CnC 5Axis Manufacturing of Gears

with

HYGEARS TM V 4.0

An Overview

Involute Simulation Softwares Inc., Québec, Canada

www.HyGEARS.com HyGEARS@HyGEARS.com

September 2019



Introduction	4
Vector Simulation	5
HyGEARS : The Vector Model	6
Face Milling and Face Hobbing	8
Calibration	9
Supported Gear Types	13
5Axis CnC Post-Processor	
Overview	22
Architectures	25-28
Main Features	29
Conversion	30
Machines / Tools	31
Display	35
Cycles	38
Metrics	56
Cycle Timing	57
Arbor	58
Tool Definition	59
Tool Reference Point	61
Part Reference Point	54



	Operations	68
	Processes	71
	Output	73
	Sample result 1	77
	Sample result 2	81
	Sample result 3	85
Sumi	mary	86

Introduction

HyGEARS V 4.0 covers all major gear types found in the gear industry.

The integrated **5Axis CnC Post-Processor** generates, from the **exact tooth definition** without any interpolation, the CnC machine part programs needed to manufacture **every gear type** of the simulation model on **any 5Axis CnC machine** available on the market: the resulting tooth flank topography is the same whether Face Mill, CoSIMT, End Mill or Ball Mill tools are used.

In one single stand alone software, HyGEARS allows :

- to design gear sets: face milled spiral-bevel, hypoid, straight bevel, Cyclo-Palloid spiral-bevel gears, Coniflex TM, spur, helical, Beveloid, herringbone and Face gears;
- to analyze the kinematics, unloaded and loaded: TE, Contact Pattern, LTCA, FFT, Bending and Contact stresses, and more, are all but one click away;
- to *develop and optimize the kinematic characteristics* of gear pairs, through specialized functions, in order to improve load carrying capacity and smoothness of operation;
- to assess the manufacturing quality through an export/import interface to common CMMs;
- to cut gears on conventional and 5 Axis CnC machines using Face Mill, Dish type cutter (for Coniflex gears), Conical Side Milling Tool (or CoSIMT, such as made by Ingersoll Rand, Sandvik, PTR-TEC), End Mill and Ball Mill tools;
- to use an *integrated Closed Loop*, i.e. seamless use of CMM output to determine machine corrections such that manufactured parts are within set tolerances when compared to the design.

Read on for a brief overview of HyGEARS.

HyGEARSTM is built on Vector Simulation

Machine root angle [

Machine center to back

3: A Numerical machine is In Vector Simulation, a theoretical gear generator is simulated created from the Vector Model by translations and rotations applied to reference frames that determine the relations between cutting tool and machine. Work Tooth Trace Radial Mean Point Offset Z1 Z٥ xj Cradle Cutter Blade rotation Zn Z 2 Γ_n \supset Swivel J 4: A Numerical gear set is Cutter tilt T Dı created with the Numerical 1: The reference machine is machine. Z1 discretized in a series of ref. frames -Machine plane fean Point

Sliding base X_k

2: The Vector Model uses the ref. frames of the discretized machine

HyGEARS™ The Vector Model

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

$$N = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos(\alpha c) \sin(\alpha c) \\ 0 & -\sin(\alpha c) \cos(\alpha c) \end{bmatrix} \begin{bmatrix} \sin(\phi) \\ 0 \\ \mp \cos(\phi) \end{bmatrix}$$

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



HyGEARS™ The Vector Model

Higher order changes, up to 6th order, are superimposed to tool and work piece movements in order to achieve specific kinematic behavior.

Example 1) Modified Roll higher order changes:

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

Example 2) Helical Motion higher order changes:

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

where:	L_{1m} :	modified cradle angle	where:	X _{bm} :	modified sliding base
	α ₃ :	work piece roll angle		α ₃ :	work piece roll angle
	R _r :	ratio of roll, cradle to work piece		R _r :	ratio of roll, cradle to work piece
	C _r :	cradle ref. position		C_r :	cradle ref. position
	-			1 st :	1 st Order parameter
	2C:	2 nd Order parameter (Gleason notation)		2^{nd} :	2 nd Order parameter
	6D:	3 rd Order parameter		3 rd :	3 rd Order parameter
	24E:	4 th Order parameter		4^{th} :	4 th Order parameter
	120F:	5 th Order parameter		5^{th} :	5 th Order parameter
	720G:	6 th Order parameter		6^{th} :	6 th Order parameter

HyGEARS™ – Face Milling and Face Hobbing

Both the Face Milling and Face Hobbing processes are supported for all Spiral Bevel type gears.



Face Milling (single indexing)

ground circle inside blade outside blade cutter rotation cutter center roll circle

Face Hobbing (continuous indexing)

HyGEARS™ – <u>Calibration</u>

HyGEARS has been extensively calibrated against Gleason's CAGE and Klingelnberg's KIMoS softwares for tooth flank coordinates, Contact Pattern and Transmission Error, CMM output, Corrective Machine Settings (Closed Loop), LTCA Contact Stresses, etc.

Some important milestones:

1993-1994:	Machine Calibration (Gleason and Yutaka machines)
1994:	Closed Loop 1 st Order
1995:	Closed Loop 2 nd Order
1996:	Experimental TE
1997:	Experimental LTCA
1998:	Fillet Stress (against FEA)
2001:	Contact Stress (against Gleason)
2004:	Bending and Contact Stress – Face Hobbing – (against Gleason)
2006:	Lapping Prediction (with AAM)
2011:	First 5Axis CnC Interface

Consistently equivalent results are obtained, as is shown in the following pages.



HyGEARS™ – <u>Calibration</u>

Tooth Flank Topography Comparison: Gleason and Klingelnberg vs HyGEARS

8x39 Face Milled Spiral Bevel gear set: comparing Nominals using the same machine settings



HyGEARS™ – <u>Calibration</u>

Tooth Flank Topography Comparison: Gleason and Klingelnberg vs HyGEARS

8x39 Face Hobbed Hypoid gear set: comparing Nominals using the same machine settings



HyGEARS™ – Supported Gear Types

The most popular gear types are supported by HyGEARS. All can be cut on any CnC machine.

- Spur/Helical
- Herringbone
- Spiral Bevel: Face Milled, Face Hobbed, Cyclo-Palloid
- Hypoids, both conventional and High Ratio (HRH)
- Straight Bevels
- Coniflex (TM The Gleason Works)
- Beveloid
- Face Gears
- Spiral Bevel Face Clutches

Spiral-Bevel/Hypoid cutting processes:

- Fixed Setting (i.e. the old 5 cut system);
- Non Generated (i.e. Formate ®)
- Spread Blade
- Modified Roll
- Duplex Helical
- Semi-Completing
- Face Hobbed
- Cyclo-Palloid



Fixed Setting Hypoid Pinion



Duplex Helical Hypoid Pinion



Face Flobbed Gear Set



Straight Bevel Gears

Worm Gears







Splines/Internal Gears

Helical Gears





Beveloid Gears





Worm & Flelical Gears





Spurniflex Gears





Spurved Gears







<u>Flirth Coupling</u>





Coniflex Bevel Gears





Cogged Teeth Coupling





Overview:

HyGEARS integrates a **Post-Processor** that can generate CnC part programs to cut **any HyGEARS supported** gear type on any 3, 4 and 5 Axis CnC machine using any tool.

The part programs, based on the exact tooth definition, **need no user intervention** and can be uploaded directly to any 3, 4 and 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 directly supports machine architectures of "AB", "AB", "BA" and "BC" 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

Other architectures are supported through workpiece coordinates in Traori/TCP/TCPM/TCPC mode

Specific machines 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, ConiflexTM 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.

Navigation: all steps are integrated; no outside software support required.

1- Design *and* optimize gear sets using HyGEARS V 4.0 tools :

- Spiral bevel / hypoid / Zerol
- Spur/helical/herringbone
- Face gears
- Straight bevel/Coniflex
- Beveloid

Contact Pattern location and TE can be modified to user's desire in a few steps.

2- Create *machine ready* part programs

- in a few steps using any cutting tool :
 - Face Mill cutters
 - Coniflex cutters
 - End Mill, Ball Mill cutters
 - CoSIMT (conical side milling tool)

Part program definitions are *parametric* and saved as re-usable Operations.

3- Cut the part on the *selected* CnC machine.

Part programs can be in Machine or Work piece coordinates.

7- Re-cut: only if needed !

6- Re-generate: *re-use* the desired Operation to re-create the part program *with the modified Machine Settings*.



5- *Integrated* Closed Loop: from CMM output, get changes in machine settings to *offset tool and machine errors*.

Constructional setures of the set of th

4- Measure the part on *any CMM* (Klingelnberg, Gleason, Zeiss, Leitz, MdM, etc.)





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

- ➤ X, Y, Z translations (tool and/or work piece)
- Work tilt about X axis: angle A
- > Work rotation : angle C



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

- ➤ X, Y, Z translations (tool and/or work piece)
- Work tilt about Y axis: angle B
- > Work rotation : angle A



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

- X, Y, Z translations (tool and/or work piece)
- Tool tilt about Y axis: angle B
- Work rotation : angle C

Note: the turntable axis may be horizontal or vertical



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

- ➤ X, Y, Z translations (tool and/or work piece)
- Tool swivel about X axis: angle A
- Tool tilt about Y axis: angle B



Main features of the Post-Processor:

- *supports "AB", "AC", "BA" and "BC" architecture machines;*
- supports GCodes, Heidenhain, Siemens, Okuma, Fanuc and Mazak controllers;
- supports Traori (Siemens), TCPM (Heidenhain), TCPC (Okuma) and TCP (Fanuc);
- allows creation of specific 3, 4 and 5Axis machines from 4 basic architectures; specific machines can be fully customized by the user to reproduce the exact implementation of any machine;
- offers 14+ 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 and multi-pass roughing/semi-finishing/finishing for CoSIMT, End Mill and Ball Mill tools;
- allows the generation of a negative 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 parts;
- allows the creation of "Processes" which are a series of "Operations" in a specific order; Processes can thus generate a complete program sequence 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 logic and 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.

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[™] dish, CoSIMT, End Mill or a Ball Mill tool in a 5Axis 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: Machine and Tool selection; display options



Machines: 4 basic CnC machine architectures are available: AB, AC, BA and BC.

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

😻 5Axis CnC - Pinion [Finishing] 7x37 Spiral.l	HyG - [mm]	
Machine/Tool Cycle Metrics Cycling Time/	Power Arbor End Mill Operation Process Stock	
		Mach. Definition Mach. Preamble Controller-Machine Head
Machine Selection	Cutting Tool	Machine Name Mikron GF [Heidenain] CoR-Wk.Spindl 0,000
© 3 Axis CnC	Face Mill Cutter V Hide Cutter Body	
		Hechine Type If the stand If the standard sta
5 Axis CnC "B-C" [Type M]	CoSIMT	"BC" Type M Work Datasian Rotation Offset 0.00
5 Axis CnC "A-C" [Type P]		"BA" Type T Work Hotation • 357 363
S Axis ChC A-B [Type P]	✓ End Mill	lool Rotation
S Adds ChC B-A [Type T]	Invert work	YY7Cime out to out to
Specific Machine		A 1 Z Signis Machine Work
Mazak Integrex i200	Probe (CMM)	ID Ref.Axis Sign Sync Out Oper. Offset
Mazak Integrex i200		
Com Mazak VTC800	Display	
Mikron GF [Heidenain] Ane Mikron GF [Heidenhain] B+-	Display Machine Head	
Mitsui HU63A-5X		
Av Mori NT3100-BC	Display T Table	A B C Signs X-
Mori NT4250 / C1 [B-] Mori NT4250 / C1 [B+]	Display Target Grid	ID Ref.Axis Sian Sync Out
Multus B400	Display Tool Path	■ ▲ ● + ● - □ □ ■ ▼ + A Rotation
Multus B400 4Axis NMV 3000-AC	Display Section	V A Rotation
NMV 3000-AC [Fanue]		C B • + O - O - O - O - O - O - O - O - O - O
Okuma MU-500VA [LH 0-360]	Detect Gouging Display Warning	
Okuma MU-500VA [LH] Okuma MU-500VA [RH 0-360]	Workpiece is Fixed	$ \begin{array}{c c} C & O + \odot - \Box & \Box & - \\ O & C+3, C+357 \end{array} $
Okuma MU-500VA [RH]		
Okuma Multus [LH 0-360]		Apply OK Cancel
Okuma Multus [RH 0-360] Ju PAMA SPEEDRAM 2000	tput Apply +/- Anim Ok Cancel	
Mac	hine Selection	Machine Editor
		32

Tools: HyGEARS offers 6	different tools:	Face Mill cutter Dish cutter CoSIMT End Mill Ball Mill Probe (CMM)	(spiral bevel, Zerol, hypoid gears) (Coniflex [™] gears) (all gear types) (all gear types) (all gear types) (all gear types; for measurement)
SAxis CnC - Pinion [Finishing] 7x37 Spiral	.HyG - [mm]		
Machine Selection 3 Axis CnC 4 Axis CnC 5 Axis CnC "B-C" [Type M] 5 5 Axis CnC "A-C" [Type P] 5 5 Axis CnC "A-C" [Type P] 5 5 Axis CnC "A-B" [Type P] 5 5 Axis CnC "B-A" [Type T] Image: Specific Machine Mazek. Integrex 1200 New Edit Delete List Compensation Apex Location 0.0000 Axis Tool Tilt 0.0000 Ignment Angle 0.0000 Jobsolute Differential	Cutting Tool Face Mill Cutter CoSIMT CosIMT	itter Body	
0	utput Apply +/- Anim	Ok Cancel	Photos courtesy of PTR-TEC.de

Tools: Each tool 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.



Definition of an 8mm Bull Nose

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

- the Machine Head,
- the Machine Turn Table
- the Work Arbor and support,
- the Target Grid, where the target coordinates are displayed in wire frame mesh,
- the Tool Path.

chine/Tool Gyde Metrics Cycling Time/Power Attor End Mill 3 Avis CnC 4 Avis CnC 5 Avis CnC "AC" [Type M] 5 Avis CnC "AC" [Type P] 5 Avis CnC "AC" [Type P] 5 Avis CnC "BA" [Type T] Ball Mil • Probe [CMM] Probe [CMM] Probe [CMM] Display Arbor Display Arbor Display Tool Path Display Statent Display Tool Path Display Statent Display Tool Path Display Tool Path Display Statent Display Tool Path Display Tool Path Display Tool Path Display Statent Display Statent Display Tool Path Display Statent Display Tool Path Display Statent Display Tool Path Display Statent Display Tool Path Display Tool Path Display Tool Path Display Tool Path Display Statent Display Tool Path Display Tool Path Display Tool Path Display Statent Display Tool Path Display Tool Path Display Statent Display Tool Path Display Tool Path Display Tool Path Display Statent Display Tool Path Display Tool Path Display Tool Path Display Tool Path <th>5Axis CnC - Pinion [Finishing] 7x37 Spira</th> <th>I.HyG - [mm]</th> <th>1</th>	5Axis CnC - Pinion [Finishing] 7x37 Spira	I.HyG - [mm]	1
Machine Selection 3 Avis CnC 4 Avis CnC 5 Avis CnC "B-C" (Type M) 5 Avis CnC "B-C" (Type M) 5 Avis CnC "AC" (Type P) 5 Avis CnC "B-C" (Type P) 5 Avis CnC "B-C" (Type P) 6 Avis CnC "B-C" (Type P) 6 Avis CnC "B-C" (Type P) 7 Avis CnC "B-C" (Type P) 7 Avis CnC "B-C" (Type P) 8 Avis CnC "B-C" (Type P) 9 Specific Machine Maxach Integreex (200 Probe (CMM) Probe (CMM) Display Machine Head Display Trade Grid Display Section Dis	Aachine/Tool Cycle Metrics Cycling Tim	e/Power Arbor End Mill Operation Process Stock	
 3 Axis CrC 4 Axis CrC 5 Axis CrC "B-C" [Type M] 5 Axis CrC "B-C" [Type P] 6 End Mil 9 Frobe [CMM] 9 Probe [CMM] 9 Probe [CMM] 9 Probe [CMM] 9 Display Machine Head 9 Display Taget Grd 9 Display Taget Grd 9 Display Section 1 Display Section<th>Machine Selection</th><th>Cutting Tool</th><th></th>	Machine Selection	Cutting Tool	
 5 Axis ChC "B-C" [Type M] CoSINT Invert Arbor Outside Blade S Axis ChC "A-B" [Type P] S Axis ChC "B-A" [Type P] S Axis ChC "B-A" [Type P] S Axis ChC "B-A" [Type P] Ball Mil Invert work Ball Mil Probe [CMM] Invert work Display Machine Head Display T. Table Display Tool Path Display Tool Path Display Tool Path Display Section Lock on Tool Detect Gouging Display Warning Warkpicce is Fixed 	 3 Axis CnC 4 Axis CnC 	Face Mill Cutter I Hide Cutter Body	Cutting Machine
 5 Avis ChC "A-B" [Type P] 5 Avis ChC "B-A" [Type T] Specific Machine Mzzak Integrex i20 New Edit Deletei List Display Display Display Machine Head Display Arbor Display Arbor Display Arbor Display Arbor Display Trable Display Trable Display Trable Display Trable Display Trable Display Trable Display Tool Path Display Section Display Tool Path Display Section Display Section Display Tool Path Display Section Display Section Display Section Display Tool Path Display Section Display Section Display Tool Path Display Tool Path Display Section Display Section Display Tool Path Display Tool Path Display Section Display Tool Path Dis	 5 Axis CnC "B-C" [Type M] 5 Axis CnC "A-C" [Type P] 	CoSIMT Invert Arbor V Outside Blade	cutong wathine the liwikion of (Heruenani) seal (Hinshing), whithey be
Specific Machine Mazak Integrex i200 New Edit Delete List Display Maxis No000 Alignment Angle 0.0000 Akis Tool Tit 0.0000 Stool Center Point [TCP] Display Target Grid Display Section Display Section Display Section Differential Detect Gouging Display Warning Workpiece is Fixed Detect Gouging Display Warning Workpiece is Fixed	 5 Axis CnC "A-B" [Type P] 5 Axis CnC "B-A"]Type T] 	Ind Mill Invert work	
New Edit Delete List Compensation Apex Location Display Display Arbor Display Arbor Display Trable Display Trable Display Tool Path Display Section Display Section Display Section Display Section Display Section Display Section Display Section Display Section Display Section Display Section Display Section Display Section Display Section Display Section Display Section Display Section Display Section Display Section Display Section Display Section Display Section Display Section Display Trable Display Section Display Norkpiece is Fixed	Specific Machine Mazak Integrex i200		
Apex Location 0.0000 Alignment Angle 0.0000 3Avis Tool Tilt 0.0000 © Tool Center Point [TCP] © Absolute © Display Tool Path © Display Section © Lock on Tool © Detect Gouging © Display Warning © Workpiece is Fixed	New Edit Delete List		
3Axis Tool Tit 0.0000 Tool Center Point [TCP] Absolute Display Tool Path Display Section Lock on Tool Detect Gouging Workpiece is Fixed 	Apex Location 0.0000 Alignment Angle 0.0000	 Display Machine Head Display Athor 	
 Tool Center Point [TCP] Absolute Display Tool Path Display Section Lock on Tool Detect Gouging Workpiece is Fixed 	3Axis Tool Tilt 0.0000	Display T.Table Display Target Grid	
Differential Lock on Tool Detect Gouging Workpiece is Fixed Other it Apply Apply Apply Apply Capped	Tool Center Point [TCP] Absolute	Display Tool Path Display Section	3561
Workpiece is Fixed Q. tput Apply	 Differential 	Lock on Tool Detect Gouging Display Warning	
		Workpiece is Fixed	[q: 9.2/R: 9.47/X -35.3863 № 17.3143/Z -15.5980 /B: -29.5956 /C: 223.7533 [1/9] <
		Dutput Apply +/- Anim Ok Cancel	

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] 7x37 Spiral.	HyG - [mm]	
Machine/Tool Cycle Metrics Cycling Time.	Power Arbor End Mill Operation Process Stock	Cutting Machine
Machine Selection	Cutting Tool	Cutting Machine CnC (MAZAKINTEGREX Siemens) Pinion (Finishing)(Nominal) - Concave-OB
 3 Axis CnC 4 Axis CnC 	Face Mill Cutter I Hide Cutter Body	
 5 Axis CnC "B-C" [Type M] 5 Axis CnC "A-C" [Type P] 	CoSIMT Invert Arbor Outside Blade	
 5 Axis CnC "A-B" [Type P] 5 Axis CnC "B-A" [Type T] 	End Mill Invert work	D1
Specific Machine	Ball Mill -	
Mazak Integrex i200 👻	Probe [CMM]	
Compensation	Display	
Apex Location 0.0000	Display Machine Head	
Alignment Angle 0.0000	Display Arbor	
3Axis Tool Tilt 0.0000	Display T.Table	
Tool Center Point [TCP]	Display Target Grid	
Absolute	Display Tool Path	Current cutting point
O Differential	Display Section	
	Detect Gauging Display Warning	
	Workpiece is Exed	× ×
		[q: -3.0 /R: -11.62 /Xw: -9.90390 //w: -47.07247 /Zw: -183.31207 / A3= -0.454883 / B3= -0.885933 / C3= 0.090573] -
0.	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.

🐇 5Axis CnC - Pinion [Finishing] 7x37 Spiral.HyG - [mm]								
Machine/Tool Cycle Metrics	Cycling Time/Power	Arbor End Mill Op	eration Process Stock					
Output Format								
	SIDERTEES	Reqd. Sugg.	Actual					
CSV Format	# Steps	21 [3] -	Start 1 🔲 Steps					
Line Numbers	# Bottomland Pts	0	End 21 V Tgt.Pts					
Include Operation Switches	# Facewidth Pts	11	Bottom Up					
Include Short Header	Retract Factor	4.0	0.0000					
Include Start Positions	Moving Contact I	H Over Ru	un 0.0000					
Explicit Indexing	Constant D-Radiu	IS Finish S	itock 0.000					
Coordinates Only	Rougning	Rough	Stock 0.381					
Work Coordinates	Clearance [mm] Indexi	ng Sequence					
Traori (Siemens)	Toe 20.000	Skip #	# /1 Start Gap 1					
Haas Horizon	Heel 10.000	Mirror	End Gap 7					
Cutting Cycle								
Slot by Slot	Conve	х (І.В.)	Concave (U.B.)					
Flank by Flank	© N	one ne -> Heel -> Toe	Toe -> Heel -> Toe					
Fillet-Root Tool Tilt	10.00 O H	eel -> Toe -> Heel	Heel -> Toe -> Heel					
Tooth Flank Tool Pive	rot 0.000 💿 T	pe -> Heel	Toe -> Heel					
Combined	Fixed 🔘 H	eel -> Toe	Heel -> Toe					
Chamfer Tool Side Depth	0.000 O IE	-OB OShape-Toe	OB-IB OShape-Toe					
Chamfer Tool End Chamfer Toe	A. 0.000	-OB OShape-Heel	OB-IB OShape-Heel MultiPage					
Chamfer Heel Pivot A.	0.000 P	unge Generation	Plunge Generation					
	Output	Apply +/-	Anim Ok Cancel					

Cycle Options for CoSIMT, End Mill and Ball Mill tools

- Stock-Feed along the face width (#Facewidth Pts) and tooth depth (#Steps)
- When cutting starts and ends (Start / End)
- Tool retraction at end of cycle (Retract Factor, based on Heel tooth depth)
- Whether the tooth description is with constant roll angles or constant radius (Constant D-Radius)
- Whether the contact point moves, or does not move, along the tool's cutting edge (Moving Contact Pt)
- Roughing and Finishing cycles
- Toe and Heel clearances
- Tip, Toe and Heel chamfering
- Indexing sequence in order to spread tool wear and thermal load over non sequential teeth (Skip#).

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





Constant D-Radius

Constant D-Roll

Cycles: Moving Contact Pt: <u>checked</u>:

contact point moves along tool edge; better Finish and reduced tool wear;

<u>un-checked</u>: contact point always at tool tip: more tool wear



Cycles:	Over Run:	= 0:	End Mill stops at Fillet Line
		> 0:	End Mill extends below the Fillet Line: prevents lip forming in the
			fillet when negative stock is used on the flank





Over Run: 0

Over Run > 0

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

🐝 5Axis CnC - Pinion [Finishing] 7>	x37 Spiral.HyG - [mm]	SAxis CnC - Pinion [Finishing] 3x60 HRH m1,03.HyG - [mm]	X
Machine/Tool Cycle Metrics Cy	cling Time/Power Arbor Face Mill Operation Process Stock	Machine/Tool Cycle Cycling Time Arbor Face Mill Operation	on Process
Output Format	Stock-Feed	Output Format Stock-Feed	
 Use Actual Tooth CSV Format Line Numbers Include Operation Switches Include Short Header Include Start Positions Explicit Indexing No Comments Coordinates Only Work Coordinates Traori (Siemens) Haas Horizon 	# Steps 21 # 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 - Clearance Toe 20.000 Skip # /1 Stat Gap Heel 10.000 Mirror End Gap	Use Actual Tooth # Steps 9 CSV Format # Bottomland Pts 0 Line Numbers # Facewidth Pts 11 Include Operation Switches # Facewidth Pts 11 Include Short Header Moving Contact Pt 4.0 Include Stat Positions Explicit Indexing Roughing No Comments Clearance [mm] Work Coordinates Toe 14.000 TCP (Fanuc) Heel 14.000	Over Run 0.0000 Finish Stock 0.000 Rough Stock 0.381 Indexing Sequence Skip # /1 Start Gap 1 Mirror End Gap 3
Cutting Cycle Face Mill Cycle Single Roll - Toe to Heel Single Roll - Heel to Toe Plunge Roll - Toe to Heel Plunge Roll - Heel to Toe Double Roll - Toe to Heel Double Roll - Heel to Toe Non Gen. Plunge Cut	Depth Fact Feed RPM Dwell (Rot) Rapid 1500 250 220 Z1: 1.050 1000 250 Z2: 0.250 200 233 Z3: 0.300 250 1.2	Cutting Cycle Face Mill Cycle Toe - Heel/ Toe - Heel Toe - Heel/ Heel-Toe Heel-Toe / Heel-Toe Heel-Toe / Toe - Heel Double Roll - Toe to Heel Double Roll - Heel to Toe Non Gen. Plunge Cut Z1: D000 D0000 D0000 D0000 D00000 D00000	RPM Dwell (Rot) 250 1.2
	Output Apply +/- Anim Ok Cancel	Output	+/- Anim Ok Cancel

Cycles for Face Mill cutters / Completing

Cycles for Face Mill cutters / Fixed Setting - Semi-Completing

Cycles: HyGEARS offers 14+ different cutting cycles for End Mill and Ball Mill tools, and 15 for CoSIMT tools. Tool can be Pivoted to improve cutting conditions.

😻 5Axis CnC - Pinion [Finishing] 7	x37 Spiral.HyG - [mm]		Durana Markia a Part PMM 300 kP. (1) Case (Social and Marcine). Case (S	
SAxis CnC - Pinion [Finishing] 7 Machine/Tool Cycle Metrics C Output Format Use Actual Tooth CSV Format Line Numbers Include Operation Switches	x37 Spiral.HyG - [mm] ycling Time/Power Arbor End Mill Ope Stock-Feed # Steps 21 [3] - # Bottomland Pts 0 # Facewidth Pts 11	eration Process Stock Actual Start 1 Steps End 21 V Tgt.Pts Bottom Up	Cutting Mischine ChC [DMP 260 HT-C] Gent [Finishing][Noninal]- Concee-DB Travel direction	
 Include Short Header Include Start Positions Explicit Indexing No Comments Coordinates Only Work Coordinates Traori (Siemens) 	Retract Factor 4.0 Moving Contact Pt Image: Constant D-Radius Constant D-Radius Image: Constant D-Radius Roughing Image: Constant D-Radius Clearance [mm] Indexing Toe 20.000	un 0.0000 Stock 0.000 Stock 0.381 ing Sequence # /1 Staft Gap 1		
Haas Horizon Cutting Cycle Slot by Slot Rank by Rank Fillet-Root Tool Tilt Tool Pivo Combined	Heel 10.000 Mirror Convex (I.B.) None Image: None Image: None Image: None <td>End Gap 7 Concave (0.8.) None Toe -> Heel -> Toe Heel -> Toe -> Heel Toe -> Heel Heel -> Toe</td> <td>R 82 # 883 X 87 23999 // -62 50409 /Z -41 48927 /B 36 55054 /C 304 50530[[14]</td> <td>T.</td>	End Gap 7 Concave (0.8.) None Toe -> Heel -> Toe Heel -> Toe -> Heel Toe -> Heel Heel -> Toe	R 82 # 883 X 87 23999 // -62 50409 /Z -41 48927 /B 36 55054 /C 304 50530[[14]	T.
 Chamfer Tool Side Chamfer Tool End Chamfer Toe Chamfer Heel 	0.000 0.0000 0.0000	OB-IB OShape-Toe OB-IB OShape-Heel MultiPass Plunge Generation 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 - Pinion [Finishing] 7x	37 Spiral.HyG - [mm]	×
Machine/Tool Cycle Metrics Cyc	cling Time/Power Arbor E	nd Mill Operation Process Stock
Output Format Use Actual Tooth CSV Format Line Numbers	Stock-Feed # Steps 21 # Bottomland Pts 0 # Facewidth Pts 11	Sugg. Actual [3] Start 1 Steps End 21 V Tgt.Pts Bottom Up 1
 Include Operation Switches Include Short Header Include Start Positions Explicit Indexing No Comments Coordinates Only Work Coordinates Traori (Siemens) Haas Horizon 	Retract Factor 4.0 Moving Contact Pt Image: Constant D-Radius Constant D-Radius Image: Constant D-Radius Roughing Image: Constant D-Radius Clearance [mm] Image: Constant D-Radius Toe 20.000 Heel 10.000	Over Run 0.0000 Finish Stock 0.000 Rough Stock 0.381 Indexing Sequence Skip # /1 Start Gap 1 Mirror End Gap 7
Cutting Cycle Slot by Slot Rank by Flank	Convex (I.B.) None Toe -> Hee	Concave (O.B.) None I -> Toe Toe -> Heel -> Toe
Fillet-Root Tool Tilt Tool Tilt Tool Pivot Combined Chamfer Tool Side Chamfer Tool End Chamfer Tool End	10.00 Heel > Too 0.000 Toe -> Hee Fixed Heel > Too 0.000 IB-OB OSh 0.000 IB-OB OSh	a -> Heel Heel -> Toe -> Heel d Toe -> Heel a Heel -> Toe ape-Toe OB-IB OShape-Toe ape-Heel OB-IB OShape-Heel
Chamfer Toe Chamfer Heel Pivot A.	0.000 0.000 Rock Me [t Plunge Ger Output Apply	babe] MultiPass heration Plunge Generation +/- Anim Ok
Finishing Cycles fo	r CoSIMT, End M	iill and Ball Mill tools

- Fillet/Root, Tooth Flank, 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 can be different on each tooth flank.*

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

🐝 5Axis CnC - Pinion [Finishing] 7x	37 Spiral.HyG - [mm]	×
Machine/Tool Cycle Metrics Cyc	cling Time/Power Arbor End	Mill Operation Process Stock
	Charle Fand	
Use Actual Tooth CSV Format Line Numbers Include Operation Switches Include Short Header Include Start Positions Explicit Indexing No Comments Coordinates Only Work Coordinates Traori (Siemens) Haas Horizon	Stock-Feed Reqd. # Steps 21 # Bottomland Pts 0 # Facewidth Pts 11 Retract Factor 4.0 Moving Contact Pt Constant D-Radius V Roughing V - Clearance [mm] Toe 20.000 Heel 10.000	Sugg. Actual [3] Start 1 Steps End 21 7gt.Pts Bottom Up Tgt.Pts Over Run 0.0000 Rnish Stock 0.000 Rough Stock 0.381 Indexing Sequence Skip # Skip # 1 Start Gap Mmor End Gap 7
Cutting Cycle Slot by Slot Rank by Rank	Convex (I.B.)	Concave (O.B.)
Fillet-Root Tool Tilt Tool Plank Combined	10.00 Image: Heal -> 10.00 Image: Heal -> 0.000 Image: Top -> Fixed Image: Heal ->	Heel Heel Heel -> Toe -> Heel Toe -> Heel Heel -> Toe
 Chamfer Tool Side Chamfer Tool End Chamfer Toe Chamfer Heel Depth Chamf A. Pivot A. 	0.000 B-OB OShape 0.000 IB-OB OShape 0.000 Center Slot 0.000 Plunge General	e-Toe OB-IB OShape-Toe e-Heel OB-IB OShape-Heel MultiPass etion Plunge Generation
	Output Apply	+/- Anim Ok Cancel
Roughing Cyc	les for End Mill and	Ball Mill tools

- *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.

👻 5Axis CnC - Pinion [Finishing] 7x	37 Spiral.HyG - [mm]	×
Machine/Tool Cycle Metrics Cyc	ling Time/Power Arbor CoSIM	T Operation Process Stock
Output Format	Stock-Feed	ag Actual
 Use Actual Tooth CSV Format Line Numbers Include Operation Switches Include Shot Header Include Start Positions Explicit Indexing No Comments 	# Steps 21 II # Bottomland Pts 0 # Facewidth Pts 11 Retract Factor 4.0 Moving Contact Pt Image: Constant D-Radius Roughing Image: Constant D-Radius	gg. Actual 3] Start End 21 Bottom Up Over Run 0.0000 inish Stock 0.000 Rough Stock 0.381
Coordinates Univ Work Coordinates Traori (Siemens) Haas Horizon	Clearance [mm] I Toe 20.000 Heel 10.000	ndexing Sequence Skip # /1 Start Gap 1 Mirror End Gap 7
 Slot by Slot Flank by Flank 	Convex (I.B.)	Concave (O.B.)
 Fillet-Root Tooth Flank Combined Tool Tilt 	10.00 Heel -> Toe -> Heel 0.000 Toe -> Heel Fixed Heel -> Toe	eel () Heel -> Toe -> Heel () Toe -> Heel () Toe -> Heel () Heel -> Toe
 Chamfer Tool Side Chamfer Tool End Chamfer Toe Chamfer Heel 	0.000 BB-OB O Shape-Ti 0.000 IB-OB O Shape-H 0.000 Center Slot 0.000 Plunge Center Slot	oe OB-IB OShape-Toe eel OB-IB OShape-Heel OMultiPass ot Plunge Generation
	Output Apply +/	- Anim Ok Cancel
Roughi	ing Cycles for CoSIM	T tools

- *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;
- 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;

Cycles: Face Mill Cutter – Completing cutting processes

chine/Tool Cycle Metrics Cy	cling Time	e/Power	Arbor	Face Mill	Operation	Process	Stock
Output Format	Stock	-Feed					
 Use Actual Tooth CSV Format Line Numbers Include Operation Switches Include Short Header Include Start Positions Explicit Indexing No Comments Coordinates Only Work Coordinates Traori (Siemens) 	# Step # Bott # Fact Retrace Movin Consta Rough Cleare Toe	omland Pt ewidth Pts st Factor g Contact ant D-Rad ning ance [mm 20.000	21 5 0 11 4.0 Pt [us [1]	- Ove - Finis Rou Ind Sk	rRun 0 hStock 0 ghStock 0 exing Sequ ip # 71	0.0000 0.000 0.381 uence Start Ga	ар 1
Haas Horizon	Heel	10.000		Mir	TOF 📃	End Ga	p 7
Face Mill Cycle Single Roll - Toe to Heel Flunge Roll - Heel to Toe Plunge Roll - Toe to Heel Plunge Roll - Heel to Toe Double Roll - Toe to Heel Nouble Roll - Heel to Toe Non Gen. Plunge Cut	Rapid Z': Z2: Z3: Z4:	1.050 0.250 0.300 0.000	Fee 150 100 200	d RP 0 25	M Dw	ell (Rot)	

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 1st roll, and then generates full depth on the 2nd 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

Machine/Tool Cycle Cycling Time	e/Power	Arbor F	ace Mill 0	peration Pr	rocess
Output Format	Stock	c-Feed			
Use Actual Tooth CSV Format Line Numbers Include Operation Switches Include Shot Header Include Stat Positions Explicit Indexing No Comments Coordinates Only Work Coordinates	# Step # Bott # Fac Retrac Movin Const Roug	ps tomland Pts eewidth Pts ct Factor ng Contact I ant D-Radiu hing ance [mm	21 0 11 4.0 Js	Over Run Finish Sto Rough Sto	0.0000 ck 0.000 cck 0.381
TCP (Mazak) Haas Horizon	Toe Heel	20.000		Skip # Mirror	1 Start Gap 1 End Gap 7
Face Mill Cycle Toe -Heel/ Toe -Heel Toe -Heel/ Heel-Toe Heel-Toe / Heel-Toe Heel-Toe / Toe -Heel Double Roll - Toe to Heel Double Roll - Heel to Toe Non Gen. Plunge Cut	Rapid Z1 Z2 Z3 Z4	Depth Fact 1.050 0.250 0.300 0.000	Feed 1500 1000 200 100	250	Dwell (Rot)

Cycles for Face Mill cutters

- xx / yy: 1st part is Convex flank; 2nd 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.



49

Cycles: Face Mill Cutter

🐝 5Axis CnC - Pinion	[Finishing] 7>	37 Spiral.HyG - [mm]	×
Machine/Tool Cycle	Cycling Time	e/Power Arbor Face Mill Operation Process	
Face Mill Details	Name Tool ID: TLU ID:	M 2" 17.5-OB/22.5-IB 1 1 0 FM 2" 17.5-OB/22.5-IB 12.5 in 2" 17.5 / 22.5 2.75" 22IB 18OB 0.032PW	•
Body Diameter Body Height Blade Depth Cutter Gaging Number of Blades Tool Length Cutter Holder	58.0479 5.0000 4.8353 0.0000 12 64.8353 	3.5" 18.33 OB 21.666 IB 3.5" 180B 22IB 3.5" 180B 22IB 3.5" 20IB 200B 53.5 mm Body 58 mm Body 50 m Expetek 7.5 in Solid FM 2" FM	ht
		Feeds [mm/min] RPM 250.0 Rapid Move 1500.0 Plunge 100.0 Cutting 200.0	
		Output Apply +/- Anim Ok	Cancel

- 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).*

	-beveij (Fi	nisningj[i	sominal) s	20-229	ionnate.ny	g - (mm) (a	
Blank Cutter	TopRem	Machine	Hi Order	Other	Operating	Rim-Materia	Bear 🔹 🕨
			Conca	ave-OB	[[in] Convex-IB	🔘 [mm]
Average Dian	neter		2.00	00	_		
Blade Angle			17.5	j	_	22.5	
B.Edge Rad.			0.00	90		0.0090	
Point Width			0.02	20			
Cutter Edge			Strai	ight	-	Straight	-
Rad. of Curva	ature		0.00	00		0.0000	
Ref. Height			0.00	00		0.0000	
Number of Bla	ades		12				
Cutter Gaging	,		0.00	00			

Face Mill cutter definition

Cycles: CoSIMT, End Mill, Ball Mill

lachine/Tool Cycle N	letrics Cyc	ling Time	Power Arb	or End	Mill Oper	ration Pro	cess Sto	ck
Output Format Use Actual Tooth CSV Format Line Numbers	Stock- # Steps # Botto	Feed mland Pts	Reqd. 21 0	Sugg. [8] – Risk of col	Actu Start 1 lision: che	al Sto	eps and #Ste	
Include Operation So Include Short Heade Include Start Position Explicit Indexing No Comments Coardinates Optic	witches er ns	# Facewidth Pts 11 Retract Factor 2 Moving Contact Pt - Constant D-Radius Roughing -		- Over Run 0.0000 Finish Stock 0.000 Rough Stock 0.381				
Work Coordinates UTCP (Mazak) Haas Horizon		Cleara Toe Heel	nce [mm] 20.000 10.000		Indexin Skip # Mirror	g Sequer	i ce Start Gap End Gap	1 7
Slot by Slot Rank by Flank			Convex None Toe	(I.B.) e -> Heel -;	> Toe	Concave None Toe	(O.B.) e -> Heel ->	Toe
 Fillet-Root Tooth Flank Combined 	Tool Tilt	10.00 0.000 Fixed	 Heel Toe Heel 	-> Toe -: -> Heel -> Toe	> Heel	 Heel Toe Heel OPU 	-> Toe -> -> Heel -> Toe	Heel
Chamfer Tool Side Chamfer Tool End Chamfer Toe Chamfer Heel	Depth Chamf A. Pivot A.	0.000 0.000 0.000	 IB-O IB-O Rod Plun 	B OShap K Me [bał ge Gener	e-Heel be] ration	O OB-I	B OShape Pass ge Genera	Heel

Cycles for CoSIMT, End Mill and Ball Mill tools

- CoSIMT, End Mill and Ball Mill tools can **rough** and **finish** tooth flanks and fillet;
- CoSIMT, 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 and Ball 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: Example: End Mill tool, Toe-Heel-Toe (IB-Side) / Heel-Toe-Heel (OB-Side)

achine/Tool Cycle Metrics C	ycling Time.	/Power Art	oor En	nd Mill Ope	ration Pr	ocess Stock		
Output Format	Stock-	Feed	Read	Suga	Act	ual		
Use Actual Tooth	# Step:	5	21	[[8]				
CSV Format	# Botto	mland Pts	0	[0]	End 21	Tet Pt		
Line Numbers	# Face	width Pte	11		Pottom I	la 🔲 igi.ri		
Include Operation Switches	Petroet	Eastar			Bottom G	tom Up		
Include Short Header	Heiraci		2					
Include Start Positions	Moving	Contact Pt		- Over Ru	n [0.00	000		
Explicit Indexing	Consta	nt D-Radius		Finish St	tock 0.000			
No Comments	Roughi	Roughing		- Rough S	Stock 0 381			
Coordinates Only	Classe	noo [mm]			- C			
Work Coordinates	Toe	20.000		Skin #	ig Seque	Start Gap 1		
United Harak	Heel	10.000		JKIP #		End Gap 7		
	neer	10.000		MIITOF				
utting Cycle		Convey	(I.B.)		-Concav	- (O R)		
Slot by Slot	((1.0.)			e (0.0.)		
Flank by Flank			ie I Haalij	Too		ie Vis Heel is Toe		
Fillet-Root Tool Titt	10.00	Here	-> Toe	-> Heel	Here	s -> Toe -> Hee		
Tooth Flank Tool Pix	at 0.000		-> Heel	-> Heer				
Combined	Fixed	Hee	I-> Toe		C Hee	el -> Toe		
Chamfer Tool Side		○ IB-0	BOSha	pe-Toe	O OB	IB OShape-Toe		
Chamfer Tool End	0.000	◎ IB-C	pe-Heel	-Heel O OB-IB OShape-He				
Chamfer Toe	. 0.000	Roc	k Me [ba	abe]	Mul	tiPass		
Chamfer Heel Pivot A.	0.000	O Plur	nge Gene	eration	O Plur	nge Generation		

- 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).



End Mill cycles

Cycles: Example: tapered End Mill tool, O-Shaped cycles

* 5Axis CnC - Pinion [Fin	ishing] 7x37 Spira	al.HyG - [m	m]				
Machine/Tool Cycle Me	etrics Cycling Tim	ne/Power A	vbor En	d Mill Ope	eration	Process	Stock
Output Format Use Actual Tooth CSV Format Line Numbers Include Operation Sw Include Short Header Include Start Position Explicit Indexing No Comments Coordinates Only Work Coordinates TCP (Mazak)	stoci # Stec # Boi # Fai Retra s Movi Cons Roug Toe	k-Feed aps ttomland Pts cewidth Pts act Factor ng Contact P tant D-Radiu ghing 0.000 0.000	Reqd. 21 0 11 3 t s	Sugg. [13] — Over Ru Finish S Rough 3 Indexia Skip #	A Start End Bottom un 0. tock 0. Stock 0.	ctual 1 21 Up 0000 000 381 jence Start G End G	Steps Tgt.Pts
Cutting Cycle Slot by Slot Rank by Rank Fillet-Root Tooth Rank Combined Chamfer Tool Side Chamfer Tool End Chamfer Toe Chamfer Heel	Tool Tilt 10.00 Tool Pivot 0.000 Fixed Depth 0.000 Chamf A. 0.000 Pivot A. 0.000		< (I.B.) one be -> Heel -> Toe -> Heel -> Toe -> Heel -> Toe -OB OShap -OB OShap -OB OShap -OB OShap -OB OShap	> Toe > Toe > Heel be-Toe be-Teel bej ration	Conca N Tr H O O O M P	ve (O.B.) one oe -> Hee eel -> Tor oe -> Hee eel -> Tor B-IB OSh B-IB OSh Ulti Pass lunge Ger	el -> Toe e -> Heel el ape-Toe ape-Heel neration
		Output	Apply	+/-	Anim	Ok	Canc

- one starting flank IB / OB and tooth end Toe / Heel - is selected, the other being slave;
- for O-Shaped cycles, the cutting cycle takes a pass along the face width on the one flank and switches to the opposite flank for return; the cycle then switches back to the starting 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.



O-Shaped cycles

Cycles: Example: CoSIMT tool, Rock-Me (babe)

💣 5Axis CnC - Pinion [Finishing] 7x	37 Spiral.HyG - [mm]		— ×
Machine/Tool Cycle Metrics Cyc	cling Time/Power Arbo	r End Mill Op	peration Process Stock
Output Format	Stock-Feed	Read. Suga.	Actual
Use Actual Tooth CSV Format Line Numbers I Include Operation Switches I Include Short Header I Include Start Positions Explicit Indexing No Comments Coordinates Only Work Coordinates	# Steps # Bottomland Pts # Facewidth Pts Retract Factor Moving Contact Pt Constant D-Radius Roughing Clearance [mm] Too 0.000	21 [13] - 0 11 3 - Over R V Finish S Rough Indexi State	Start 1 Steps End 21 Tgt.Pts Bottom Up and the steps Stock 0.000 Stock 0.381
Haas Horizon	Heel 0.000	Mirror	End Gap 7
Slot by Slot Ank by Flank	Convex (I None Toe	B.) > Heel -> Toe	Concave (O.B.) None Toe -> Heel -> Toe
 Fillet-Root Tooth Flank Combined Tool Pivot 	10.00 ○ Heel 0.000 ○ Toe ∹ Fixed ○ Heel	> Toe -> Heel > Heel > Toe	 Heel -> Toe -> Heel Toe -> Heel Heel -> Toe
 Chamfer Tool Side Chamfer Tool End Chamfer Toe Chamfer Tee Pivot A. 	0.000 (© IB-OE 0.000 (© IB-OE 0.000 (© Rock 0.000 (© Plung	OShape-Toe OShape-Heel Me [babe] e Generation	 OB-IB OShape-Toe OB-IB OShape-Heel MultiPass Plunge Generation
	Output	y +/-	Anim Ok Cancel

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: Example: End Mill tool, Fillet

achine/Tool Cycle Metrics Cy	cling Time/Power Arbor End	d Mill Operation Process Stock
Output Format Use Actual Tooth CSV Format Line Numbers Include Operation Switches Include Short Header Include Start Positions Evolucit Indexing	Stock-Feed # Steps 6 # Bottomland Pts 0 # Facewidth Pts 11 Retract Factor 3 Moving Contact Pt Constant D-Badius	Sugg. Actual [13] Start 1 Steps End 21 Tgt.Pts Bottom Up Over Run 0.0000
No Comments Coordinates Only Work Coordinates TCP (Mazak) Haas Horizon	Roughing Clearance [mm] Toe 0.000 Heel 0.000	Fillet Stock 0.000 Flank Stock 0.000 Indexing Sequence Skip # 1 Start Gap 1 Mirror End Gap 7
Cutting Cycle Slot by Slot and Kank by Rank	Convex (I.B.) None Toe -> Heel -	Concave (O.B.) None > Toe
Fillet-Root Tool Tilt Tool Tilt Tool Pivot Combined Chamfer Tool Side Chamfer Tool End Chamfer Toe Chamfer Heel Pivot A.	10.00 ○ Heel -> Toe - 0.000 ○ Toe -> Heel Fixed ○ Heel -> Toe 0.000 ○ IB-OB OShap 0.000 ○ IB-OB OShap 0.000 ○ Rock Me [bal 0.000 ○ Plunge Gene	> Heel Heel -> Toe -> Heel Toe -> Heel Heel -> Toe Heel -> Toe Heel -> Toe Heel -> Toe OB-IB OShape-Toe Heel -> Toe OB-IB OShape-Toe

- 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 CoSIMT, End Mill or Ball Mill tools;
- *negative Stock can be imposed to produce a protuberance;*
- End Mill and Ball Mill tools can be tilted away from the tooth to avoid interference;
- Fillet finishing uses the same cycles as for Flank finishing.



Fillet cycles

Metrics: Profile-wise step depth, slot width, expected surface quality



Metrics: Length-wise step depth, slot width, expected surface quality



Metrics: Scallop height: for Plunge Generation with CoSIMT







Power Required: Estimate of average cutting torque required from tool

	Cycle Times					
	Flank:	173.78	[sec]			^
	Concave-OB					
	Line:	50.60	[sec]			
	Face:	202.39	[sec]			
	Plunge/Retract:	1.93	[sec]			
	Return:	0.00	[sec]			
	Flank:	206.24	[sec]			
	Total/Slot:	380.02	[sec]			
	Indexing:	0.72	[sec]			
	# Slots:	6				
	Operation:	38.07	[min]			
	Cutting Feed:	187.50	[mm/min]			
	Plunge Feed:	1500.00	[mm/min]			
	Rapid Move Feed:	3000.00	[mm/min]			
	Tool RPM:	12000.00				
		Pov	ver Required	 	 I	I
	Matl const Kc:	1800.0		 		
	Cut depth ap:	1.339	[mm]			
	Cut width ae:	0.200	[mm]			
Dower required	Table feed:	200.00	[mm/min]			
Power required	Ave. Power:	0.0020	[Kw]			
	Ave. Torque:	0.0016	[N-m]			
						V

CoSIMT, End Mill Ball Mill: depending on the type of cutting cycle selected, HyGEARS will calculate the *ae* value, which is the size of the cut / tool blade or flute, in order to estimate torque and power based on material *Kc* value.

Face Mill / Coniflex:

HyGEARS calculates the volume of material to be removed from the gap and the time required to remove this volume in order to obtain the Ave. Torque and Ave. Power values.

Arbor: Blank supports on the machine.



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



Tools: CoSIMT tools (or Conical Side Milling Tool; same as Sandvik's InvoMill and Gleason's UpGear) can have circular cutting edges which allow the generation of tooth profiles with concave profile curvature, such as Face Gears. Blade angles are totally flexible.



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: Probe and ConiflexTM dish type cutter: TCP.



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



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



Part Reference Point: Hypoid gears.



Part Reference Point: Face gears.



Operation: Saves all switches and choices such as to be reusable.



Operations: 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 CnC - P	inion (Finis	hing] 7x37	Spiral.HyG -	[mm]	0.0007	0.0	ation D	
Machine/Tool (Cycle Met	rics Cyclin	ng Time/Power	Arbor	CoSIMT	Ope	ration Pr	ocess Stock
Operation								
Name CoSIM	IT 001_2292	263R75_D1		CoS	SIMT 001	22926	3R75_D1	-
ID #: 6002					_		V In	temal Subroutine
Save	Delete	Import	STEP	Ou	tput			
								<u> </u>
roor onlingo	Tool ID	1	0	0	0		0	0
	TLU ID	0	0	0	0		0	0
	Gap #	1	0	0	0		0	0
Switches	Coola	nt On	Coolant On	Code	48]		
			Coolant Of	f Code	49			
	V Spind	le CW				Vc:	124.4	[m/min]
	Spind	le CCW	Spindle	e RPM (500.0	fz:	0.0175	[mm]
			1			ae:	0.000	[mm]
	Retun	n Trip				Kc:	1800.0	
Feeds [mm/m	#S	teps	11					
	Rapid Mo	ve	3000.0					
	Plunge		1500.0					
	Cutting		IB Toe->Heel	IB Heel	⇒Toe C	B Toe	>Heel 0	B Heel->Toe
			126.0	100.0	1	0.00	1	00.0
			Output	Apply	+/-		Anim	Ok Canc
			Operati	ons Ta	b			

- an Operation is specific to a geometry, i.e. it is saved in the "Operations.fil" file stored in a 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.



Process: Organizes Operations in a user defined sequence.



Process: 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" first, and then Operation "Rough Fil-MPass"

Proces	sses	• A l'idess is specific to a geometry, i.e. u
Name ID #:	66811146000_Rou_L 66811146000_Rou_L 6001 ✓ Internal Sut Save Delete Import Summ Output No Commer Available Operations ✓ ✓ Process Content ✓ G.C.BM.Fin_THT_049/49_D4_B. G.C.EM.Ch_Heel-0.5_PiA210_D8_B. G.C.EM.Ch_Heel-0.7_D19_B. G.C.EM.Ch_Heel-0.7_D19_B. G.C.EM.Ch_Heel-0.7_D19_B. G.C.EM.Ch_Heel-0.7_D19_B. G.C.EM.Ch_Heel-1.0_D19_B. G.C.EM.Ch_Heel-1.0_D19_B. G.C.EM.Ch_Tip-0.5_Cv_D19_B. G.C.EM.Ch_Tip-0.5_Cv_D19_B. G.C.EM.Ch_Tip-0.5_Cv_D19_B. G.C.EM.Ch_Toe-0.7_PiA45_D8_B. G.C.EM.Ch_Toe-0.7_PiA45_D8_B. G.C.EM.Ch_Toe-0.7_PiA45_D8_B. G.C.EM.Fin_THT_0-11/11_D12_B. G.C.EM.Fin_THT_0-11/11_D12_B. G.C.EM.Fin_THT_0-15/15_D8_B. G.C.EM.Fin_THT_0-15/15_D8_B. G.C.EM.Fin_THT_0-15/15_D8_B. G.C.EM.Fin_THT_0-15/15_D8_B. G.C.EM.Fin_THT_0-15/15_D8_B. G.C.EM.Fin_THT_0-15/15_D8_B. G.C.EM.Fin_THT_0-15/15_D8_B. G.C.EM.Fin_THT_0-15/15_D8_B. G.C.EM.Fin_THT_0-15/15_D8_B. G.C.EM.Fin_THT_0-15/15_D8_B. ▼ Output Apply +/- Anim Ok	 saved in the "Processes.fil" file stored in geometry's folder; A Process can contain any number of operations – the controller's memory bein 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.

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.

st 5Avis CoC - Pinion (Finishing)	7x37 Spiral HvG - [mm]						
Machine/Tool Cycle Metrics Cycling Time/Power Arbor End Mill Operation Process Stock							
Output Format Use Actual Tooth CSV Format Line Numbers Include Operation Switches Include Shott Header Include Start Positions Explicit Indexing No Comments Coordinates Only Work Coordinates	Stock-Feed Reqd. Sugg. # Steps 21 [13] # Bottomland Pts 0 # Facewidth Pts 11 Retract Factor 3 Moving Contact Pt — Over Ru Constant D-Radius Image: Constant D-Radius Roughing Image: Clearance [mm]	Sugg. Actual [13] Start 1 End 21 Tgt.Pts Bottom Up 1 Finish Stock 0.0000 Rough Stock 0.381					
TCP (Mazak)	Toe 0.000 Skip # Heel 0.000 Mirror	1 Start Gap 1 End Gap 7					
Cutting Cycle	Convex (LB)	Concave (O B)					
 Slot by Slot Flank by Flank 	None	None					
 ○ Fillet-Root ○ Tooth Flank ○ Combined 	10.00 Heel -> Toe -> Heel ot 0.000 Toe -> Heel Fixed Heel -> Toe	 Heel -> Toe -> Heel Toe -> Heel Heel -> Toe 					
 Chamfer Tool Side Chamfer Tool End Chamfer Toe Chamfer Toe Chamfer Heel 	0.000 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							
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.

Edit		File Edit			
*****	*****				
GRAM NAME : #2 Finish	Moving Contace [1-10/10]	; GEAR [FINISHING]			
GRAM DATE • 07-21-201	5	; CUTTER SPECIFICATION	15	[I.B.]	[O.B.
MARY VERSION . [Nominal]	5 N	· · · · · · · · · · · · · · · · · · ·			
T. TD 120121 27	588 367				
OL DIAMETER : 6 00[mm]	365 367	= ; Average Diameter	:	304.8	8000
OL LENGTH : 40.00[mm]		; Blade Angle	:	28.4178	11.4156
***************************************	****	; Blade Edge Radius	:	4.1	1910
• Date / Time	• 21/07/2015 / 6•13•44 PM	; Point Width	:	6.3	1112
; General Units	: [mm] [dd.mm.ss]	; Rad. of Curvature		6350.0000	6350.0000
· Cutter Units	· [mm]	; Rad. of Curvature-Re	ef. Height :	0.0000	0.0000
; Prepared by	: Claude Gosselin	; TopRem Depth	:	0.0000	0.0000
· Version	· 4 0 404 60-457	; TopRem Radius	:	88.9000	0.0000
, ,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,		; Cutter Gaging	:	0.0000	0.0000
	Start Header				
: HVGEARS V 4.0 @ @					
,		; GEAR [FINISHING] :S]	bread Blade		
: Part Program	: 13x33d400 final REG.hvg	; MACHINE SETTINGS -	175-8		
		· · · · · · · · · · · · · · · · · · ·			
: Machine	: CnC [Ultrix] - [Finishing][Nominal]	Devided Distances		4.4.9	
	(; Radial Distance		148.9870	
: Operation	: #2 Finish Moving Contace [1-10/10]	; Cutter lilt	:	6.1644	
·	. #2 finion noving consider [1 10,10]	; Swivel Angle	:	197.3272	
. Member	Gear	; Blank Offset	:	0.0000	
, Member	. Sigmona	; Machine Root Angle	:	64.5626	
, Condinator	. Nork Diego	; Machine Center To Ba	ack :	0.0947	
, Coordinates	: WOIK Flece	; Sliding Base	:	13.7400	
; Indexing	: Controller code	; Rate of Roll	:	1.07255	
; Contact Point	: Fixed	; Cradle Angle	:	54.3272	
; looth line sep.	: CSt D-ROII				
; Stock left	-0.5000	; WORKPIECE DIMENSION	5		
; Tool Length	: 40.000	;	_		
; Apex Location	: 0.000	; # Teeth	:		33
; # Gaps	: 33	; Module	:	12	2.121
; Start	: 1	; Face Angle	:	65	9.746
; End	: 33	; Face Width	:	78	8.749
; Increment	: 1	; Front Crown to Xp	:	49	9.047
; # Steps	: 6	; OD Toe	:	26	6.512
; Start	: 1	; OD Heel	:	400	0.036
; End	: 6	;			
; # Points width	: 11	; END MILL TOOL DEFIN	TION		
; Tool Tilt 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		31	0.000
; Target	: Fillet Area	, Cutting Length in H		31	0.000
; IB/Left Cycle	: Toe-Heel-Toe	, Tool Jeasth			0.000
; OB/Right Cycle	: Toe-Heel-Toe	; TOOT Length	:	41	0.000
;		; Stem Diameter			0.000
,		, Holder Diameter		(0.000

Output: Header – 1st part

Output: Header -2^{nd} *part*

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

🛫 Part Program for : Gear [Finishing] 13x33d400_final_REG.hyg	
File Edit	
; Start of Program	V4 -
SEQINDEX[1] = 1	Telephone
SEQINDEX[2] = 2	1 dec
SEQINDEX[3] = 3	
SEQINDEX[4] = 4	
SEQINDEX[5] = 5	
SEQINDEX[6] = 6	
SEOINDEX[7] = 7	
SEQINDEX[8] = 8	
SEQINDEX[9] = 9	
SECINDEX[10] = 10	
SEOINDEX[11] = 11	
SEOINDEX[12] = 12	
SEQINDEX $[13] = 13$	
SFOTNDFX[14] = 14	
SFOINDEX[11] = 15	
SEQUENCES $[16] = 16$	
SEQUADEX[10] 10 SECINDEX[17] = 17	
SEQUADEX[17] 17	
SEQUEDEX[10] = 10 SECUEDEX[10] = 10	
SEQINDEX[13] = 15	
SEQINDEX[20] - 20	
SEQUNDEX[21] = 21	
SEQINDEX[22] = 22	
SEQINDEX[23] - 23	
SECTIOEX[24] = 24	
SEQINDEX[25] = 25	
SEQINDEX[20] - 20	
SEQINDEX[2/] = 2/	
SEQINDEX[28] = 28	
SEQINDEX[29] = 29	
SEQINDEX[30] = 30	
SEQINDEX[31] = 31	
SEQINDEX[32] = 32	
SEQINDEX[33] = 33	
TEETH_ANGLE = (360/IOTAL_TEETH)	
TEETH_ANGLE = (ROUND(TEETH_ANGLE*100000)/100000)	
TRAORI	
ORIAXES	
; Start of Cycle	
; Section 1	
1120121 M6	
; Tooth Space # 1	
RESTART_TEETH=1	
TRANS C= (TEETH_ANGLE*SEQINDEX[(RESTART_TEETH)])	
STOPRE	
EXTCALL "PROC1"	
; Tooth Space # 2	
RESTART TEETH=2	

Output: Header – Indexing Sequence

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

Part Program for : Gear [Finishing] 13x330400_final_KEG.nyg	
File Edit	
; Cutting Cycle	V4
STARTI:	444
TRANS C=(IEEIn_ANGLE*SEQINDEX[(RESIARI_IEEIn)])	beec.
STOPRE	
· Convex	
; Toe	
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)	
GI X14.2906/ 1136.78683 Z-63.44583 A36.550894 C=DC(390.645807)	
GI XIU.IU552 Y144.3U33U Z-66.99599 A36.62565U C=DC(388.69526/)	
GI X 0 00620 VIE0 06522 7 72 05076 326 716022 C-DC(200.040//9)	
G1 X-5 97993 V166 04370 7-77 34803 336 731920 C=DC(382 244733)	
G1 X-12 60486 Y172 90406 7-80 68036 336 732909 C=DC(379 913287)	
G1 X-19.90785 Y179.49789 Z-83.95180 A36.709655 C=DC(377.447298)	
G1 X-27.93179 Y185.77627 Z-87.14607 A36.670126 C=DC(374.886054)	
G1 X-36.71690 Y191.67622 Z-90.26119 A36.607962 C=DC(372.189166)	
G1 X-46.31630 Y197.12535 Z-93.28604 A36.523252 C=DC(369.350248)	
G1 X-54.77268 Y201.37599 Z-95.73668 A36.434894 C=DC(366.904596)	
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 X0.29936 Y158.66957 Z-74.21937 A35.178710 C=DC(382.154580)	
G1 X5.62143 Y151.41360 Z-70.76635 A35.171167 C=DC(384.222515)	
G1 X10.35029 Y144.01533 Z-67.26063 A35.146073 C=DC (386.193376)	
GI X14.50776 YI36.50658 Z-63.70516 A35.103886 C=DC(388.071190)	
GI X22 66820 V115 04751 7-53 04874 334 020071 C=DC(389,902054)	
GI X25 31506 V102 07743 7_47 70827 N34 774315 C=DC(205 239174)	
G1 X26 04511 Y90 00484 7-41 64624 334 591863 C=DC(395.2381/4)	
; Toe	
C1 V26 12023 VR0 08651 7-41 01066 333 485440 C=DC(304 572160)	

Output: Tool path coordinates (with comments)

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



Sample Result 1:

13x37 6.5 mm module, Face Milled 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, Face Milled 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, Face Milled 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,
crowning remains in the GAGE corrected tooth while it is not visible in the
HyGEARS corrected tooth.
In both the GAGE and HyGEARS corrected teeth, spiral and pressure angle
errors have been eliminated.



GAGE correction

HyGEARS correction

Sample Result 3: Gouging detection is a desirable feature to prevent the mutilation of the tooth flank opposite that being cut by the back face of the tool. The left figure below shows the HyGEARS detected gouging points (pink crosses) on the concave side while the convex side is being cut. The right figure shows what happened in practice. The correlation is obvious.



<image>

HyGEARS predicted gouging on OB

Actual gouging on OB

<u>Summary</u>

- 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 Dimension sheet and 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. Geometry kinematics 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 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, Okuma, Fanuc and Mazak;
- 10. Part programs can be in *Machine coordinates*, *Work piece coordinates* with axis angles, or Work piece coordinates with tool axis vector (*Traori, TCPM, TCP and TCPC*);

<u>Summary</u>

- 11. Users can define their own tool box for Face Mill, CoSIMT, End Mill, Ball Mill and Probe tools;
- 12. Cutting Cycles include **Slot by Slot** and **Flank by Flank**, both for tooth flank and fillet; Toe, Heel and 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 adjusted to optimize quality 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. The "Roughing mode" allows to quickly remove material before the finishing operation;
- 18. "Operations", including all user selections for a given task, may be saved for later re-use; "Processes" allow the organization of several Operations in 1 file;
- 19. Closed Loop (i.e. Corrective Machine Settings) is integral to HyGEARS and allows the seamless manufacture of gears to the required topography and tolerances.
- 20. The HyGEARS Closed Loop corrections match (and in some respect are better than) those of Gleason's GAGE.

HyGEARS covers just about all your needs for the design and manufacture of gears.