis vector (*Traori, TCPM* and *TCP*);

- 11. Users can define their own tool box for Face Mill, CoSIMT, End Mill and Ball Mill tools;
- 12. Cutting Cycles include **Slot by Slot** and **Flank by Flank**, both for tooth flank and fillet; tip chamfering is available;
- 13. Animations and single stepping allow the visualization of tool movements and the verification of tool paths and possible interference;
- 14. A "Metrics" function gives an *estimate of the deviations* between the theoretical tooth flank and the "flats" and "peaks" created by the discrete movements of the tool; thus, the # of depth wise and face width steps can be optimized to minimize "flats", "peaks" and cycle time;
- 15. Toe and Heel clearances allow smooth tool entry and exit, and full speed tool plunge;
- 16. "Stock" allowance is available for roughing and finishing;
- 17. A "Roughing mode" moves the selected tool in the center of the gap to quickly remove as much material as possible;
- 18. "Operations", including all user selections for a given task, may be saved for later re-use;
- 19. *Closed Loop*, also called Corrective Machine Settings, is *integral to HyGEARS* and allows the seamless manufacture of gears to the required tolerances.
- 20. The HyGEARS Closed Loop corrections match (and in some respect are better than) those of Gleason's GAGE.

### Inputting an *Existing* Geometry

HyGEARS allows the *direct input of existing* <u>*Face Hobbing*</u> *summaries* through the Existing Geometry Definition Window coupled to the Geometry Summary Editor.

The Existing Geometry Definition Window offers input fields and *navigation tools to input the needed parameters*.

The Existing Geometry can be *processed at once, and saved in a file* for later retrieval.

💒 Existing Geometry Definition - [n	nm] [dd.mm.ss]
General Machine	
Geometry Name	
Directory	E:\HYGEARS4Data
Geometry Type	Spiral-Bevel 👻
Pinion Tooth Hand	Left 👻
Tooth Taper	Uniform 👻
Module	1.82500
Depth Factor	3.8800
Addendum Factor	0.1700
Pinion Offset	0
	<u>Finish</u>

### **Graphic Display Functions (User Mode)**



Interpolation Options (with Error Surface)

Op	~	Lagrange
No <u>C</u>		Rational
XY		Cubic Spline
011		Parabolic
Thic		Linear
Lap		Blended Parabolic
Sni		1st Order Regression
<u>o</u>		2nd Order Regression
NOF		3rd Order Regression
No <u>E</u>		PoC

Interpolator Name	Order of Preference		
Lagrange	N/R		
Rational	N/R		
Cubic Spline	# 4		
Parabolic	# 2		
Linear	# 1		
Blended Parabolic *	N/R		
1 <sup>st</sup> Order Regression	# 3		
2 <sup>nd</sup> Order Regression	N/R		
3rd Order Regression	N/R		



#### LTCA Editor

💭 Load Sharing	×
Data Material Links	
Applied Pinion Torque [N-m]	1.00
# Iterations	2 ~
Result Output	No 🗸
Contact Stress/Def	Roark ~
Stiffness Calculation	Westinghouse 🗸
Strength Calculation	AGMA-Mod 🗸
Include A Bear. Stiffess Pin CElm Relaxation	□ Bear. Stiffess Gea □ A □ Tooth Base Rotation □ Adjacent Teeth
	Apply OK Cancel

#### Stiffness Calculation:

- Westinghouse formula,
- Nakada formula,
- Finite Strips (option).

#### Strength Calculation:

- AGMA-Mod (J factor at each contact point),
- AGMA ("),
- Aida and Terauchi,
- Finite Strips (option).



#### Teeth and Machine

<ul> <li></li> </ul>	Pinion Gear Pinion and Gear Reference Frames HPGL Graphic File		
	Tooth - M/C		Tooth
			Blank
	Kinematics +		Tooth Surface Normal Vectors
			Cutter Blade
	Measurement +		Dia. over Ball
			Caliper Measurement
	2D Graph		Full Model
			Cutting Machine
	Complete Summary		
		L -	
	Meshing •	J	

#### *Tooth* – *M*/*C* -> *Tooth Child Window*

#### Blade animation (FH only)



#### Finish + rough (fixed setting)





#### *Tooth* – *M*/*C* -> *Tooth Child Window*

STEP Pinion	
<u>File Edit</u>	
<pre>ISO-10303-21; HEADER; FILE_DESCRIPTION (( 'STEP AP203' ), '1' ); FILE_NAME ('Pinion-Test-1-Spiral-Bevel.hyg', '02/10/2013T4:00:52 PM', ( 'Claude Gosselin' ), ( 'Claude Gosselin' ), ( 'Involute Inc.' ), 'HyGEARS STEP 1.5 Interface', 'HyGEARS STEP 1.5 Interface', 'HyGEARS V 4.0 © @', '' ); FILE_SCHEMA (( 'CONFIG_CONTROL_DESIGN' )); ENDSEC:</pre>	<b>*4</b> (())
DATA; #1 = CARTESIAN_POINT ( '', ( 15.702577952996100, 14.489643175898500, #2 = CARTESIAN_POINT ( '', ( 15.636813644223000, 14.620253700541000, #3 = CARTESIAN_POINT ( '', ( 15.613800501060400, 14.773798593130100, #4 = CARTESIAN_POINT ( '', ( 15.635730953434000, 14.943850576310500, #5 = CARTESIAN_POINT ( '', ( 15.703583839822100, 15.123545951902100, #6 = CARTESIAN_POINT ( '', ( 15.703583839822100, 15.123545951902100, #6 = CARTESIAN_POINT ( '', ( 14.237243583965500, 17.115940942050600, #7 = CARTESIAN_POINT ( '', ( 14.152523009450300, 17.240930229767700, #9 = CARTESIAN_POINT ( '', ( 14.108690052219800, 17.395493910587900, #10 = CARTESIAN_POINT ( '', ( 14.154943603244100, 17.767914256125100) #11 = CARTESIAN_POINT ( '', ( 14.257637612903300, 17.990602473490700) #13 = CARTESIAN_POINT ( '', ( 12.353898951210800, 19.591489344223100) #14 = CARTESIAN_POINT ( '', ( 12.25054652640200, 19.70790304211900)	122.95860843815 122.95158522947 122.93492375326 122.90985151103 122.87718856034 122.83400668272 128.21740333228 128.21012079283 128.19277927917 , 128.166718245 , 128.1326317819 , 128.0877421457 , 133.4760093970 , 133.4685067954
<pre>#15 = CARIESIAN_POINT ( '', ( 12.185150835663900, 19.860355529578800 #16 = CARTESIAN_POINT ( '', ( 12.161687195283900, 20.043007032240400 #17 = CARTESIAN_POINT ( '', ( 12.183101340744100, 20.249205851146600 #18 = CARTESIAN_POINT ( '', ( 12.258504970765400, 20.491810927715800 #19 = CARTESIAN_POINT ( '', ( 10.063953414960400, 21.854772134822900 #20 = CARTESIAN_POINT ( '', ( 9.943051471613530, 21.959298863951100,</pre>	, 133.4505428744 , 133.4234697258 , 133.3881330306 , 133.3416273469 , 138.7350121761 138.72671289712 -





STEP Output -> Export to CadCam

*Tooth* – *M*/*C* -> *Blank Child Window* 



### $Tooth - M/C \rightarrow Dia. over Balls Child Window - Bevel gears$



Give Ball dia. + distance -> Get Dia over Balls



#### Give Ball dia. + Diameter -> Get distance

### *Tooth* – *M*/*C* -> *Caliper Measurement* Child Window – Cylindrical gears



Give # Teeth -> Get measurement

#### *Tooth* – *M*/*C* -> *Cutting Machine Child Window* -> *Conventional Generator*



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### *Tooth* – *M*/*C* -> *Cutting Machine Child Window* -> *Phoenix Generator*



#### Kinematics and Contact Pattern

>	Pinion Gear Pinion and Gear Reference Frames		
	Tooth - M/C		
	Kinematics +		Path of Contact
	Measurement +	-	Bearing Pattern
	2D Graph TE - Peak to Valley		Bearing Pattern (LTCA) Bearing Pattern Development Sliding Speeds
	Complete Summary	_	Ease Off (Composite Tooth Mismatch)
	Meshing	<u> </u>	

### *Kinematics -> E/P Grids*

👷 E/P Grid - [mm] - [N-m]	×					
📝 E: (Pinion Ver)	0.20000					
P: (Pinion Hor)	0.20000					
G: (Gear Hor)	0.0000					
Shaft Angle	0.0000					
Misalignment	0.0000					
Pinion Runout	0.0000					
Cear Runout	0.0000					
Pinion Radial	0.0000					
Cear Radial	0.0000					
Pinion Torque	866.01					
Rendering Grey Scale						
	<u>DK</u>					



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Kinematics -> Path of Contact Child Window



#### Kinematics -> Path of Contact Child Window



PoC on Hypoid gear

PoC on Spur gear

Kinematics -> Path of Contact Child Window





#### PoC on Hypoid gear

PoC on Spur gear

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Kinematics -> Contact Pattern Child Window



#### Kinematics -> Contact Pattern Child Window



Relationship between Error Surface and CP

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Kinematics -> Contact Pattern Child Window

Example: Use the Demo1441.dat geometry, for the Gear.

Test the following Contact Pattern child window function buttons, one by one :

- ^N toggle in and out of the calculation of the PoC by the normals
- E/P change Horizontal to 25%, 75% then Cancel check the EP values
- Limi toggle in and out of limited PoC
- NoRs toggle into rendered display
- Thick change CP compound thickness
- **PoC** toggle in and out the display of the PoC

Kinematics -> Contact Pattern Child Window

### Grid – display a grid with E and P = 0.200 mm (Apply button)



HyGEARS V 4.	0 © ® - E/P Grid			-		×
		E/P Grid (TCA) - Den	HyGEARS V 4.0 © ° no1441.dat - Gear [Finishing] Co	nvex-1B - 202.1 [N-m]		The VA
	E: -0.200	E: -0.100	E: 0.000	E: 0.100	E: 0.200	
P: -0.200	Heel	Heel	Heel	Heel	Heel	
P:-0.100 -	Heel	Heel	Heel	Heel	Heel	
P: 0.000	Heel	Heel	Heel	Heel	Heel	
P:0.100 -	Heel	Heel	Heel	Heel	Heel	
P: 0.200	Heel	Heel	Heel	Heel	Heel	
-						
Kinematics -> Contact Pattern Child Window

Grid – display a grid with E and P = 0.200 mm + rendering (Apply button)



High Product Colspan="4">Colspan="4"Colspan="4">Colspan="4"Colsp	×				(manual)	0 © ® - E/P Grid	HyGEARS V 4.0
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	Ta		onvex-IB - 202.1 [N-m]	HyGEARS V 4.0 © ° mo1441.dat - Gear [Finishing] Co	E/P Grid (TCA) - Der		
P: -0.200 Heel		E: 0.200	E: 0.100	E: 0.000	E: -0.100	E: -0.200	
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$		Heel	Heel	Heel	Heel	Heel	P: -0.200 <sup>—</sup>
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$		Heel	Heel	Heel	Heel	Heel	P: -0.100 -
P: 0.100 Heel H		Heel	Heel	Heel	Heel	Heel	P: 0.000
P: 0.200 Heel Heel Heel Heel Heel Heel		Heel	Heel	Heel	Heel	Heel	P: 0.100 -
		Heel	Heel	Heel	Heel	Heel	P: 0.200 -
							-

Kinematics -> Contact Pattern Child Window

### With CMM Data

- Delete the Contact Pattern child window
- Create a new Contact Pattern child window
- XYZ make sure "Gear" is displayed in the Geometry field
- Use the [...] button to browse
- Select the demog128.mes file
- Click on "Apply"

CMM-Simulation	n Comparison - Gear Demo1441.HyG 🛛 🗾 🔁	٢
Geometry Displayed Tooth #	Gear -	
CMM File:	e:\vb\hygear25\demo\demog128.mes	
5	Apply OK Cance	ł

Kinematics -> Contact Pattern Child Window

### With CMM Data

- Click to select "Pinion" in the Geometry field
- Use the [...] button to browse
- Select the demo\_p12.mes file
- Click on "Apply"
- Click on "Ok"

🐖 Error Surface - Bearing Pattern Gear Demo1441.HyG	×
Geometry Displayed Tooth # CMM File: e:\vb\hygear25\demo\demog128.mes	
Apply OK Can	rror Surface - Bearing Pattern Gear Demo1441.HyG
	Geometry     Pinion       Displayed Tooth #     1       CMM File:     e:\vb\hygear25\demo\demo_p12.mes
	Apply OK Cancel

Kinematics -> Contact Pattern Child Window

### With CMM Data

- Click on the "NoEr" function button watch the CP change
- Click on the "Opt" function button Select 2<sup>nd</sup> Order Regression watch the CP change
- Press "^S" to save the measurement datafile names in the geometry file



Kinematics -> Contact Pattern LTCA Child Window

HyGEARS can calculate how *load is shared between adjacent tooth pairs*, accounting for tooth bending and shearing stiffness, and contact deformation.

Pitch errors can also be introduced in the analysis.

Results include

- Contact stress (by Hertz) (Roark, Formulas for Stress and Strain, 1975),
- Maximum Shear stress,
- *Depth* of maximum shear,
- Minimum Oil film thickness (Hamrock, 1994),
- *Flash temperature* (ΔT over mesh; Blok' s Flash Temperature, Erichello, 1991).







### Kinematics -> Contact Pattern LTCA Child Window



Evolution of the CP with applied torque

### Kinematics -> Contact Pattern LTCA Child Window

### LTCA Solution:



is the main tooth pair;

is a tooth pair on either side of the main tooth pair (up to two on each side);

- $F_{i/j}$  is the load applied on each meshing tooth pair;
- $K_{i/j}$  is the tooth stiffness obtained from the Westinghouse beam formula or the FSM;
- $\delta H_{i/i}$  is the Hertz contact deformation;
- $\delta W_{i/j}$  is the displacement of a contact point caused by web shearing;
- $\delta R_{i/j} \ \ \, is the displacement of a contact point caused \\ by tooth base rotation; \ \ \, \\$
- $\delta I_{i/j}$  is the initial tooth separation;
- $R_{i/j}$  is the radius of the point of contact;
- $T_{i/j}$  is the torque share of each meshing tooth pair.

Kinematics -> Contact Pattern LTCA Child Window

- Surface principle curvatures are calculated (numerically) at each contact point.
- Relative directions of the principle curvatures affect contact stress and deformation.

### Principle curvatures

Feed Marks



Kinematics -> Contact Pattern LTCA Child Window

Bending Displacement : Westinghouse beam formula (Ted Krenzer, The Gleason Works, "Tooth Contact Analysis of Spiral Bevel and Hypoid Gears Under Load")

$$\delta_{w} = \frac{P}{3 E \left(\frac{F t_{l}^{3}}{12}\right)} \left\{ 1 + 1.3 t_{l} + \left(0.25 + 0.75 \left(1 - \nu\right) t_{l}^{2}\right) + 0.35 t_{l}^{3} \right\}$$



- displacement at point of applied load Ptooth height, between the applied load Pand tooth root
- tooth thickness at base
- applied load (perpendicular to  $H_c$ )
- tooth face width (projected in the direction perpendicular to P)
- Young's modulus
- Poisson's ratio
  - $\frac{E_b}{H_c}$

Kinematics -> Contact Pattern LTCA Child Window

LTCA – Lewis beam formula:

• J Factor extracted from the actual tooth section at the considered point along the PoC



$$\sigma = \frac{W_N \cos \phi_L h}{\frac{(Ft^2)}{6}} - \frac{W_N \sin \phi_L}{tF}$$

$$W_t = W_N \cos \phi_c$$

$$\left(\frac{t}{2}\right)^2 = h X$$

$$\sigma = \frac{W_t P}{F} \left[\frac{\cos \phi_L}{\cos \phi_c} \left(\frac{1.5}{XP} - \frac{\tan \phi_L}{tP}\right)\right]$$

$$\frac{1}{Y} = \left[\frac{\cos \phi_L}{\cos \phi_c} \left(\frac{1.5}{XP} - \frac{\tan \phi_L}{tP}\right)\right]$$

$$K_f = 0.18 + \left(\frac{t}{r_f}\right)^{0.15} \left(\frac{t}{h}\right)^{0.45}$$

$$J = \frac{Y}{K_f}$$

$$\sigma = \frac{W_t P}{FJ}$$

Kinematics -> Contact Pattern LTCA Child Window

### Minimum oil film thickness:

$$\Lambda = \frac{H_{min}}{\sigma_m}$$

For elliptical contacts:

$$H_{min} = 3.63 \ U^{0.68} \ G^{0.49} \ W^{-0.073} \left(1 - e^{-0.68k}\right)$$

For rectangular contacts:

$$H_{min} = 1.714 \ U^{0.694} \ G^{0.508} \ W^{-0.128}$$

Blok's flash temperature:

$$\Delta T_f = \frac{0.8 \,\mu X_r W_{nr} \left| \sqrt{V_{rp}} - \sqrt{V_{rg}} \right|}{b_m \sqrt{b_H}}$$

Λ:	Oil film thickness ratio
H <sub>min</sub> :	Minimum oil film thickness
$\sigma_{ m m}$ :	Composite surface roughness

U:	Dimensionless speed parameter
G:	Dimensionless materials parameter
W:	Dimensionless load parameter
k:	Ellipticity parameter

u: Coefficient of friction	n (in oil)
----------------------------	------------

- $X_r$ : Load sharing factor (= 1 in HyGEARS)
- W<sub>nr</sub>: Normal unit load
- $V_{rp}$ : Rolling velocity of the pinion
- $V_{rg}^{rr}$ : Rolling velocity of the gear
- $b_{m}$ : Thermal contact coefficient
- b<sub>H</sub>: Semi-width of the Hertzian contact

Kinematics -> Contact Pattern LTCA Child Window

Use the 11x45a.dat geometry, for the Gear. Test the following Contact Pattern LTCA child window function buttons, one by one :

- Opt -> Results select "Depth Max Shear"
- 2D get into 3D mode
- $^J$  change to user defined projection mode (3 rotation arrows enabled)
- Get a proper view angle with the rotation buttons



Kinematics -> Contact Pattern LTCA Child Window / Contact Element

HyGEARS offers a Contact Element which is integrated to the LTCA.

The Contact Element:

- Subdivides the contact area into small rectangular areas, or *contact cells*;
- On each *contact cell*, the pressure is varied until the *sum of the initial separation and deformation* is equal on all contacting cells (Love, 1929)
- Provides results identical to Hertz for full contact ellipses; (results are different when ellipse is truncated);
- Contact Grid can be modified for increased precision / decreased computing times;
- Can account for surface deviations as obtained from the CMM



Kinematics -> Contact Pattern LTCA Child Window / Contact Element

X

Contact deformation (Love, 1929).

2a

Path of Contact

Cell where pressure

is applied

Contact Line

Contact Grid

2b



- E: Young's modulus
  - Poisson's ratio

ν:

p:

Cell where deformation is desired

- u<sub>z</sub>: surface deformation on a given cell
  - surface pressure on a given cell
- x, y: coordinates of a point in relation to the center of a given cell
- 2a, 2b: sides of a given cell

### Kinematics -> Contact Pattern LTCA Child Window / Contact Element



**Contact Separation** 



**Contact Deformation** 



**Contact Pressure** 



Contact Force

### Kinematics -> Contact Pattern LTCA Child Window / Contact Element



Values are hidden



Values are displayed

Kinematics -> Contact Pattern LTCA Child Window / Contact Element

Ridging + Pits present on pinion tooth after initial run in:

- Gleason Summary was entered in HyGEARS
- LTCA run at expected operating position

### Pinion tooth shows ridging + pits

### HyGEARS simulation (Hertz)





Pinion + Gear teeth measured

- Pinion + gear teeth R.E.
- LTCA run with Error Surface
- Use of Error Surface with Contact Elements analysis



#4







Pinion + Gear teeth measured

- Pinion + gear teeth R.E.
- LTCA run with Error Surface
- Use of Error Surface with Contact Elements analysis •

122.0

97.6

73.2

48.8

24.4

303 299

287 306



127.6

102.1

76.5

51.0

25.5

0.0

153.9

123.1

92.3

61.6

30.8

Pinion redesigned:

- Moved the CP away from fillet at heel
- Kept same blank, cutter, etc.
- Lower Hertz stresses at contact entry



#### <u>Original</u>

#### Redesigned



#### Comparative Contact Element Analysis:

### Original



Redesigned

**#8** 

### Comparative Contact Element Analysis:

#7

Original



**#9** 

Kinematics -> Contact Pattern LTCA Child Window

- "NoCE" toggle into Contact Element display
  "^Z" zoom onto the desired tooth area
- "Opt" select "Contact Pressure"





Kinematics -> Contact Pattern LTCA Child Window

- "NoDi" toggle in dimension display
- "Opt" select "Contact Deformation"
- +/- scan through the PoC





Kinematics -> Contact Pattern LTCA Child Window

- Close the Contact Pattern LTCA child window
- Create a new Contact Pattern LTCA child window
- Click on "Grid" select Torque and leave inputted value click "Ok"



# LTCA Testing: Fixed Setting Hypoid Gear Set



# LTCA Testing: Fixed Setting Hypoid Gear Set



# Fixed Setting LTCA Testing: TE



# LTCA Comparison – Spur HyGEARS

### LTCA - Compressive Stress - MPa - Gear:

















# LTCA Comparison – Spiral-Bevel FM HyGEARS

### LTCA - Compressive Stress - MPa - Gear Convex:















# LTCA Comparison - Straight-Bevel (MRoll) HyGEARS

### LTCA - Compressive Stress - MPa - Gear:















### Kinematics -> Contact Pattern Development Child Window

💒 B.Pattern Development - Gear Convex-IB		
BP Definition D-MSett [mm] LTCA E/P	Prop. Links	
Mean Point / Convex-IB Horizontal Position 47.0 %	Mean Point / Concave-OB Horizontal Position 48.7 %	
Vertical Position 50.0 %	Vertical Position 50.0 %	
PoC Bias / Convex-IB	PoC Bias / Concave-OB	
◎ Free	◎ Free	
Fixed 5.4 deg	Fixed 29.0 deg	
T.E.	Т.Е.	
Free     Free     InBad	Free     In Rad	
Pixed 44 V Unvature		
Backlash		
<ul> <li>Free</li> <li>Fixed</li> <li>0.120</li> <li>[mm]</li> </ul>		
Apply < <back next="">&gt;</back>	Reset Print OK Cancel	



### Kinematics -> Contact Pattern Development Child Window

B.Pattern Development	t - Gear Convex	-IB	×
BP Definition D-MSett [mm	n] LTCA E/P	Prop. Links	
Mean Point / Convex-II	В	Mean Point / Concave-OB	
Horizontal Position	50.0 %	Horizontal Position 50	.0 %
Vertical Position	50.0 %	Vertical Position 50	.0 %
PoC Bias / Convex-IB		PoC Bias / Concave-OB	
Free		Free	
Fixed 25	deg	Fixed 25	deg
-T.E.		T.E.	
Free		Free	
Fixed 147	🗧 (uRad	) Fixed 85 🔶	uRad
🔽 2nd-3rd 📃	Curvature		
Backlash			
Free			
Fixed 0.072	[mm]		
Apply < <back< td=""><td>Next&gt;&gt;</td><td>Reset Print OK</td><td>Cancel</td></back<>	Next>>	Reset Print OK	Cancel



👷 📽 B.Pattern Development - Gear Convex-IB	×
BP Definition D-MSett [mm] LTCA E/P Prop. Links	
BP Ltca      2D Graph Torque [N-m] 5     IB	⊚ ов
5.0 [N-m][Roark/Westinghouse] - Hertz Stress [Mpa]	
Heel	1944 1823 1701 1580 1458 1337 1215 1090 972 608 486 608 486 965 243 122 0
Apply < <back next="">&gt; Reset Print QK</back>	<u>C</u> ancel



BP Definition     D-MSett (mm)     LTCA     E/P     Prop.     Links       Machine Settings-Pinion     IB     0     0       Cutter Diameter     IB     0     0       Mtb     Current value:     2.7738       Offset     [mm]       Cutter Swivel     New value:       Cutter Tit     M. Root Angle       Decimal Ratio     Image: Current Value	📽 B.Pattern Development - Gear Co	onvex-IB
Machine Settings-Pinion Cutter Diameter Mctb Current value: 2.7738 Offset fmm] Cutter Swivel Cutter Swivel Mew value: mm] M. Root Angle Decimal Ratio	BP Definition D-MSett [mm] LTCA	E/P Prop. Links
<ul> <li>Pinion Tooth Depth</li> <li>Gear Tooth Depth</li> </ul>	Machine Settings-Pinion Cutter Diameter Mctb Offset Cutter Swivel Cutter Tilt M. Root Angle Decimal Ratio Pinion Tooth Depth @ Gear Tooth Depth	IB  OB Current value: 2.7798 [mm] New value: [mm]
Apply < <back next="">&gt; Beset Print QK Cancel</back>	Apply < <back next="">&gt;</back>	<u>R</u> eset <u>Print</u> <u>OK</u> <u>Cancel</u>



Kinematics -> Contact Pattern Development Child Window

Use the 11x45a.HyG geometry, for the Gear. Test the following Contact Pattern Development (Pinion) child window function buttons, one by one :

- "CPat" - call the Contact Pattern Development selection window

- Input the values as displayed below



Kinematics -> Contact Pattern Development Child Window

- Scan through the various Tabs to see the displays
- Input the values as displayed below

🦉 B.Pattern Development - Gear Convex-IB	
BP Definition [D-MSett [mm]] LTCA E/P Prop. Links	
B.Pattern Development (O.B.) (I.B.	
Machine Root Angle : 0.00.00	elonment - Gear Convex-IR
Cradia langle	
Heel Swivel Angle - 0.00.07 BP Definition C	tl Parame D-MSatt [mm] E/P Prop links
Cutter Spindle Angle : 0.00.00	
Decimal Ratio : 0.00970	e 
Machine Center To Back : 1,4530	e Off Surface - Pinion [Concave-OB]
Sliding Base : -0.3206	e Off Surface - Pinion [Convex-IB]
Apply < <back next="">&gt; Reset Print C Blank Offset : [Up] 0.0000 [Up]</back>	- Pinion [Convex-IB]
	- Pinion [Concave-OB]
Blade Angle : 0.00.00	Model - Pinion&Gear [Convex-IB]
Point Diameter : 0.0000	of Contact - Pinion&Gear [Convex-IB]
Point Width : 0.0000	
Apply < <back next="">&gt; Reset Print O</back>	
Annty	< <back next="">&gt; Reset Print OK Cancel</back>
	valute Simulation Softwares Inc.
*Kinematics -> Contact Pattern Development Child Window* 

- Click on the "E/P" tab
- Select 25% for the Horizontal and click on "Apply"; watch the EP values
- Click on "Cancel"

📽 B.Pattern Development - Gear Convex-IB	×
BP Definition D-MSett [mm] LTCA E/P Prop. Links	
E/P Control	
● IB ◎ OB	
Horizontal Position: 25.0 %	
· · · · · · · · ·	
Vertical Position: 50.0 %	
· · · · · · · · · · ·	
	-
<u>Apply</u> << <u>B</u> ack <u>N</u> ext>> <u>R</u> eset <u>P</u> rint <u>O</u> K	Cancel



Kinematics -> Contact Pattern Development Child Window

Use the 11x45a.dat geometry, for the Gear. Test the following Contact Pattern Development (Pinion) child window function buttons, one by one :

- Click on the "Prop" tab
- Input the values as displayed below click on "Apply"



### Kinematics -> Sliding Speeds Child Window





### Hypoid gear

Straight Bevel gear

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Kinematics -> Ease Off Child Window



### Kinematics -> Ease Off Child Window



' HyG	EARS V 4.0 © ® - Surface	e Statistics		
<u>F</u> ile	<u>E</u> dit			
	-			<b>V4</b>
	н	IVGEARS V 4.0 © ® -	Surface Statistics	11a
		-		
		Ease Off Surface -	Pinion Concave-OB	
	_			
	Date	. 03/10/2013		
	Time	: 8:44:47 AM		
	Units	: [mm] [D.dec]		
	Prepared by	: Claude Gosselin		
	AVERAGE ERRO	DRS	Pinion Concave-OB	
			0.0677	
	Fressure Ang	Tre [D'dec] :	0.0677	
	Spiral Angle	[D.dec]:	0.0201	
	Profile Curv	ature [mm] .	0.0001	
	Warp Factor	[/10 mm] :	0.3787	
	Sum Errors S	guared [in]:	0.03241090	
	-			
	H	HyGEARS V 4.0 © 🛚 -	Surface Statistics	
		Lase OII Surface -	Pinion Convex-IB	
	_			
	Dete			
	Date	: U3/10/2013		
	Inte	: 0:11:1/ Ari : [mm] [D dec]		
	Prepared by	: Claude Gosselin		
	AVERAGE ERRC	DRS	Pinion Convex-IB	
	Pressure Ang	gle [D.dec] :	-0.1517	
	Spiral Angle	[D.dec] :	0.0269	
	Crowning	[mm] :	0.0641	
	Profile Curv	vature [mm] :	0.0013	
	Warp Factor	[/10 mm] :	1.0023	
	Sum Errors S	iquared [in]:	0.04770345	
_				

#### Ease off Surface statistics

HyGEARS offers several tools for Production control. For Spiral-Bevel and Hypoid gears, CMM functions have been developed to:

- define where measurement on the tooth flank is to be performed;
- convert and display surface measurement (from any CMM) for quality control check;
- calculate *Corrective Machine Settings*; deviations can be added to pre-compensate for heat treat. deformations;
- Reverse-Engineer measured surfaces using the proprietary Surface Match algorithm.





Measurement, Corrective Machine Settings and Reverse Engineering



### Measurement -> CMM Data selection and conversion

💒 Measurement-Simulation Comparison - Pinion Demo1441.dat							
Comparison Data							
Geometry	Pinion 👻						
Displayed Tooth #	1-14 👻						
X Conversion Factor (Multiply)	Auto 👻						
Y Conversion Factor	Auto 👻						
Z Conversion Factor	Auto 👻						
Measured Data Filename	E:\VB\Demo\Demop.ram						
	Apply OK Cancel						

Test if the data file is of :

- "Ram" type;
- "Rfd" type;
- "Gleason-Zeiss" type;
- "Hoeffler" type;
- "MdM" type;
- "Klingelnberg-P" type;
- "GAGE" type;
- "Zeiss Gear Pro" type;
- "HyGEARS" type.

RAM File Name:	e:\vb\demo\demop.ram
	Create Nominal
	Mirror Image (Punch Mode)
	Overall Punch Height 0.0000
Thickness Error:	0.0000
RFD File Names:	E:\VB\Demo\Demo_p1.fd E:\VB\Demo\Demo_p2.fd
	-
Measured Tooth #s:	1;
Output File Name:	e:\vb\demo\demop.mes

*Measurement -> Surface Match Algorithm for Correction / R.E.* 

The Surface Match algorithm (1994) :

- Changes the machine settings of the selected member until the *measurement surface* statistics are within given tolerances;
- Uses the sensitivity of the error surface (difference between measurement and simulation) to chosen control parameters to iterate until the desired tolerances are met;



- Applies a Newton-Raphson based iterative process to solve the objective functions.

*Measurement -> Surface Match Algorithm for Correction / R.E.* 

Pressure Angle Error:



Spiral Angle Error:



### Crowning Error:



*Measurement -> Surface Match Algorithm for Correction / R.E.* 

#### Warp Error:



#### Taper Error:



Measurement -> Surface Match Algorithm for Correction / R.E.

#### Surface Statistics:



#### Where:

- i is the index of row measurement data, along the tooth flank;
- j is the index of column measurement data, across the tooth flank;
- mid is the index of the mid-column or mid-row measurement data;
- $e_{i,i}$  is the error value at point ij of the measurement grid;
- $\vec{x_{i,j}}$  is the distance between measurement points along the tooth flank;
- $y_{i,j}$  is the distance between measurement points across the tooth flank.

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*Measurement -> Surface Match Algorithm for Correction / R.E.* 

### **Objective Functions:**

1<sup>st</sup> Order:

$$\begin{split} \Phi & (\tau, \kappa, SlBase) - T_1 \leq L_1 \\ \Psi & (\kappa, \psi, SlBase) - T_2 \leq L_2 \end{split}$$

#### $\Phi$ is the average *pressure angle error*;

 $\Psi$  is the average *spiral angle error*;

#### 2<sup>nd</sup> Order

 $\Xi(\tau, \kappa, \psi, SlBase, Offset) - T_3 \leq L_3$  $\zeta(\tau, \kappa, \psi, SlBase, Mctb) - T_4 \leq L_4$ 

- $\Xi$  is the averaged *crowning error;*
- $\zeta$  is the averaged *warp (bias) error;*

- $T_i$  are the requested *deviations*;
- $L_i$  are the *tolerance limits*;

*Measurement -> Surface Match Algorithm for Correction / R.E.* 

Jacobian (or 1<sup>st</sup> order sensitivity) matrix:

1<sup>st</sup> Order:

2<sup>nd</sup> Order:



- is the average pressure angle error;
- is the average *spiral angle error*;
- is the averaged *crowning error;*

Φ

Ψ

Ξ

ζ

is the averaged warp (bias) error;

*Measurement -> Surface Match Algorithm for Correction / R.E.* 

Algorithm flow chart:



### *Measurement -> Corrective Machine Settings and R.E. selection window*

Corrective Machine Settings P	inion - [Finishing]	x	Corrective Machine Settings	Pinion - [Finishing]	×
Tolerance Order Machine			Tolerance Order Machine		
Actual vs Actual			Cutting Changes Order	Tooth Flank	Selection
Targets and Tolerances			Ord	O Drive	II 🕅
	Drive	Coast	<ul> <li>1st</li> </ul>	Coast	Spiral Angle
Tooth Thickness [mm]	0.0000 ± 0.0127	0.0000 ± 0.0127	<b>2</b>	Drive - Count	Pressure Angle
Pressure Angle [dd.mm.ss]	0.00.00 ± 0.00.10	0.00.00 ± 0.00.10	Middle Row	Drive + Coast	Tooth Taper
Spiral Angle [dd.mm.ss]	0.00.00 ± 0.00.10	0.00.00 ± 0.00.10			Tooth Thickness
Crowning [mm]	0.0000 ± 0.0015	0.0000 ± 0.0015	# Iterations	Machine	Bias
Profile Curvature [mm]	0.0000 ± 0.0010	0.0000 ± 0.0010	Max. # Iteratio 20	116F 👻	
Warp Factor [/10 mm]	0.00.00 ± 0.00.10	0.00.00 ± 0.00.10			
Tooth Taper [dd.mm.ss]	0.00.00 ± 0.00.25	0.00.00 ± 0.00.25	Calculation Trace	Recalc	Jacobian each iteration
			Auto Damping	Maintai	n Point Width
	<u>A</u> pply <u>R</u> eset	Print <u>OK</u> <u>Cancel</u>		<u>A</u> pply <u>R</u> eset	Print <u>OK</u> Cancel

Tolerance Order Machine Correction Expected Stats Errors options on target values and tolerances; options on what is to be corrected; options on control parameters constraints; calculated changes in machine settings; what HyGEARS hopes to achieve after correction; point by point differences

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### *Measurement -> Corrective Machine Settings and R.E. selection window*

🕈 Corrective Machine Settings Pinion - [Finishing]						
Tolerance Order Machine		Tolerance Order Machine Co	prrection [mm]	Expected Stats	Errors	
Tooth Bias	Machine Root Angle	1st Order Changes		(O.B.)	(I.B.)	
Decimal Ratio	Fixed					=
MCTB Pinjon	C Free	Machine Root Angle	:	0.00.00	0.00.00	
		Eccentric Angle	: -	-0.04.57	-0.13.57	
Blank Offset	Cutter Spindle Angle	Cradle Angle	:	0.06.52	0.19.41	
Roll Ratio		Swivel Angle	: -	-0.46.43	0.50.56	
<ul> <li>Eccentric</li> </ul>	⊘ Fixed	Cutter Spindle Angle	:	0.00.00	0.00.00	
Pressure Angle	Free	Decimal Ratio	:	0.00000	0.0000	
Decimal Ratio	Crowning	Marking Grater To Back		0.0100	0.0001	
Cutter Tilt	Point Diameter	Machine Center To Back	c :	-0.0122	0.0081	
Dianis Officiat	<ul> <li>Machine Center To Deals</li> </ul>	Black Offeet		-0.4642	0.3089	
Blank Offset	Machine Center To Back	Blank Oliset	- [0p]	1 0.0000 1	[0p] 0.0000	
Machine Root Angle	Blank Offset	Blade Angle	-	0 00 00	0 00 00	
Gaging Angle	Roll Ratio	Point Diameter	-	0.0000	0.0000	
Blade Angle	Eccentric		-			-
						- F
Дор	Ny Reset Print OK Cancel			ply <u>R</u> eset	Print OK	Cancel

Tolerance Order Machine Correction Expected Stats Errors options on target values and tolerances; options on what is to be corrected; options on control parameters constraints; calculated changes in machine settings; what HyGEARS hopes to achieve after correction; point by point differences

#### *Measurement -> Corrective Machine Settings and R.E. selection window*

💒 Corrective Machine Settings Pinion - [Finishing]								
Tolerance Order Machine Correction	[mm] Expected Stats	Errors						
	Drive	Coast						
Tooth Thickness [mm]	-0.51371							
Pressure Angle [dd.mm.ss]	-0.00.00	0.00.00						
Spiral Angle [dd.mm.ss]	0.00.00	-0.00.00						
Crowning [mm]	0.00127	-0.00699						
Profile Curvature [mm]	0.00034	0.00083						
Warp Factor [/10 mm]	0.02.59	0.00.01						
Sum Errors Squared [in]	0.000000	0.000001						
Tooth Taper [dd.mm.ss]	-0.00.00							
	Apply Reset	Print OK Cancel						

and C	Corrective Machine Settings Pinion - [Finishing]								x	
Tol	erance	Order	Machine	Correctio	n (mm)	Expected S	itats Erro	rs		
e	nce [m	m] To	oth 1							
c	: 1		2	3	4	5	6	7	1	в
	Root C .00057 .00146 .00210 .00214 .00068 Tip] .00581 .00635 .00741 .00832	-0.003 -0.000 -0.000 -0.000 -0.001 -0.002 -0.003 -0.004 -0.005	-OB] 08 0.000 24-0.003 09-0.000 68 0.003 25-0.003 92-0.000 36-0.003 18-0.003	062 0.00 134-0.00 135-0.00 100-0.00 173-0.00 049 0.00 065 0.00 189-0.00 305-0.00	0108 0 0126-0 0157 0 0053-0 0274-0 0013-0 0041-0 0054 0 0147 0	0.00191-0 0.00139-0 0.00000 0 0.00049-0 0.00202 0 0.00053-0 0.00006-0 0.00000-0 0.00000-0	.00069- .00257- .00100- .00068 .00010 .00041- .00026- .00025- .00076-	0.00014 0.00316- 0.00089 0.00029 0.00052 0.00052 0.00276- 0.00341- 0.00260- 0.00260- 0.00173-	0.0001 0.0018 0.0010 0.0010 0.0011 0.0045 0.0045 0.0045 0.0045	1-( B-( 5 ( 3 ( B ( ≡ 2-( 6-( 1-( 2-(
•										F.
					App	ply <u>R</u> es	et <u>P</u>	int (	<u>o</u> k	<u>C</u> ancel

Tolerance Order Machine Correction Expected Stats Errors

options on target values and tolerances; options on what is to be corrected; options on control parameters constraints; calculated changes in machine settings; what HyGEARS hopes to achieve after correction; point by point differences

Measurement -> Corrective Machine Settings

HyGEARS offers Corrective Machine Settings (similar to Gleason's GAGE)

CMM data is used to calculate changes in machine settings needed for the actual tooth surface to match the theoretical tooth surface.

Corrective Machine Settings support:

- 1<sup>st</sup> order errors: spiral angle, pressure angle, tooth taper;
- 2<sup>nd</sup> order errors: crowning and tooth warp (bias);
- Roughing and Finishing;
- All FM and FH cutting processes

Tolerance Order Machine							
Actual vs Actual							
Targets and Tolerances	Drive	Coast					
Tooth Thickness [mm]	0.0000 ± 0.0127	0.0000 ± 0.0127					
Pressure Angle [dd.mm.ss]	0.00.00 ± 0.00.10	0.00.00 ± 0.00.10					
Spiral Angle [dd.mm.ss]	0.00.00 ± 0.00.10	0.00.00 ± 0.00.10					
Crowning [mm]	0.0000 ± 0.0015	0.0000 ± 0.0015					
Profile Curvature [mm]	0.0000 ± 0.0010	0.0000 ± 0.0010					
Warp Factor [/10 mm]	0.00.00 ± 0.00.10	0.00.00 ± 0.00.10					
Tooth Taper [dd.mm.ss]	0.00.00 ± 0.00.25	0.00.00 ± 0.00.25					

Corrective Machine Settings Pinion - [Finishing]							
Tolerance Order Machine							
Cutting Changes Order	Tooth Flank	Selection					
Ord	Drive	V AI					
Ist	Coast	Spiral Angle					
2nd	Orive + Coast	Pressure Angle     Tooth Taper					
Middle Row		✓ Tooth Thickness					
Middle Column		Bias					
# Iterations	Machine	Crowning					
Max. # Iteratio 20	116F 👻	Profile					
Calculation Trace	Recalc	Jacobian each iteration					
Auto Damping	Maintain Point Width						
	Apply Reset	Print OK Cancel					

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Measurement -> Reverse Engineering

HyGEARS uses the Surface Match algorithm to Reverse Engineer existing tooth surfaces.

Reverse Engineering is useful to:

- identify the machine settings of existing gear sets for which the summaries are lost;
- *analyze existing gear sets* and identify the machine settings or provide a reference surface leading to quietness;
- *diagnose the reason for a failure* by simulating meshing and load sharing;
- optimize the Stock Distribution;
- use different cutters on a given geometry (Fixed Setting only);
- calibrate mechanical machines to pre-compensate for their inaccuracies;
- etc.



Measurement -> Measured Surfaces Child Window



Measurement -> Measured Surfaces Child Window

Use the Demo1441.HyG geometry. Test the following Measured Surfaces child window function buttons, one by one :

- Create a Measured Surfaces Child window for the Gear
- -"3D" toggle in and out of 3D mode
- "XYZ" to select which tooth to display (use #1)
- "NoPo" toggle in the display of the Contact Pattern
- "ErrS" toggle the CP into using the Error Surface use "Linear" in "Opt"
- "Scal" change the scale such as to view the Error Surface deviations



### Measurement -> Compare Meas-Sim Surfaces Child Window



Measurement -> Compare Meas-Sim Surfaces Child Window



1<sup>st</sup> order errors

2<sup>nd</sup> order errors

Measurement -> Compare Meas-Sim Surfaces Child Window

Use the Demo1441.HyG geometry. Test the following Comp Meas-Sim Surfaces Child window function buttons, one by one :

- Create a Comp Meas-Sim Surfaces child window for the Pinion

- "Stat" – call the Surface Statistics Output – compare with the Error Surface



Measurement -> Compare Meas-Sim Surfaces Child Window

- "Scal" – experiment changing the scale from Auto to any available value



Auto-Scale



Scale = 10 um

Measurement -> Compare Meas-Sim Surfaces Child Window

- "Outp" – call the Error Surface Output

💒 Comp. MeasSim	Gear [Finishing] - Demo1441.dat	- 0 ×
<u>F</u> ile <u>E</u> dit		
	HyGEARS V 4.0 © © Comp. MeasSim. Gear [Finishing] [mm] - Demo1441.dat	
	Date / Time : 03/10/2013 / 10:16:45 AM General Units : [mm] [dd.mm.ss] Cutter Units : [in] Prepared by : Claude Gosselin Version : 4.0.402.40	E
Difference [mm Ia3\Iac: 1	Measured data file : e:\vb\demo\demo1-28.mes 	
[Tooth Root Co 1 0.00023 2 0.00273 3 0.00183 4 0.00032 5 -0.00038- [Tooth Tip] 5 -0.00067- 4 -0.00109 3 -0.00025 2 0.00007 1 0.00070 [Tooth Root Co	ncave-OB] 0.00086 0.00089 0.00194 0.00189 0.00140 0.00120 0.00175 0.00122 0.00263 0.00166 0.00114 0.00113 0.00082 0.00071 0.00090 0.00107 0.00072 0.00019-0.00034 0.00000-0.00045 0.00003-0.00026 0.00034 0.00114-0.00018-0.00048-0.00052-0.00065-0.00082-0.00014-0.00002 0.00018-0.00095-0.00053-0.00121-0.00109-0.00062-0.00045-0.00036 0.00055-0.00040-0.00024 0.00008 0.00061 0.00063 0.00066 0.00064 0.00033-0.00023-0.00086-0.00046 0.00007-0.00021-0.00024 0.00010 0.00050 0.00045-0.00005 0.00000 0.00006 0.00016 0.00070 0.00083 0.00171 0.00097 0.00092 0.00062 0.00142 0.00150 0.00105 0.00239 0.00259 0.00161 0.00202 0.00197 0.00221 0.00236 0.00258 0.00255 nvex-IB]	
		-

Measurement -> Stock Distribution Child Window



Measurement -> Corrective Machine Settings Child Window

Corrective M/C Settings: machine changes for the manufactured tooth to match the design tooth



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Measurement -> Corrective Machine Settings Child Window

Use the Demo1441.HyG geometry. Test the following Corrective Machine Settings child window function buttons, one by one :

- Create a Corrective Machine Settings child window for the Pinion
- "Sett" call the Corrective Machine Settings selection
- "Order" Tab select 2<sup>nd</sup> Order


### Measurement -> Corrective Machine Settings Child Window



Corrective Machine Setting	s Pinion - [Finishing]	
Tolerance Order Machine	Correction [mm] Expected Stats	Errors
Cutting Changes Order Ord 1st 2nd V Middle Row V Middle Column # Iterations Max. # Iteratio 20	Tooth Flank Drive Coast Orive + Coast Machine	Selection All Spiral Angle Pressure Angle Tooth Taper Tooth Thickness Bias Crowning Profile
Calculation Trace Auto Damping	Recalc     Maintai Machine Settings Pinion - [Finis der Machine Correction [mm]	Jacobian each iteration n Point Width shing]
Tooth Press Spira Crow Profil Warp Sum Tooth	Drive n Thickness [mm] [1 sure Angle [dd.mm.ss] [0, I Angle [dd.mm.ss] [0, ning [mm] [0] e Curvature [mm] [1] Factor [/10 mm] [1] Errors Squared [in] [0, n Taper [dd.mm.ss] [1]	e Coast 11122 00.05 -0.00.09 0.00.09 0.00.08 00001 -0.00006 0.0042 -0.00001 0.0042 -0.00001 0.00.06 0.00.06 0.00001 0.00000
	Др	ply <u>R</u> eset <u>Print</u> <u>O</u> K <u>C</u> ancel

Measurement -> Corrective Machine Settings Child Window

- Check the displays in all other Tabs
- Click on "Ok" to keep, "Cancel" to dump

Corrective Machine Settings	Pinion	- [Finishing]		×							
olerance Order Machine C	orrectio	n [mm] Expected Sta	ats Errors								
2nd Order Changes		(O.B.)	(I.B.)	<u>^</u>							
Machine Root Angle	:	0.00.00	0.00.00	E	ishinal		×	ו			
Eccentric Angle	:	-0.04.04	-0.02.28			_					
Cradle Angle	:	-0.09.22	0.10.11		Expected Stats	Errore					
Swivel Angle	:	-0.56.53	-0.06.34								
Cutter Spindle Angle	:	0.00.00	0.00.00								
Decimal Ratio	:	0.0000	0.00000		ve	Coast		nishing]			×
Machine Center To Bac	<b>b</b> -	-0.3091	0 2494		0.50390			n] Expected Stats	Errors		
Sliding Base		-0.4048	-0.1898		0.00.01	0.00.00		-			
Blank Offset	:	[Up] 0.0000	[Up] 0.0000		0.00.01	-0.00.03					
Blade Angle		0 00 00	0 00 00		0.00.01	0.00.03					
Point Diameter	:	-0.0225	0.0101	_	0.00037	0.00101					
•				•	0.00140	0.00027		5 6	7	8	
					0.02.10	0.00.08			0.00150.		
		<u>A</u> pply <u>R</u> ese	t <u>P</u> rint <u>O</u>	K <u>C</u> ancel	0.000000	0.000000		0114-0.00131-	0.00159 (	0.00229-0	.002
			-					0000-0.00031-	0.00206 0	0.00117-0	.000
			looth laper [dd.m	m.ss]	0.00.01			0127-0.00071-	0.00082-0	0.00003-0	.000
								0356-0.00303-	0.00224-0	0.00190-0	.002 🗉
								0083 0.00004-	0.00074 (	0.00035 0	.000
								0020 0.00008-	0.00141 (	0.00107-0	.000
					oply <u>R</u> eset	<u>P</u> rint <u>O</u> K	<u>C</u> ancel	0000-0.00110-	0.00032-0	0.00076 0	.000
								0043-0.00093-	0.00001-0	0.00031 0	- 000
					•			III			+
							-				
							L	<u>Apply</u> <u>R</u> eset	<u>P</u> rint	<u>О</u> К	<u>Cancel</u>

Measurement -> Reverse Engineering Child Window

Reverse Engineering: machine changes for the design tooth to match the manufactured tooth



### **Reverse Engineering : Duplex Helical Example**

### Measurement -> Reverse Engineering



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85.8

85.9

## **Reverse Engineering : Fixed Setting Examples**

### Measurement -> Reverse Engineering



## <u>Reverse Engineering : Face Hobbed Example - Quiet Drive Side</u>

#### Measurement -> Reverse Engineering







## Reverse Engineering : Face Hobbed Example - Noisy Coast Side

#### Measurement -> Reverse Engineering









Measurement -> CMM Nominal Data Child Window



Measurement -> CMM Nominal Data Child Window

HyGEARS allows the definition of the Target CMM grid.

- Output can be done for several popular CMMs
- Edge reductions can be inputted at tooth Bottom, Top, Toe and Heel;
- After measurement, the CMM output file is converted into a HyGEARS specific format for fast access;
- Probe ball can be displayed and moved at target points to visualize potential interference;

🥵 CMM Interface - Demo1441.da	t - [mm]
Geometry	Pinion 👻
Axial # Points	9
Radial # Points	5
Bottom Clearance	1.0000
Top Clearance	1.0000
Toe Clearance	2.0000
Heel Clearance	2.0000
🔲 Rectangular Grid	
	oeffler ZP350
🔘 Gear Bevel (Unix) 🛛 🔘 M	dM Mecatronics
🔘 Klingelnberg P 🛛 🔘 C	DS
◯ GAGE ◯ Z	eiss
Probe Diameter	0.0000
Show Probe Ball	
Anim +/- Apply	OK Cancel





Measurement -> CMM Nominal Data Child Window

- "2D" to change to 3D view;
- Rotate the display until a proper viewing angle is obtained;
- "Dims" to hide the CMM grid dimensions;
- "^Z" to toggle into Manual Zoom; zoom onto the Grid area;
- "Ram" function button check the "Show Probe Ball" and enter 2.0 mm as the Probe Diameter; click on the "Apply" button;
- "+/-" with the left and right mouse buttons to move the probe along the tooth flank;

👷 K CMM Interface - Demo1441.dat	- [mm] 🛛 💌
Geometry	Gear 👻
Axial # Points	9
Radial # Points	5
Bottom Clearance	1.0000
Top Clearance	1.0000
Toe Clearance	2.0000
Heel Clearance	2.0000
🔲 Rectangular Grid	
🔘 Ram 300 🛛 🔘 Hoe	effler ZP350
🔘 Gear Bevel (Unix) 🛛 🔘 Mdl	M Mecatronics
🔘 Klingelnberg P 🛛 🔘 CDS	S
○ GAGE	35
Probe Diameter	2.0000
Show Probe Ball	
Anim +/- Apply	<u>Q</u> K <u>Cancel</u>





### 2D Graphs Child Window



### 2D Graphs Child Window



### 2D Graphs Child Window



### 2D Graphs Child Window

### **Display Options**

- TCA:
- LTCA:
- Torque:
- Transm. Force:
- Bending Def.:
- Contact Def.:
- Lamda:
- Efficiency Ltca:
- Temp Increase:
- B. Stress Gear:
- J Factor-Gear:
- Kt G:
- #1... Gage Gear:
- K-Flex:
- Tooth Separation

- FFT TCA:
- FFT LTCA:
- Load:
- Sum Load:
- Contact Stress:
- Min. Oil Film:
- Efficiency:
- Frict. Coef. Ltca:
- B. Stress Pinion:
- J Factor-Pinion:
- Kt P:
- #1... Gage Pinion
- %:
- K-Mesh:
- Sliding Speeds:

### 2D Graphs Child Window

Graphic	Output Den	no1441.dat		
<u>F</u> ile <u>E</u> c	lit			
				×4
				144
		HyGH	EARS V 4.0 © ®	800
		Graphic Ou	utput - Demo1441.dat	
		Pinion [Finishir Pinion Concave-(	ng] + Gear [Finishing] DB [NoEr]	E
		Date / Time General Units Cutter Units Prepared by Version	: 03/10/2013 / 11:10:03 AM : [mm] [dd.mm.ss] : [in] : Claude Gosselin : 4.0.402.40	
TC2	A 			
		Theta3 [°]	TCA [uRad]	
	-	Amplitude : Average :	44.2807 0.0000	
		48,9631	-1296.14392	
		55.8125	-1013.03022	
		62.6594	-804.65380	
		69.5047	-674.10725	
		76.4014	-630.41190	
		79.8379	-361.82410	
		83.3430	-62.46720	
		86.9267	-4.53667	
		90.5337	-3.57589	<b>T</b>

Text output of a 2D graph

### 2D Graphs Child Window



### 2D Graphs Child Window

- "2D Graph" Create a 2D Graph child window; select "TCA", click on "Ok";
- "Grid" function button enter E and P as 0.200 mm; click on "Ok"



### LTCA TE-P2V Child Window

#### Need to see how some LTCA metrics evolve with torque;

- Display TE under load *f*(Torque)
- Display Sc *f*(Torque)
- Display SCP, SbG *f*(Torque)







Meshing -> FEA Model Child Window

HyGEARS offers an advanced meshing interface in which a FEA mesh can be defined and outputted *in a matter of seconds*.

- An FEA mesh is based on the same tooth surface as that obtained by the machine settings.
- Loads can be applied, in different manners, anywhere on the tooth surface.
- Export in Patran Neutral file format



Meshing -> Finite Strips Child Window

HyGEARS offers a proprietary solution to bending stiffness and stresses: the Finite Strips.

In short, the Finite Strips are a subset of the Finite Elements.

Using *thick plate* theory combined to smooth series, *accurate tooth stiffness and bending stresses* can be obtained in a matter of seconds.



Meshing -> Finite Strips Child Window

Strips of width *b* and length (or height) *a* are parallel to the  $\lambda$ -axis and connected by nodal lines; the nodes are used to define the displacement function.



Meshing -> Finite Strips Child Window

The displacement function  $\delta$  of a strip is expressed as the sum of a series of *l* terms:

$$\delta = \sum_{m=1}^{l} \sum_{i=1}^{2} \Phi_i^m a_i^m$$

where  $\Phi_i^m$  is a combination of polynomial  $N_i$  and series  $\phi_m^w$ ,  $\phi_m^{\Theta_r}$  and  $\phi_m^{\theta_{\lambda}}$ :

$$\Phi_{i}^{m} = \begin{bmatrix} N_{i}\phi_{m}^{w} & 0 & 0\\ 0 & N_{i}\phi_{m}^{\theta_{r}} & 0\\ 0 & 0 & N_{i}\phi_{m}^{\theta_{\lambda}} \end{bmatrix}$$

Using Mindlin's plate theory, the mid-plane displacement vector of a strip is Midplane

$$\boldsymbol{\delta} = \begin{bmatrix} \boldsymbol{w}, & \boldsymbol{\theta}_r, & \boldsymbol{\theta}_\lambda \end{bmatrix}^T$$

The vector of nodal parameters of node i for the  $m^{th}$  function is:

$$a_i^m = \begin{bmatrix} w_i^m, & \theta_{ri}^m, & \theta_{\lambda i}^m \end{bmatrix}^T$$

The Finite Strip stiffness matrix for functions m, n and nodal lines i, j is written as:

$$\left[k_{i,j}^{m,n}\right] = \iint \left[B_i^m\right] \left[D\right] \left[B_j^n\right] r \, d\lambda \, dr$$



Meshing -> Finite Strips Child Window





Meshing -> Finite Strips Child Window

The figures below show the bending stresses in a Helical gear tooth, in two different contact positions using the results of the Loaded Tooth Contact Analysis for applied load and extent of the Contact Pattern.

Typical pre-processing and *solution times* < 0.3 sec. on standard 2.4 GHz computer. The Finite Strips are therefore an *excellent tool to design and optimize a geometry*.



Meshing -> Finite Strips Child Window



Meshing -> Finite Strips Child Window



Meshing -> Finite Strips Child Window





Meshing -> Finite Strips Child Window





### Addendum 1: Bearing Reactions





2<sup>nd</sup> harmonic higher than 1<sup>st</sup> harmonic, high response at 730 Hz



# Addendum 2: Influence of Bearing Stiffness (TCA / LTCA)

### Worst Case Scenario

- -Contact Pattern / Contact Stresses
- -Transmission Error

### Stiff bearings and supports



### Support stiffness = 50 k-lbs/in



### Support stiffness = 50 k-lbs/in



### Gleason Summary provided by customer

### Data entered in HyGEARS

			DINENSION SHEEL												
HYPOID GEAR DIMENSIONS	NO.	FH2B3A	VERSION:1.0.1.3 11/25	2003 15:2			🙀 Existing Geome	try Definition - [in]	[dd. mm. ss]		🙀 Existing G	eometry Def	finition - [in] [d	d. mm. ss]	
American Axle & Manufacturing	PINION	GEAR	FITCH APEX BEYOND CROSS FT . FACE APEX BEYOND CROSS FT . ROOT APEX BEYOND CROSS FT .	PINION GE -0.597" ( -0.031" ( -0.819" (	GEAR 0.742" 0.807" 0.365"		General Machine	Neutral Data			General Ma	chine Neutral E	Data		
NUMBER OF THEFT PART NUMBER DIALOTRAL FITCH PART NUMBER FILLION FILLION FILLION FILLION STATE STAT	2.050 2.050 2.050 2.050 2.050 2.050 2.050 2.050 2.050 2.050 2.050 2.050 2.050 2.050 2.050 2.050 2.050 2.0510	4.767 1.348" 5.031" 4.287" 8.601"	DOONT TO CROATEL FORT. FACE AND UNCT TO CROAT FOIL FACE AND UNCT TO CROATE FACE AND UNCT TO CROATE AND OF THE ADDRESS OF THE AND OF STRALL AND CL AND OF STRALL AND OF STRALL ENVISE MEMORY BEEN ENVISE M	-4.847 12 2.5957 12 2.5957 12 2.09577 12 2.80396 54 2.80396 54 2.80396 54 2.80396 54 2.80396 54 2.80396 12 2.80396 12 2.80396 12 2.80396 12 2.80396 12 8.0056 12	0.383" 1.822" 0.114" 58D 448 58D 448 58D 448 58D 448 58D 448 58D 448 58D 488 58D 586 58D 58		Geometry Name Directory Geometry Type Pinion Tooth Hand	C218 E:\VE Hypo Left	-Test B\hygear32 vid _		Machine Number of T Spiral Angle Mounting Di	Feeth stance	Pinion 175B 10 51.57.41 3.54330	999 41 27.3 3.8	Gear IR 37.56
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DEPENDENT OF EXPLANANCE AND A MARK THE OWNER AND A	Gear C	1224 230 774 270 130 C218A- Finishin	Test.dat [Conce ng]	ave-OB]	9.239 9	Gear [Hypoid] Blank Cutter Io Misc # Teeth Diametral Pitch Tooth Hand Face Width Addendum Dedendum Add Angle Ded Angle Front Angle Back Angle	[Finishing]         C218-Test.         Op           pRem         Machine         Other         Op           [41         5.3770         0           [Flight         1         1810         0           0.0474         0.2742         0.0000         0           0.0000         65.8500         65.8500         65.8500	Jat - [in] [dd.mm.ss]         gerating       Bim-Material         Outer CD       Pinion Offset         Blank       Pitch Angle         Pitch Angle       Face Angle         Root Angle       PApex to Xp         F Apex to Xp       Crown to Xp         FCrown to Xp       FCrown to Xp	Bearings           #1780           15000           65.8500           65.8500           65.8500           0.3220           0.3740           0.0230           1.3440           0.8609		inion [Hypoid] k Cutter TopF sc Teeth iametral Pitch both both both ddendum edendum dd. Angle ed. Angle ed. Angle ack Angle	[Finishing] C Rem Machine 5.3770 Left 1.4670 0.2294 0.1388 0.00.00 0.00.00 0.00.00 0.00.00	Cate-Test.dat - Other Ogerating Outer Pinior Pinior Blank Pitch, Face. Root, PApe RApe Crowr PCrow	(in) [dd.mm. Bim-Material CD Offset Angle Angle x to Xp x to Xp x to Xp to Xp in to Xp	<b>55]</b> Beau 3.83 1.50 22.0 22.0 22.0 -0.13 3.63 2.24

Visually verify Pinion and Gear teeth for:

- Insufficient Topland
- Undercutting



### Design, is analyzed for:

- Position/Alignment sensitivity










#### Design, is analyzed for:

Worst case scenario



#### Worst Case Scenario

- Contact Pattern / Contact Stresses
- Transmission Error



#### Worst Case Scenario: Check for Fillet Interference

E=0.0185 P=-0.011 G=0.044 Sigma= 0.00 Align=0.00°





#### Worst Case Scenario: Pinion fillet stresses



#### Worst Case Scenario: Gear fillet stresses



## **Addendum 4: Lapping Prediction**

Abrasive rate of wear is proportional to:

- L Sliding distance
- W Load
- H Hardness

$$V_m = k \; \frac{W L}{H}$$

#### Calculated CP before lapping



#### After lapping



### Addendum 4: Lapping Prediction / 2

Experimental wear coefficients 11x41:

Table 3 Calculated wear coefficients using the error surface in the contact pattern.								_
Gear Set	$h_{\epsilon}^{p}(\mu m)$	$h_{\epsilon}^{s}(\mu m)$	$k_{\scriptscriptstyle bl}^{\scriptscriptstyle p}$	k:	$k_{\scriptscriptstyle al}^{\scriptscriptstyle p}$	$k_{\scriptscriptstyle al}^{\scriptscriptstyle g}$	<u>k</u> .	
P1G1	17.4	9.7	0.901	0.940	0.997	1.025	0.967	
P2G2	15.6	8.8	0.896	0.908	1.033	0.998	0.959	
Table 4 Calculated wear coefficients neglecting the error surface in the contact pattern								
Gear Set	$h_{\epsilon}^{p}(\mu m)$	$h_{\epsilon}^{s}(\mu m)$	$k_{\scriptscriptstyle bl}^{\scriptscriptstyle p}$	$k_{\scriptscriptstyle bl}^s$	$k_{\scriptscriptstyle al}^{\scriptscriptstyle p}$	$k_{\scriptscriptstyle al}^{\scriptscriptstyle g}$	k.	
P1G1	17.4	9.7	0.912	0.967	0.912	0.967	0.939	
P2G2	15.6	8.8	0.898	0.909	0.898	0.909	0.903	

# Addendum 4: Lapping Prediction / 3

#### Experimental wear coefficients 12x41:

Table 5. Lapping parameters used for wear coefficient determination - 12x41 gear set.							
Torque \ RPM	1500 RPM	2000 RPM	2500 RPM				
5 N-m	Gear set A	Gear set B	Gear set C				
10 N-m	Gear set D	Gear set E	Gear set F				

#### Table 6 Calculated wear coefficients for gear sets A B C D E F.

Gear Set	Reference	k			
Gen ber	Reference	Pinion	Gear	Average	
	Before lapping	0.877	0.722	0.801	
PA-GA	After lapping	1.066	1.037	1.053	
	Average		0.930		
	Before lapping	0.804	1.260	1.039	
PB-GB	After lapping	1.155	1.404	1.273	
	Average			1.183	
	Before lapping	0.871	0.823	0.846	
PC-GC	After lapping	1.153	1.134	1.143	
	Average			1.018	
	Before lapping	0.721	0.683	0.702	
PD-GD	After lapping	0.919	0.947	0.933	
	Average			0.843	
	Before lapping	0.925	0.735	0.826	
PE-GE	After lapping	1.266	1.129	1.197	
	Average			1.052	
	Before lapping	0.716	0.746	0.732	
PF-GF	After lapping	1.186	1.274	1.230	
	Average			0.949	
Average A to F				0.996	
Average A, B, C, E, F				1.026	

# Addendum 4: Lapping Prediction / 4

#### Prediction and measured ...



# Summary

- 1. HyGEARS' tooth flank generation and TCA calculations match Gleason's CAGE and Klingelnberg's KIMoS; therefore, the **reference topography** in HyGEARS is the **exact tooth** *definition*;
- 2. *HyGEARS designs gear set geometries*, i.e. the machine settings for all HyGEARS supported geometries are calculated and a Summary is created;
- 3. Geometries can be imported from Gleason SPA and KIMoS ND files;
- 4. Spiral bevel cutting processes such as Face Milling and Face Hobbing are integral to HyGEARS;
- 5. Geometries can be analyzed unloaded and loaded for contact and tooth fillet stresses;
- 6. *5Axis CnC machine Post-Processing*, *i.e. the generation of a part program "machine ready", is integral to HyGEARS;*
- 7. Part programs are **generated in reference to the exact tooth surface** definition (rather than an interpolated surface as is the case with the many other softwares);
- 8. Part program generation is based on user selected cycle features;
- 9. Any **5Axis CnC machine architecture** can be accommodated; current architectures include "AB", "AC", "BA" and "BC"; **any controller can be accommodated**; current controllers include GCodes, Siemens, Heidenhain and Fanuc;
- 10. Part programs can be in *Machine coordinates, Work piece coordinates* with axis angles, or Work piece coordinates with tool axis vector (*Traori, TCPM* and *TCP*);

# Summary

- 11. Users can define their own tool box for Face Mill, CoSIMT, End Mill and Ball Mill tools;
- 12. Cutting Cycles include **Slot by Slot** and **Flank by Flank**, both for tooth flank and fillet; tip chamfering is available;
- 13. Animations and single stepping allow the visualization of tool movements and the verification of tool paths and possible interference;
- 14. A "Metrics" function gives an **estimate of the deviations** between the theoretical tooth flank and the "flats" and "peaks" created by the discrete movements of the tool;
- 15. Toe and Heel clearances allow smooth tool entry and exit;
- 16. "Stock" allowance is available for roughing and finishing;
- 17. A **"Roughing mode"** moves the selected tool in the center of the gap to quickly remove as much material as possible;
- 18. "Operations", including all user selections for a given task, may be saved for later re-use;
- 19. *Closed Loop*, also called Corrective Machine Settings, is *integral to HyGEARS* and allows the seamless manufacture of gears to the required tolerances.