Involute Simulation Softwares Inc.

HyGEARS ™ V 4

Updates / Recent changes

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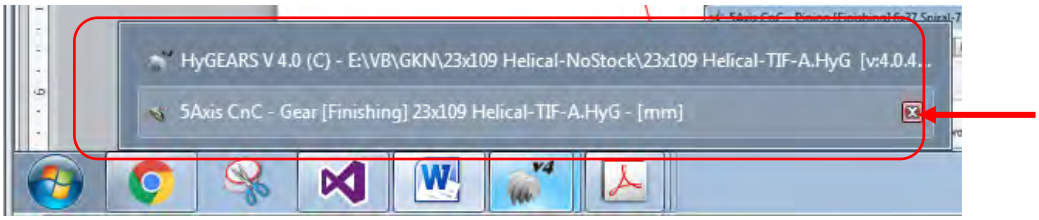
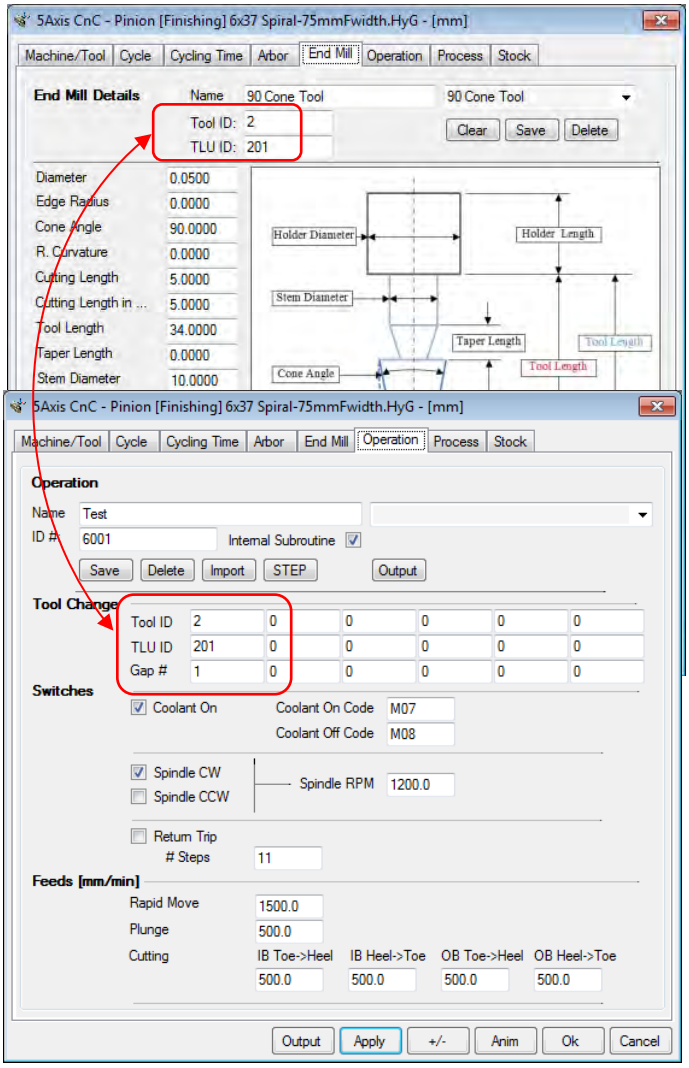
HyGEARS™ Updates Contents

HyGEARS update –29 November 2017 - Build 405.90 - 462

1) In 5Axis, the *5Axis CnC* window is not imposed to be in front of the Graphic Parent window anymore, and 2 icons appear in the Tool Bar: one for HyGEARS itself, the other for the *5Axis CnC* window. Therefore, the *5Axis CnC* window can sit anywhere on the screen. If the *5Axis CnC* window is hidden by the Graphic Parent window, it can be accessed through the icon on the Windows tool bar.

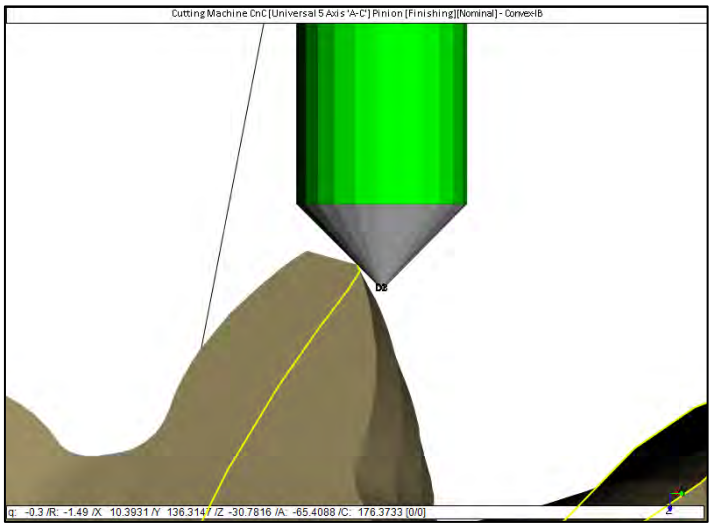


2) In 5Axis, all Tool definitions now include entry fields for *Tool ID* and *TLU ID*. The *Tool ID* and *TLU ID* are fields used in the Operation to inform the controller of the tool used.

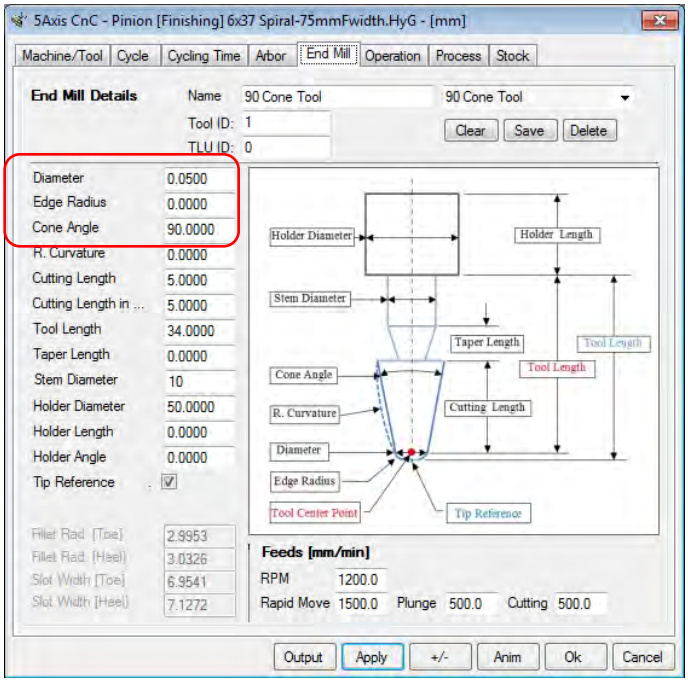


3) In 5Axis, Chamfer Tool Side / Toe / Heel, HyGEARS now detects if a *Chamfering End Mill* tool is used. A

Chamfering End Mill tool [Cone Tool for short] is an End Mill with a 45° to 90 ° cone angle at the tip, as shown below.

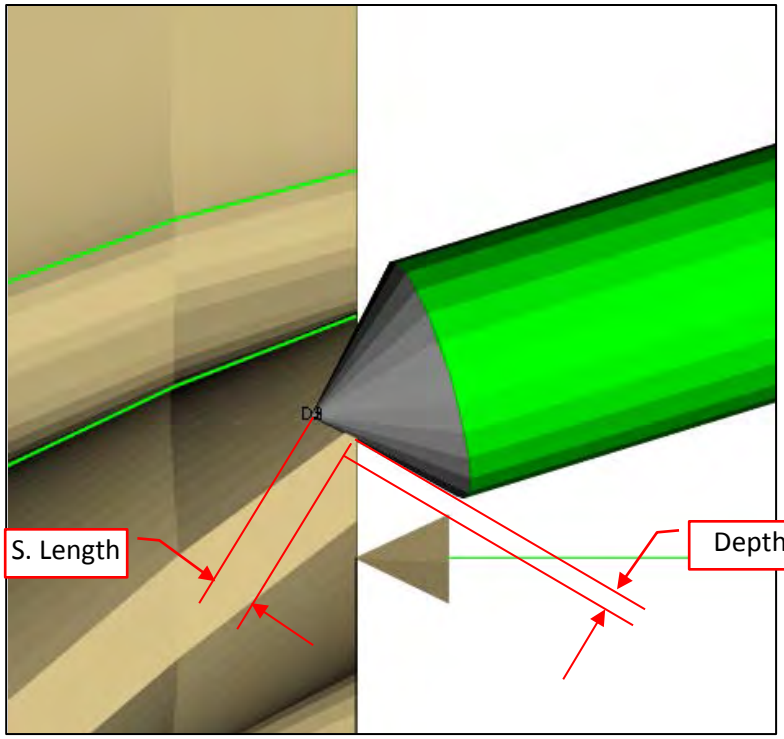


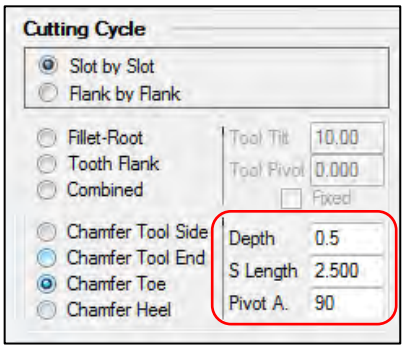
The Cone Tool is described as a usual End Mill, except that the Diameter is expected to be nearly zero (0.050 mm, figure below), the Edge Radius is zero, and the Cone Angle ranges from 45° to 90°.

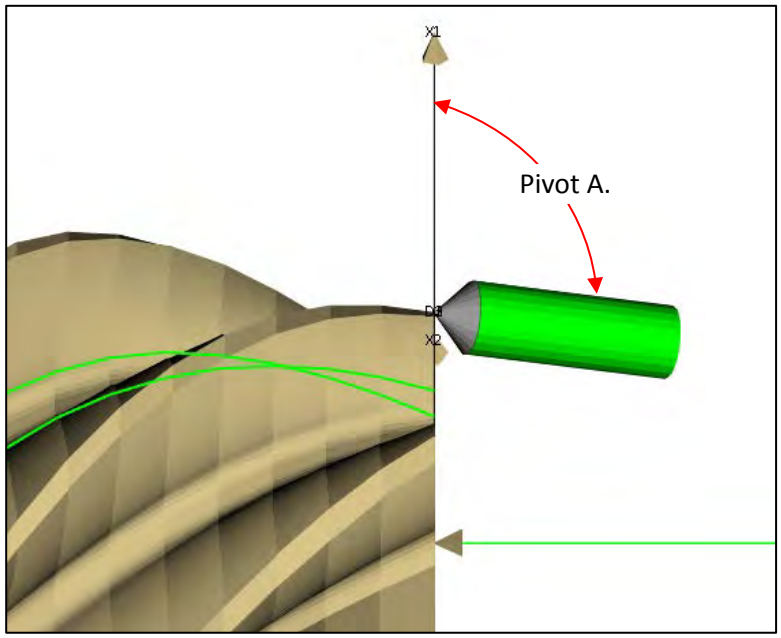


Whenever a Cone Tool is detected, in the Chamfer Toe / Chamfer Heel cycles, HyGEARS offers a different set of entry fields, as follows:

- Depth: depth to which the chamfer is to be cut;
- S.Length: distance along the edge of the Cone Tool;
- Pivot A.: angle to pivot the Cone Tool out of the gap (+ value) or into the gap (- value);



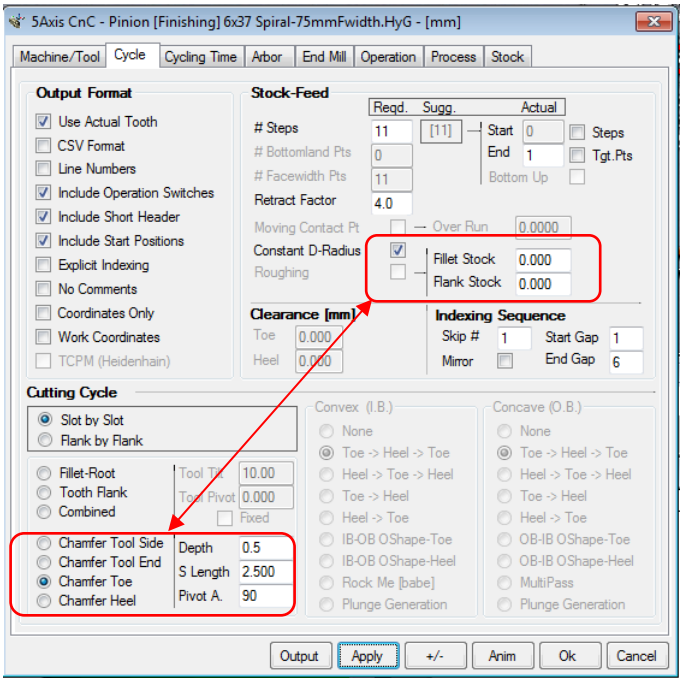




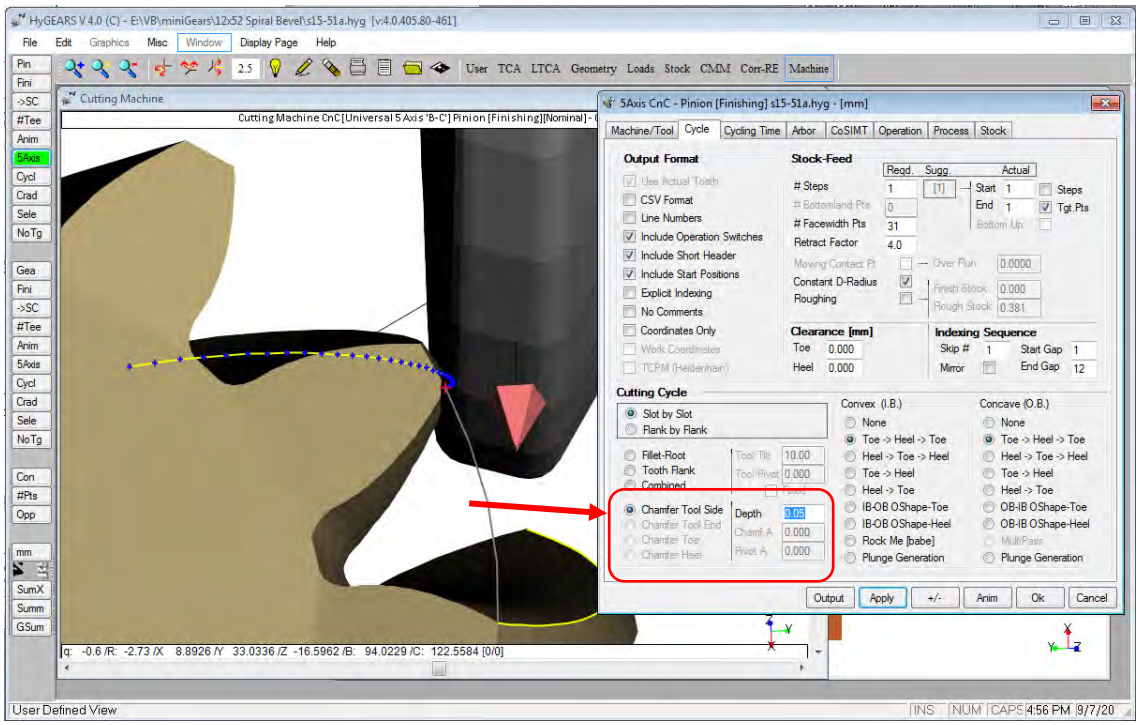
4) In 5Axis, Chamfer Toe / Chamfer Heel, HyGEARS offers Stock for both Fillet and Flank, such that the location of the tool can account for the fact that, for example, the Flank may have a +Stock, while the Fillet has a protuberance, and thus –Stock.

In addition, the *Start* step is now imposed as 0.

Finally, when the Output button is clicked, the starting tooth flank is based on the CW or CCW spindle rotation as defined in the Operation tab.

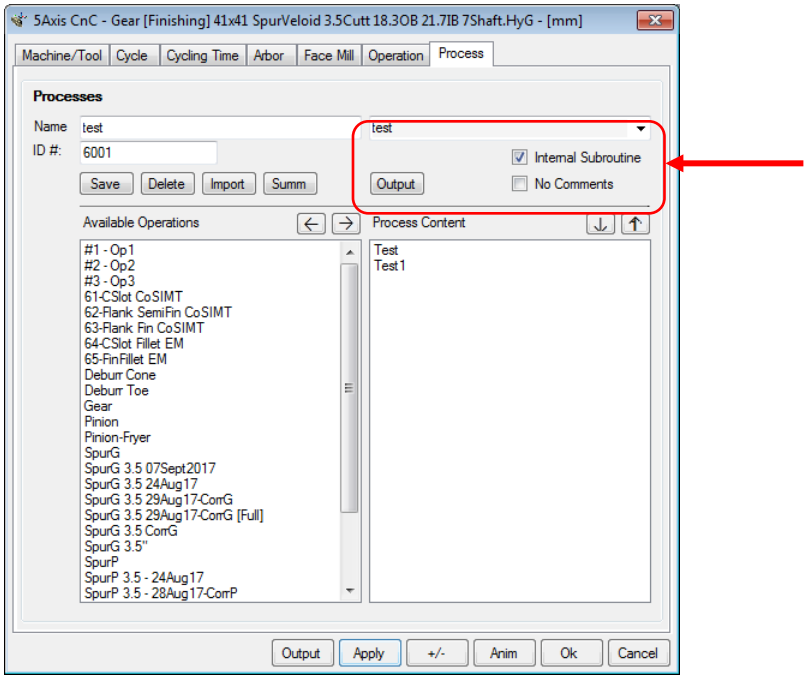


5) In 5Axis, Tip Chamfer, Tool Side, is now allowed with a CoSIMT.

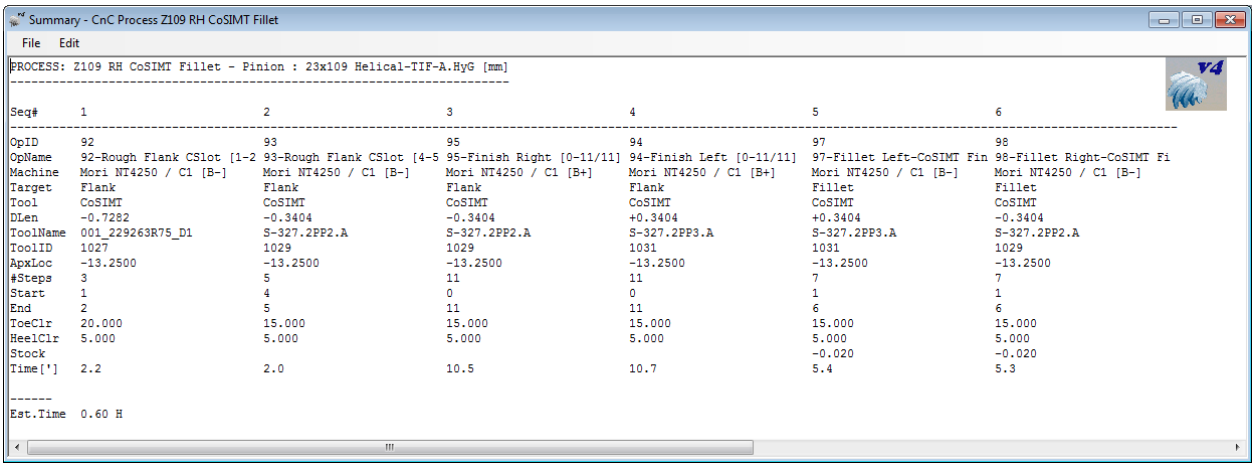


6) In 5Axis, *Process* tab, addition of the *No Comments* switch, which allows imposing or disabling comments globally to all the Operations of a given Process, without having to edit each individual Operation.

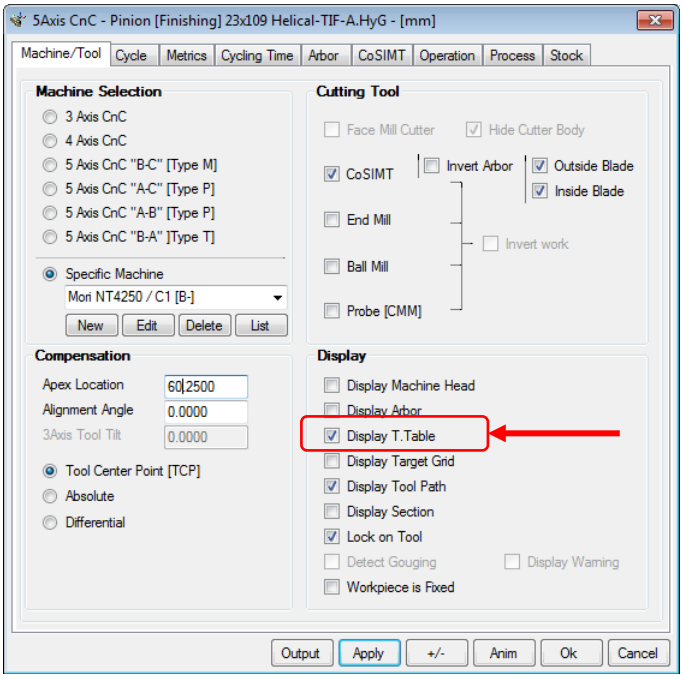
Also, the *Output* button has been moved such as to stand out and be more visible.



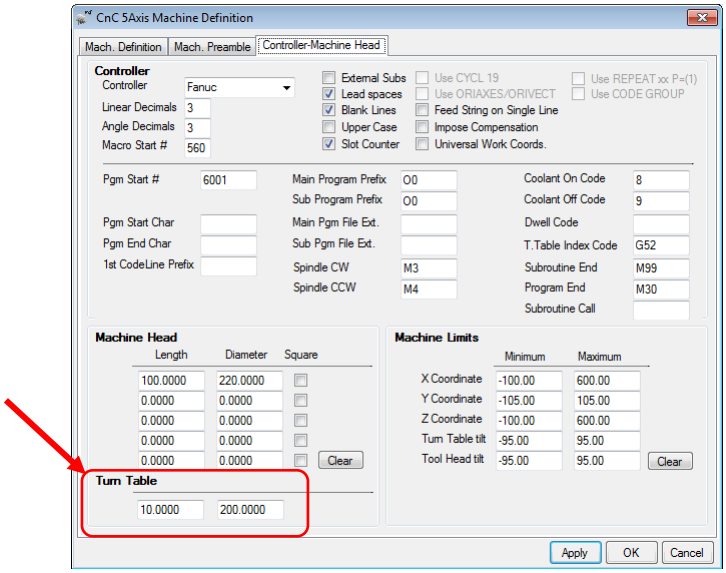
7) In 5Axis, *Process* tab, the *Summ* button now prints out the Process Summary in column form rather than the original linear form. This allows addition of more info, and makes for easier consultation of each step.



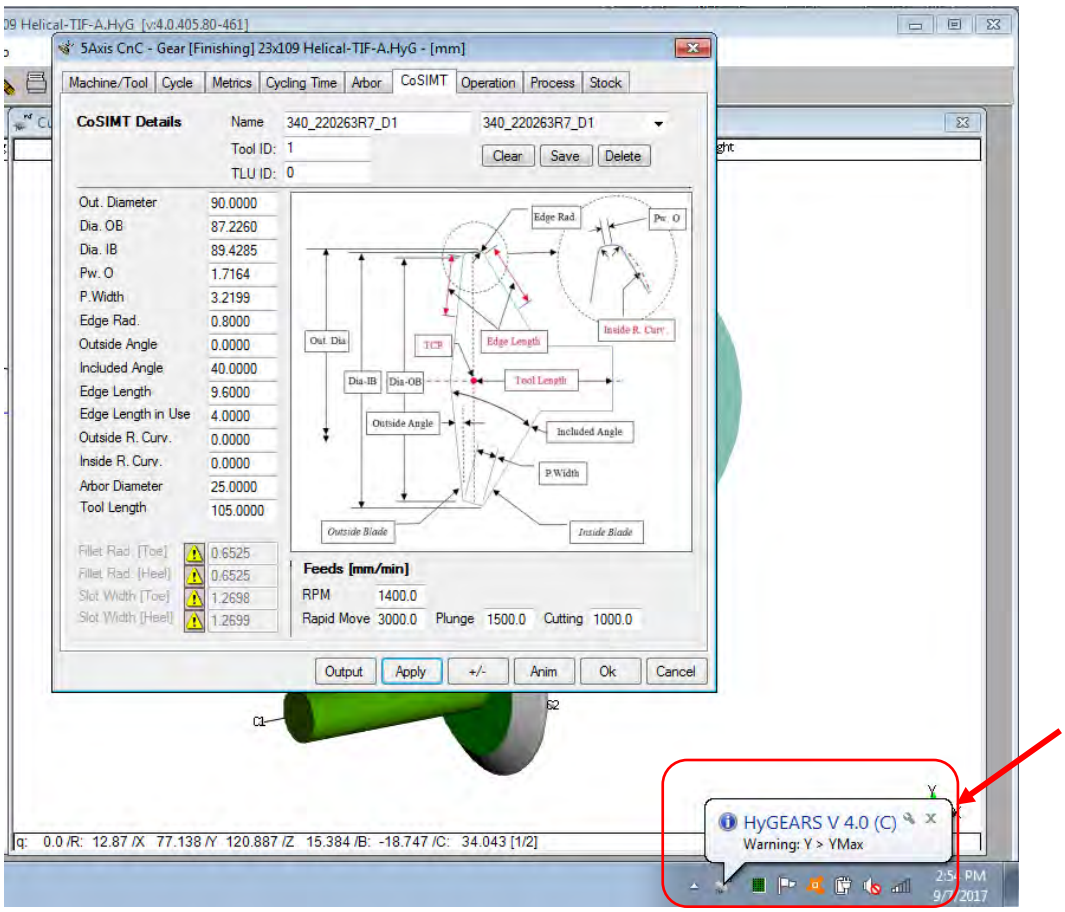
8) In 5Axis, *Machine/Tool* tab, it is now possible to selectively display the machine's Turn Table on which the work piece and its supporting arbor are installed.



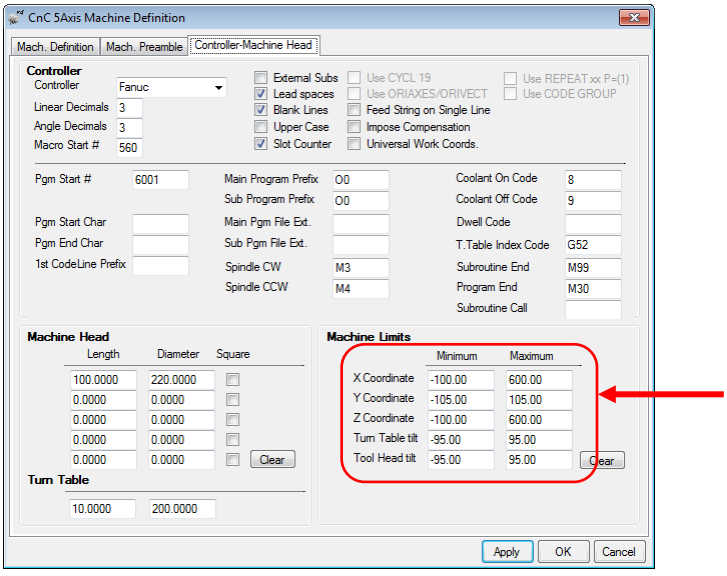
The Turn Table dimensions are defined in the machine's data, *Controller-Machine Head* tab:



9) In 5Axis, when animating (*Anim* button) or single stepping (*+/-* button) an Operation HyGEARS now checks the min and max X Y Z A B values and outputs a balloon in the lower right corner of the screen if any of these exceeds the machine limits.



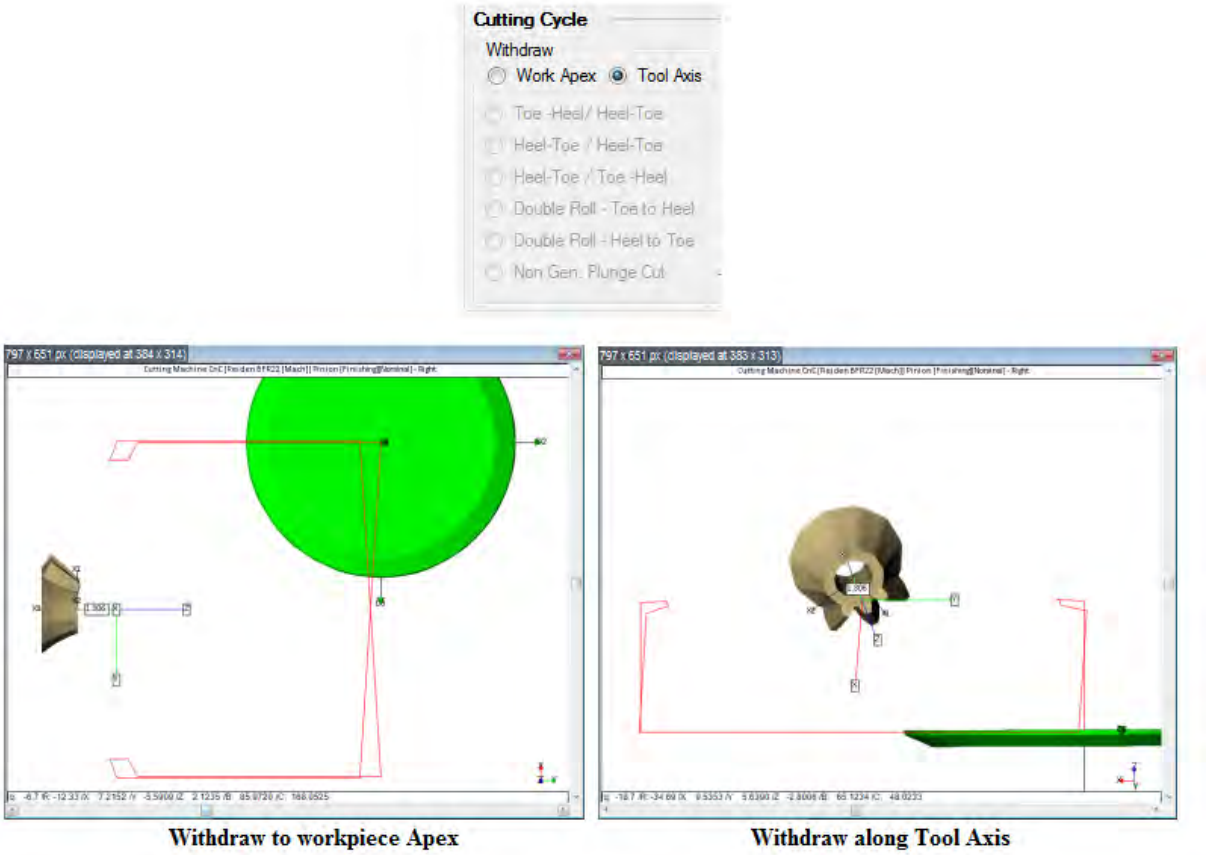
For this warning to be displayed, the machine's limits must have been defined by editing the desired machine and entering the values in the *Controller-Machine Head* tab, Machine Limits section, as shown below.



Since HyGEARS is distributed with the master Machine definition file, each time HyGEARS is installed, the current Machine file is updated and therefore, any machine limits entered by a user should be transferred to Involute Inc. in order to maintain the master Machine file.

10) In 5Axis, for Coniflex gears cut with a Coniflex Dish type cutter, the tool can now be withdrawn to either the *Work Apex* or along the *Tool Axis*.

For example, in AC type machines, retracting to the Work Apex is usually not an issue because of a large volume; this is not so in a Gleason Phoenix machine where travel along the work piece is limited, and then withdrawing along the Tool Axis becomes compulsory. This has limited effect on cycle time, and is usually based on what the machine can allow.



Withdraw to workpiece Apex

Withdraw along Tool Axis

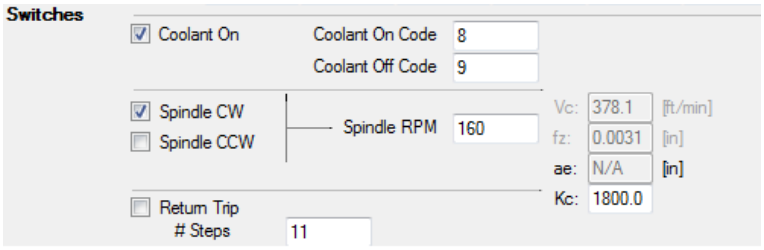
11) In 5Axis, the Non Gen Plunge cutting cycle (Face Mill cutter), the Retract Factor now relates to tooth depth at Heel rather than at mid-face.

12) In 5Axis, HyGEARS now estimates the Torque and Power required for a cutting operation. This is subdivided in 2 data pages:

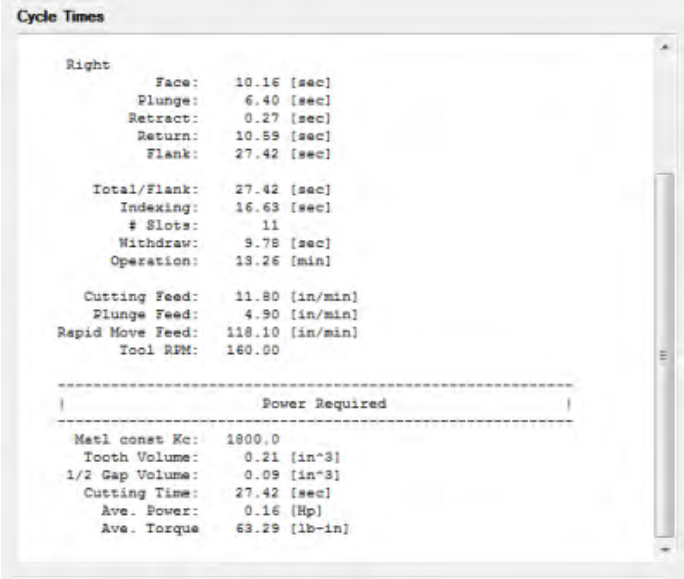
Operation page: Next to the Spindle RPM, tool cutting data is given; when the Spindle RPM or Cutting Feed is modifed, *Vc* and *fz* are updated (*fz* is based on the largest of the enabled Cutting Feeds).

- *Vc*: cutting speed, i.e. tangential speed at the tool OD;
- *fz*: feed / tooth, i.e. size of the cutting bite / tool blade or flute;
- *ae*: working engagement, i.e. shape of the cut; may be disabled and replaced by "*N/A*" when *Not Applicable,* for for Face Mill tools;

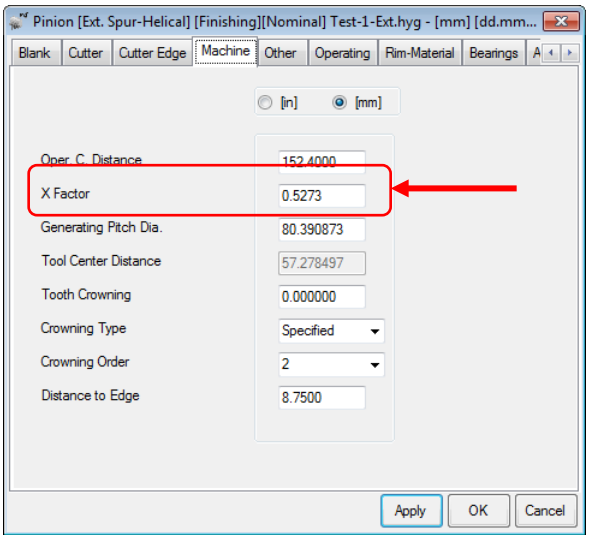
- *Kc:* material constant; see tables in the documentation (https://www.sandvik.coromant.com/en-us/knowledge/milling/formulas_and_definitions/formulas).



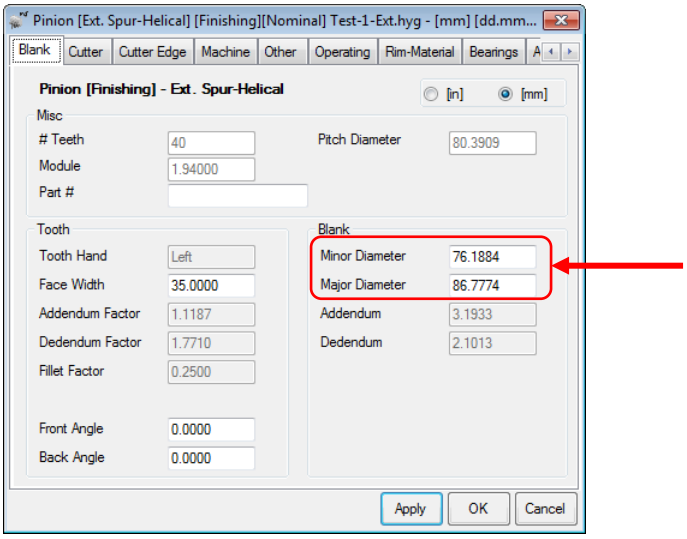
Cycling Time page: the estimated average spindle Torque and Power is displayed below the cycling time. Cutting torque and power are based on the relations provided by Sandvik.



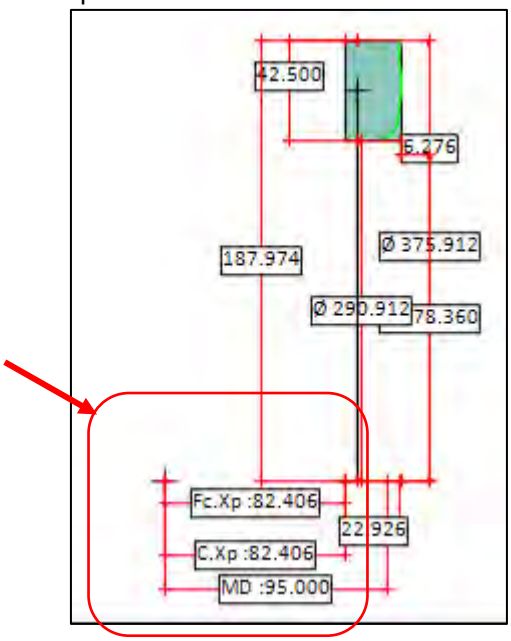
13) For Spur/Helical gears, in the Geometry Summary Editor (*Pin* / *Gea* function buttons), the X Factor (i.e. the Profile Shift factor) can now be edited. This allows adjusting the X Factor to reach a target tooth thickness.



In addition, whenever the Minor Diameter (i.e Root Diameter) or Major Diameter (i.e. Outside Diameter) is changed and the *Apply* button is clicked, the cutting blades are adjusted in order to produce the required diameters.

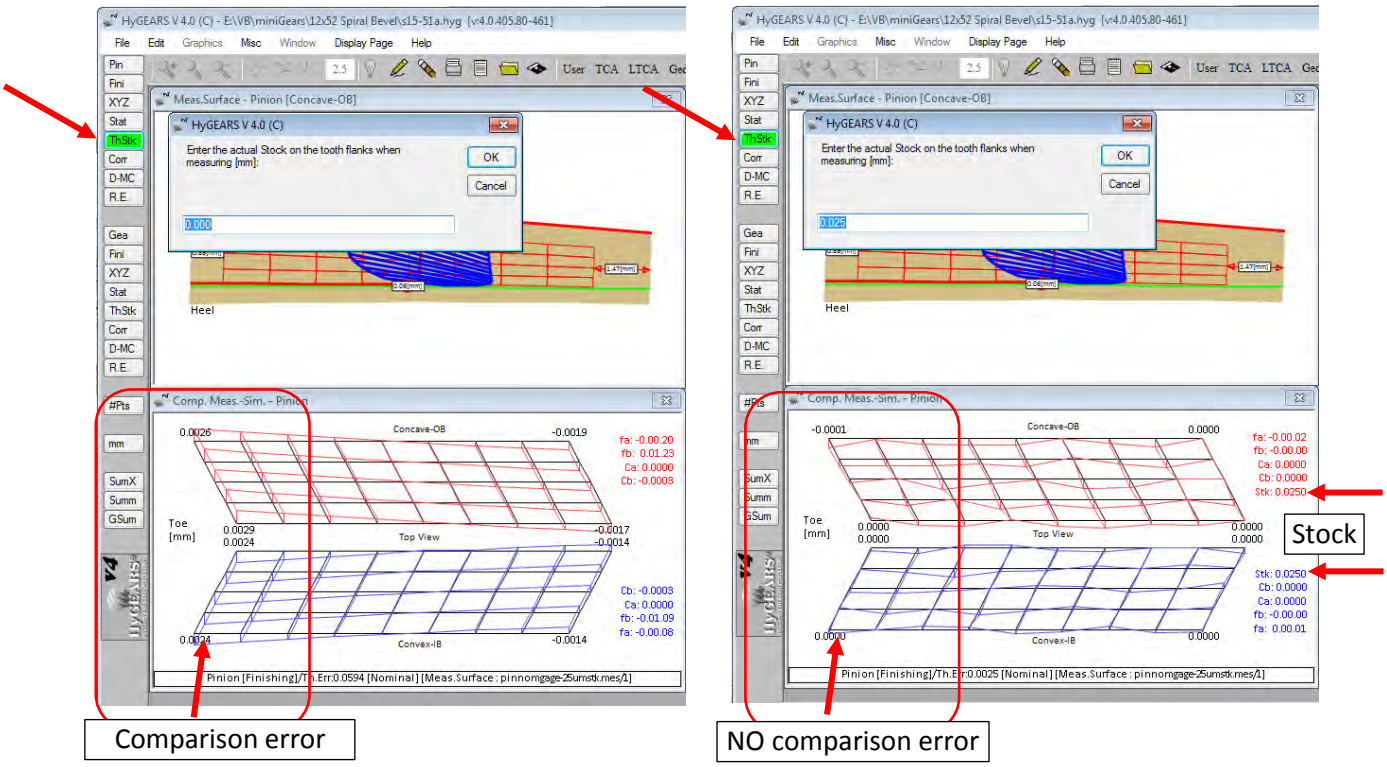


14) For Face gears (gear member only), the Fc.Xp, C.Xp and MD values are now displayed in the Blank Child window. These are used to locate the pinion axis of rotation in reference to the Face Gear.



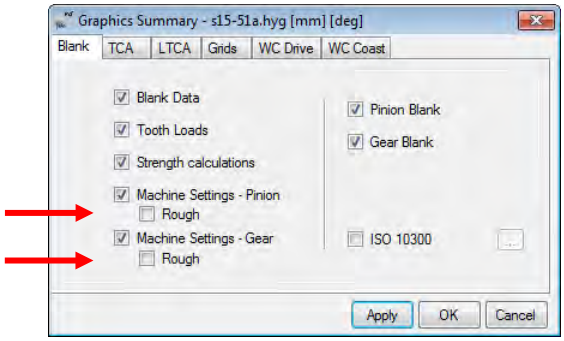
15) In *Corr-RE* display mode, addition of the "ThStk" function button. This is used to enter the desired Stock used to define the CMM Nominal target (*CMM* display mode).

For example, suppose the CMM Nominal target has been defined with +0.025 mm stock on each flank, since the targeted cut is roughing. When measuring, the requested stock will be accounted for. However, when importing the CMM output into HyGEARS, the CMM output is *always* compared to the nominal tooth, i.e. without any stock.



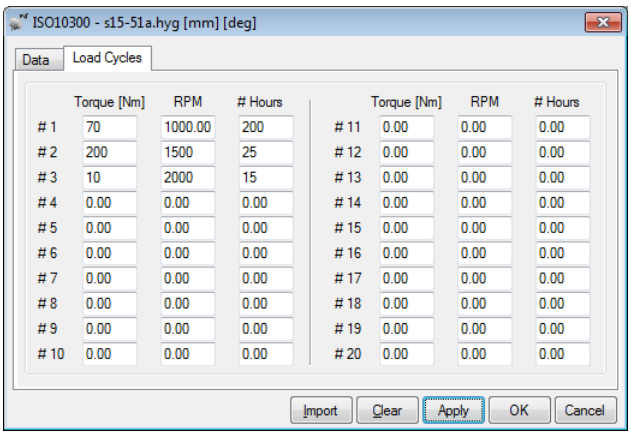
An error will therefore appear in the comparison because of the difference in stock between the nominal and actual teeth, as is shown, left figure above. If the Stock used in defining the CMM Nominal is entered, as in the right figure above, then no error is generated. The Stock value is also shown in the display – right figure above.

16) In the Graphic Summary selection window, *GSum* function button, it is now possible to define whether the Roughing machine settings are outputted or not. By default, this option is unselected.

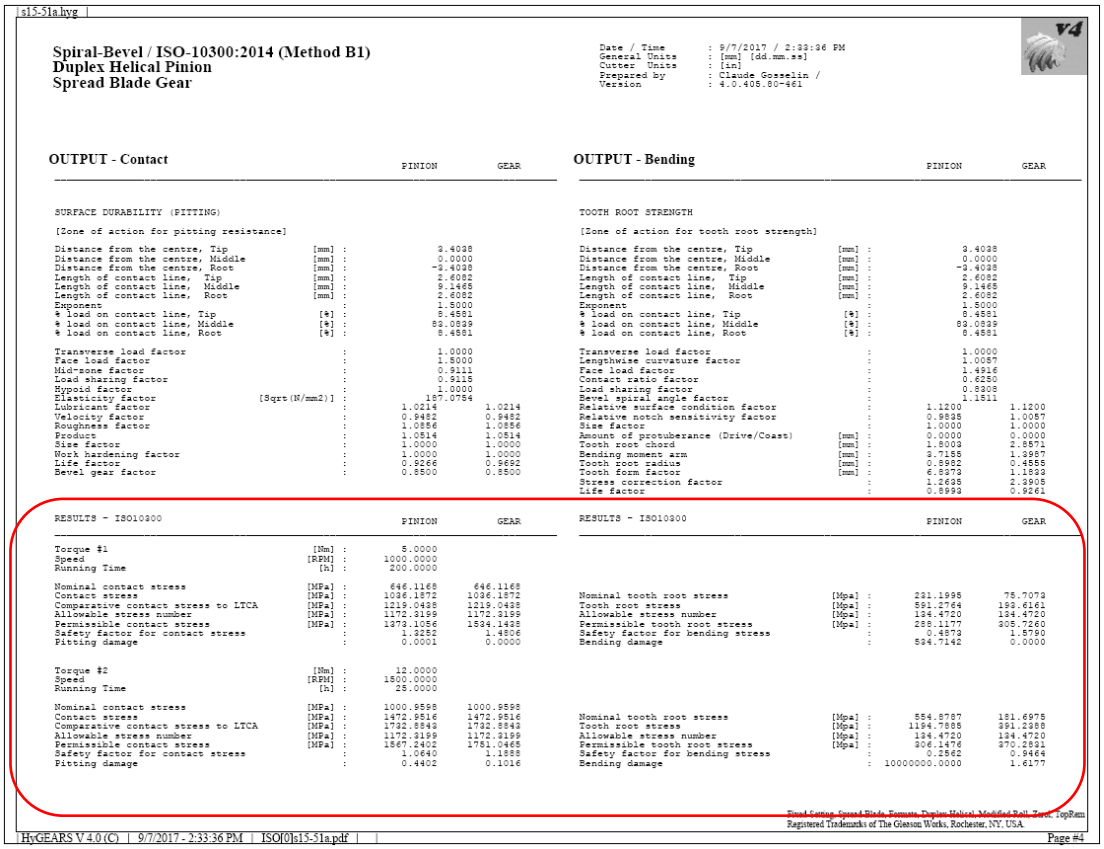


17) In ISO-10300, load cycles can now be entered such as to estimate the cumulative damage caused by contact and bending stresses.

Load cycles are entered as a series of pinion Torque, pinion RPM and # Hours runtime. Up to 20 values can be entered.



Output gives the results for each load cycle, and the cumulative Contact and Bending damage at the end of the document.



s15-51a.hyg

Spiral-Bevel / ISO-10300:2014 (Method B1)
Duplex Helical Pinion
Spread Blade Gear

Date / Time : 9/7/2017 / 2:33:36 PM
General Units : [mm] [dd.mm.ss]
Cutter Units : [in]
Prepared by : Claude Gosselin /
Version : 4.0.405.80-461

OUTPUT - Contact

		PINION	GEAR
SURFACE DURABILITY (PITTING)			
[Zone of action for pitting resistance]			
Distance from the centre, Tip	[mm] :	3.4038	
Distance from the centre, Middle	[mm] :	0.0000	
Distance from the centre, Root	[mm] :	-3.4038	
Length of contact line, Tip	[mm] :	2.6082	
Length of contact line, Middle	[mm] :	9.1465	
Length of contact line, Root	[mm] :	2.6082	
Exponent	:	1.5000	
% load on contact line, Tip	[%] :	8.4581	
% load on contact line, Middle	[%] :	83.0839	
% load on contact line, Root	[%] :	8.4581	
Transverse load factor	:	1.0000	
Face load factor	:	1.5000	
Mid-zone factor	:	0.9111	
Load sharing factor	:	0.9115	
Hypoid factor	:	1.0000	
Elasticity factor	[Sqrt(N/mm2)] :	187.0784	
Lubricant factor	:	1.0214	1.0214
Velocity factor	:	0.9452	0.9452
Roughness factor	:	1.0856	1.0856
Product	:	1.0514	1.0514
Size factor	:	1.0000	1.0000
Work hardening factor	:	1.0000	1.0000
Life factor	:	0.9266	0.9692
Bevel gear factor	:	0.8500	0.8500
RESULTS - ISO10300		PINION	GEAR
Torque #1	[Nm] :	5.0000	
Speed	[RPM] :	1000.0000	
Running Time	[h] :	200.0000	
Nominal contact stress	[MPa] :	646.1168	646.1168
Contact stress	[MPa] :	1036.1872	1036.1872
Comparative contact stress to LTCA	[MPa] :	1219.0438	1219.0438
Allowable stress number	[MPa] :	1172.3199	1172.3199
Permissible contact stress	[MPa] :	1373.1056	1534.1438
Safety factor for contact stress	:	1.3252	1.4806
Pitting damage	:	0.0001	0.0000
Torque #2	[Nm] :	12.0000	
Speed	[RPM] :	1500.0000	
Running Time	[h] :	25.0000	
Nominal contact stress	[MPa] :	1000.9598	1000.9598
Contact stress	[MPa] :	1472.9516	1472.9516
Comparative contact stress to LTCA	[MPa] :	1732.5843	1732.5843
Allowable stress number	[MPa] :	1172.3199	1172.3199
Permissible contact stress	[MPa] :	1567.2402	1781.0465
Safety factor for contact stress	:	1.0640	1.1858
Pitting damage	:	0.4402	0.1016

OUTPUT - Bending

		PINION	GEAR
TOOTH ROOT STRENGTH			
[Zone of action for tooth root strength]			
Distance from the centre, Tip	[mm] :	3.4038	
Distance from the centre, Middle	[mm] :	0.0000	
Distance from the centre, Root	[mm] :	-3.4038	
Length of contact line, Tip	[mm] :	2.6082	
Length of contact line, Middle	[mm] :	9.1465	
Length of contact line, Root	[mm] :	2.6082	
Exponent	:	1.5000	
% load on contact line, Tip	[%] :	8.4581	
% load on contact line, Middle	[%] :	83.0839	
% load on contact line, Root	[%] :	8.4581	
Transverse load factor	:	1.0000	
Lengthwise curvature factor	:	1.0057	
Face load factor	:	1.4916	
Contact ratio factor	:	0.6250	
Load sharing factor	:	0.8208	
Bevel spiral angle factor	:	1.1511	
Relative surface condition factor	:	1.1200	1.1200
Relative notch sensitivity factor	:	0.9838	1.0057
Size factor	:	1.0000	1.0000
Amount of protuberance (Drive/Coast)	[mm] :	0.0000	0.0000
Tooth root chord	[mm] :	1.8009	2.8871
Bending moment arm	[mm] :	2.7155	1.3987
Tooth root radius	[mm] :	0.9982	0.4555
Tooth form factor	[mm] :	6.8279	1.1839
Stress correction factor	:	1.2695	2.3905
Life factor	:	0.8993	0.9261
RESULTS - ISO10300		PINION	GEAR
Nominal tooth root stress	[Mpa] :	231.1995	75.7073
Tooth root stress	[Mpa] :	591.2764	193.6161
Allowable stress number	[Mpa] :	134.4720	134.4720
Permissible tooth root stress	[Mpa] :	288.1177	305.7260
Safety factor for bending stress	:	0.4873	1.5790
Bending damage	:	834.7142	0.0000
Nominal tooth root stress	[Mpa] :	554.8787	181.6975
Tooth root stress	[Mpa] :	1194.7885	391.2388
Allowable stress number	[Mpa] :	134.4720	134.4720
Permissible tooth root stress	[Mpa] :	306.1476	370.2891
Safety factor for bending stress	:	0.2562	0.9464
Bending damage	:	10000000.0000	1.6177

Spiral Cutting, Spread Blade, Formate, Duplex Helical, Modified Roll, Zerol, TopRem
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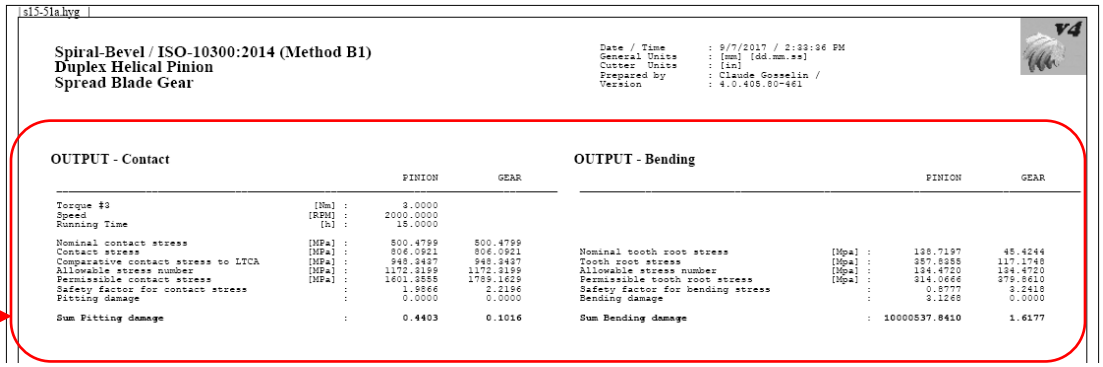


s15-51a.hyg

Spiral-Bevel / ISO-10300:2014 (Method B1)
Duplex Helical Pinion
Spread Blade Gear

Date / Time : 9/7/2017 / 2:33:36 PM
General Units : [mm] [dd.mm.ss]
Cutter Units : [in]
Prepared by : Claude Gosselin /
Version : 4.0.405.80-461

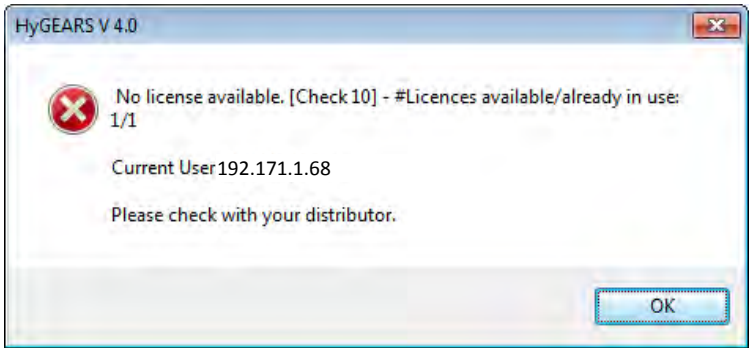
OUTPUT - Contact

		PINION	GEAR
Torque #3	[Nm] :	3.0000	
Speed	[RPM] :	2000.0000	
Running Time	[h] :	15.0000	
Nominal contact stress	[MPa] :	500.4799	500.4799
Contact stress	[MPa] :	806.0921	806.0921
Comparative contact stress to LTCA	[MPa] :	948.3497	948.3497
Allowable stress number	[MPa] :	1172.3199	1172.3199
Permissible contact stress	[MPa] :	1601.3555	1789.1629
Safety factor for contact stress	:	1.9866	2.2196
Pitting damage	:	0.0000	0.0000
Sum Pitting damage	:	**0.4403**	**0.1016**

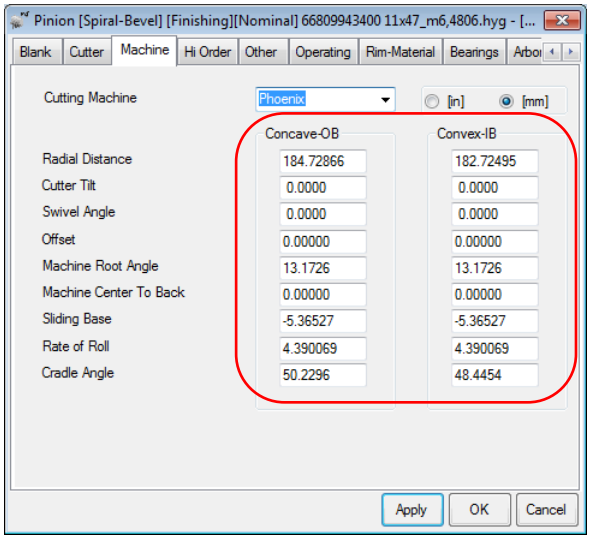
OUTPUT - Bending

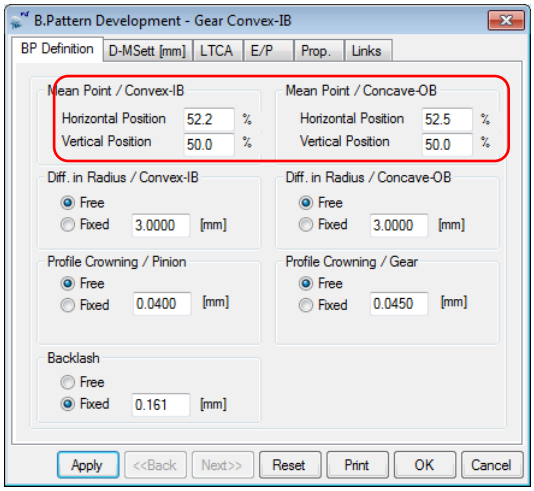
		PINION	GEAR
Nominal tooth root stress	[Mpa] :	138.7197	45.4244
Tooth root stress	[Mpa] :	357.8355	117.1748
Allowable stress number	[Mpa] :	134.4720	134.4720
Permissible tooth root stress	[Mpa] :	314.0666	379.8610
Safety factor for bending stress	:	0.8777	3.2418
Bending damage	:	3.1268	0.0000
Sum Bending damage	:	**10000537.8410**	**1.6177**

18) If the Network option has been purchased, and a user attempts to run HyGEARS, a message notifying the user that no license is available is displayed when all licenses are currently used; the IP address of the last user to log into HyGEARS is also displayed, such that one can ping this user to check for how long he will be busy with HyGEARS.



19) When developing Cyclo-Palloid gear sets (*BPat* function button), the cutting cycle is now seen as a semi-completing process and therefore, machine settings for both the IB and OB flanks are available. This also means that the Vertical Position of the Bearing Pattern on each tooth flank can be controlled individually.





20) When using the *File -> Save As* command to save an existing gear set under a new name or in a different folder, HyGEARS checks to see if the geometry is saved in a different folder and, if so, HyGEARS copies the *Operations.fil* and *Processes.fil* files from the origin folder to the destination folder.

21) Improvement in the stability of the *RemT* function (Remove Tilt) where cutter tilt is replaced by a combination of Ratio of Roll and Helical Motion in generated gear sets.

22) Addition of the *DXF* function button [optional] to the *Geometry* display mode. The DXF function exports the different aspects of the tooth of the selected member:

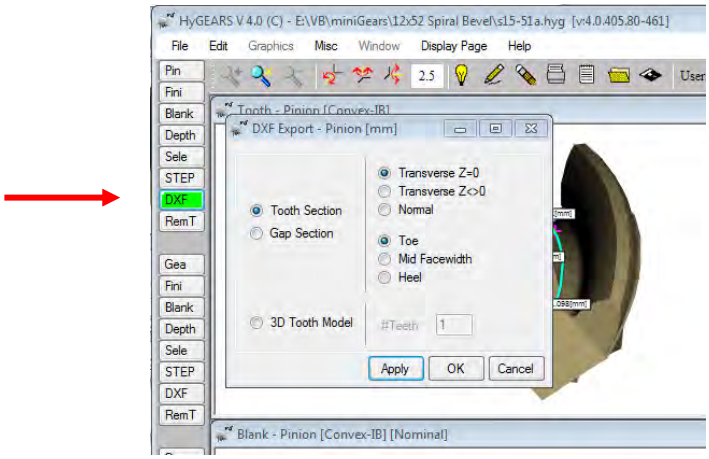
- the Tooth Section,
- the Gap Section,
- the 3D Tooth Model (with 1 to *Z* teeth).

The Tooth and Gap sections can be obtained:

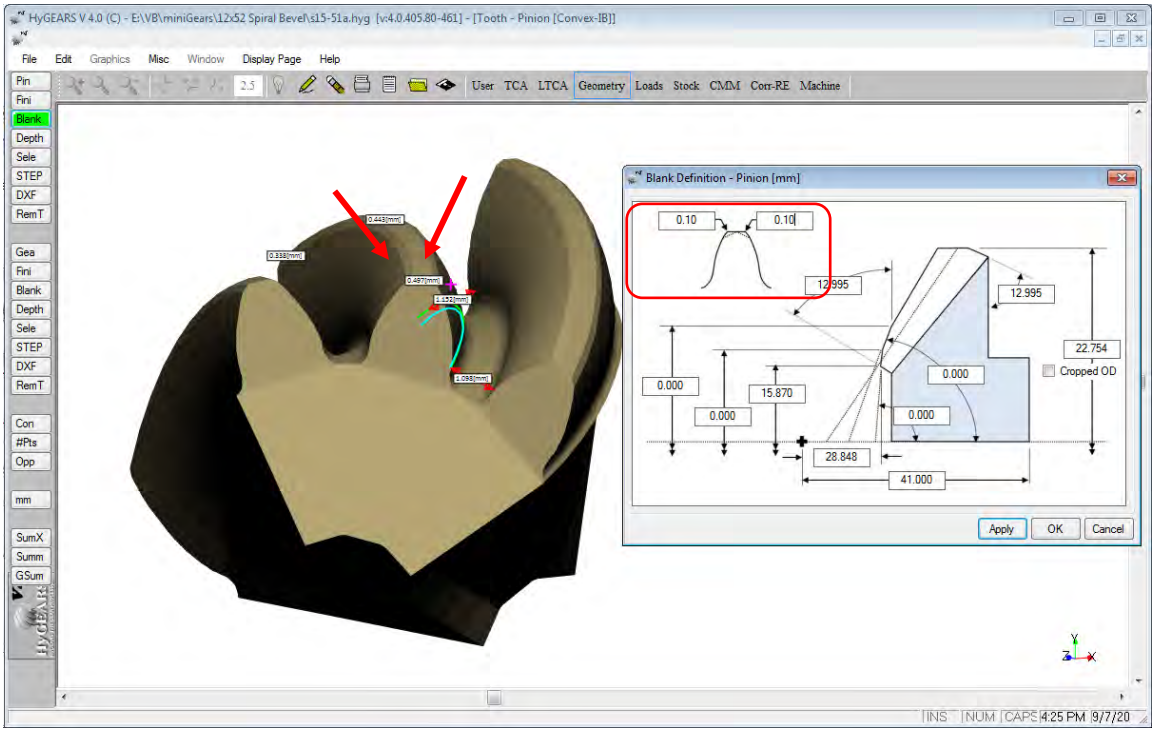
- at Toe,
- at Mid Facewidth,
- at Heel.

Furthermore, the Tooth and Gap sections can be obtained:

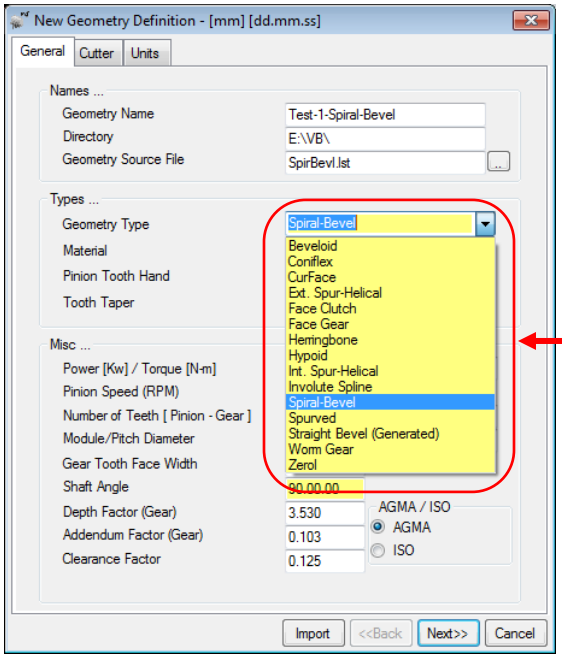
- In the Transverse plane, with the axial coordinate Z = 0,
- In the Transverse plane, with the actual axial coordinate Z,
- In the Normal plane.



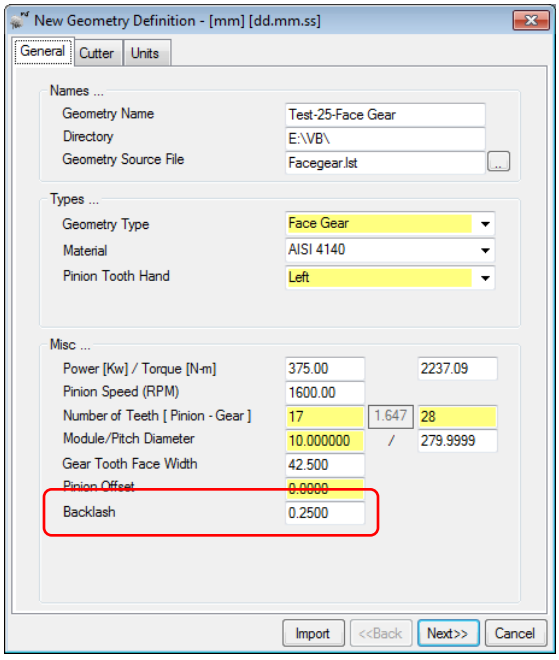
23) Addition of Tip Chamfer to the Blank definition. The Tip Chamfer value is assumed to bisect the tooth flank and topland in equal parts to the given depth. It is used **solely** for kinematic purposes, i.e. to determine how large the chamfer should be in order to prevent tip to fillet interference, and therefore has no connection with any Operation in 5Axis mode.



24) When creating a New Geometry, the various gear types offered in HyGEARS are now displayed in an alphabetically sorted list.

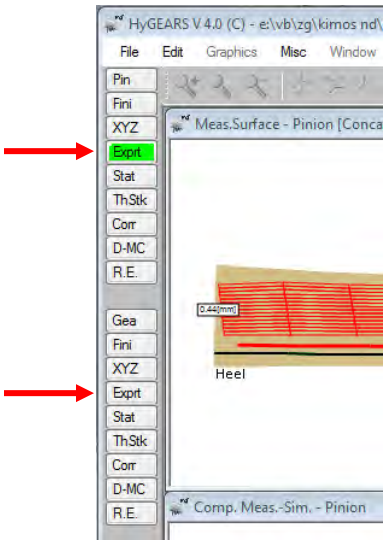


25) When creating a new Face Gear geometry, the desired Backlash is now offered as an input field, as shown below.

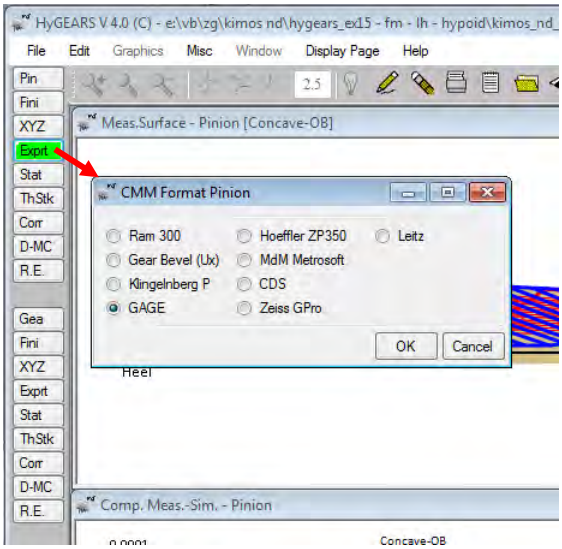


If the entered Backlash is less or equal to zero, HyGEARS will use as is the given XFactor (i.e. Profile Shift factor) for the Gear member. If the entered Backlash is greater than zero, then HyGEARS will adjust the XFactor for the Gear member to reach the desired Backlash.

26) In the Corr-RE display mode, addition of the "*Exprt*" function button to the Pinion and Gear groups.

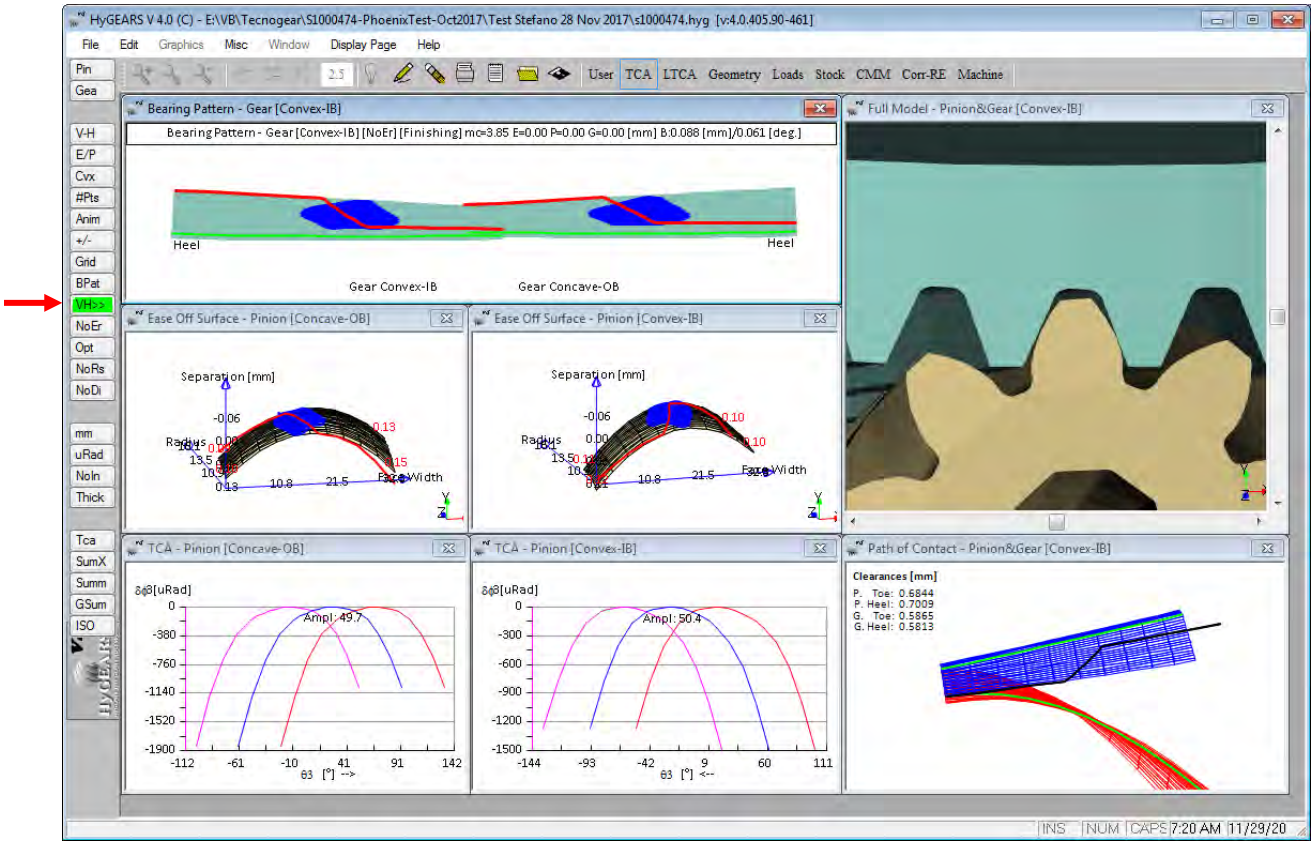


The *"Exprt"* button calls the CMM Nominal Format window, figure below, where one can select the format in which the currently loaded CMM file will be exported (can be a Nominal or an actual CMM output file).



This means than the coordinates of the currently loaded CMM file will be exported in the selected format (GAGE is selected in the figure above), whatever the format the CMM coordinates came in. Since the tooth flank normal vector at each point of the original CMM file are not conserved - often, they simply are not given in a CMM output file - HyGEARS will provide normal vector values based on the machine settings of the digitized tooth, Pinion or Gear. Therefore, slight differences in normal vector components can be expected if there is a significant difference between the digitized tooth and the CMM data. In practice, the noted differences in normal vector components are at the 2nd or 3rd decimal, and are therefore rather insignificant in effect.

27) Addition of the *VH>>* function to the TCA mode.



The VH>> function is used during Bearing Pattern Development to convert actual E, P and G *V-H Settings* into machine settings changes used to produce the desired Bearing Pattern. This avoids using Gleason's Proportional Changes.

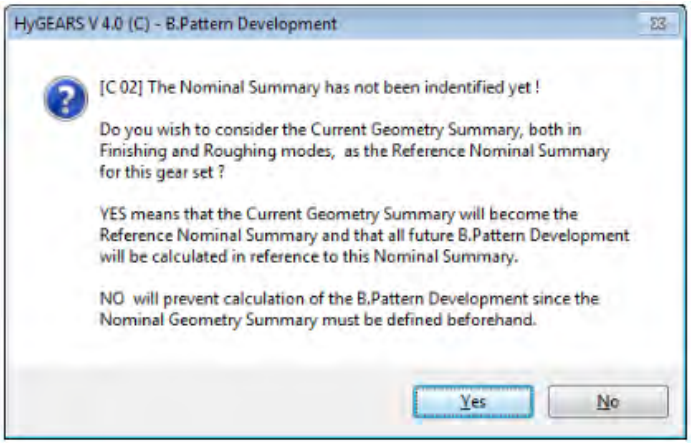
At the manufacturing stage of a gear set, it is common practice to use surface measurement to quantify the difference between the theoretical tooth surfaces and those produced on actual machines, which requires the use of a Coordinate Measurement Machine, or CMM.

When a CMM is not available, the V-H test is used, where the pinion and gear members are operated under a light load using marking compound to locate the Bearing Pattern on the tooth flank and modify the relative operating positions of the pinion and gear member until the desired Bearing Pattern is obtained.

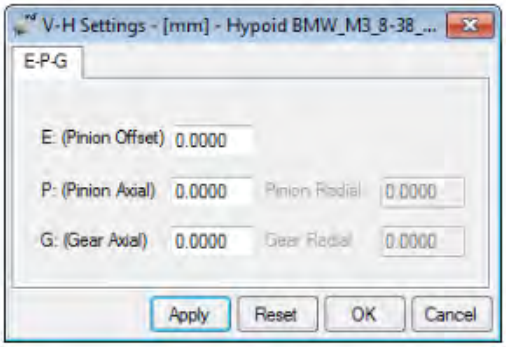
Once the E P G positions needed to produce the desired Bearing Pattern are found, they must be converted to actual pinion machine settings changes. The VH>> function is used to convert the E P G values of the V-H test into actual machine settings.

As for Corrective Machine Settings, before calculating any VH>> machine settings changes, the Nominal Summary must be defined. This is done by HyGEARS upon confirmation by the user the first time the VH>> machine settings changes algorithm is accessed (see figure below).

Once the Nominal Summary has been defined, all *VH>>* machine settings changes will be calculated in reference to the defined Nominal.



The E P G values required for the VH>> function are entered through the following *V-H Settings* window, which is displayed after the above confirmation has been done:



The E P G values and signs are as recorded on the VH tester, i.e.:

P+: when the Pinion moves away from the Xp
G+: when the Gear moves away from the Xp;
E+: when a LH Pinion goes up (the movement is considered on the Pinion).

In short, the VH>> algorithm uses the Nominal Summary to evaluate the differences between the theoretical and actual (meaning under E, P and G changes) Bearing Pattern location, and bases the modification of each machine setting on the amount of change in Bearing Pattern position.

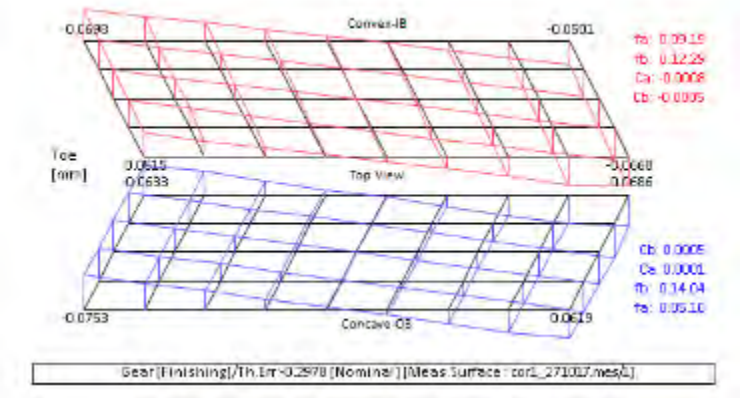
Each machine setting modification is then added to the latest Summary version in the history of the considered pinion. It is therefore imperative that the geometry data file be saved on disk after VH>> machine settings changes have been calculated and applied. HyGEARS automatically proposes to do so.

HyGEARS maintains a history of the different VH>> machine settings changes that were calculated for the pinion, provided the geometry is saved after VH>> machine settings changes have been calculated and applied. The Bearing Pattern Development History can be reset, or completely erased, using the Main Menu *Edit->Reset Bearing Pattern History* function.

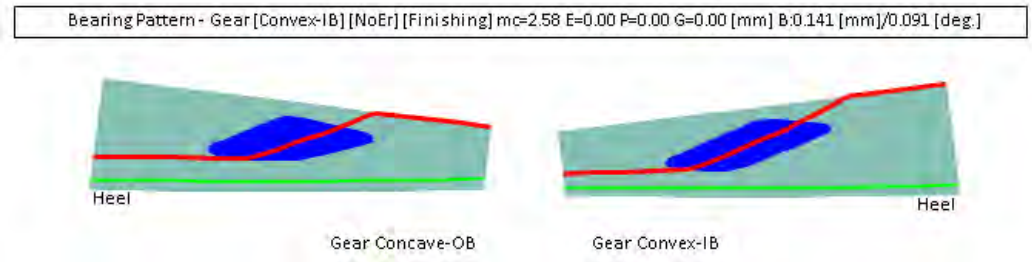
Up to 7 VH>> machine settings changes steps are currently allowed in HyGEARS, which should be sufficient for most applications.

Example:

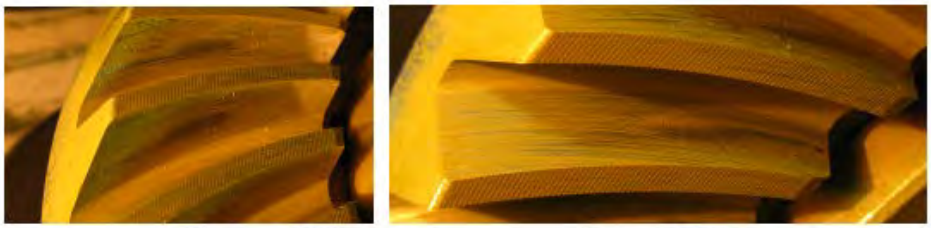
A 9x37 RH spiral bevel gear set is being developed. The gear member is already cut - but differs from the original design as shown below - and the pinion needs to be cut to mesh correctly with the gear.



The target contact patterns appear below:



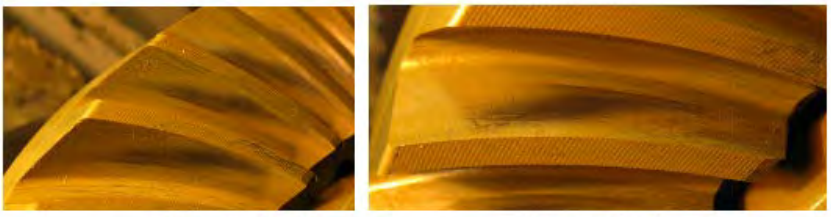
Upon running the gear set on the VH tester with the design MD (mounting distance), the contact patterns came out as show below, i.e Toe heavy on the gear convex flank, and a bit towards Heel on the gear concave flank:



Concave Flank **Convex Flank**

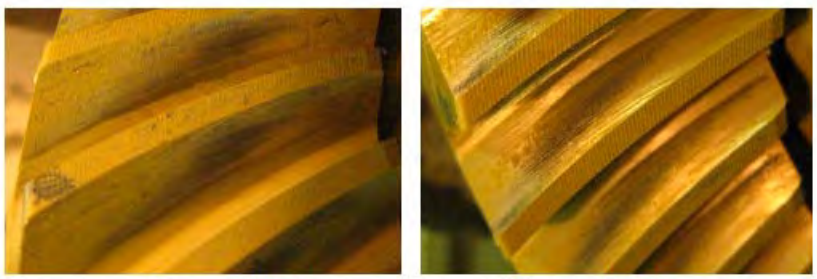
In order to center the contact pattern on the tester, the following E P G values were required, which yielded the contact patterns shown below:

- E: -0.62 mm
- P: +0.70 mm
- G: -0.35 mm



Concave Flank **Convex Flank**

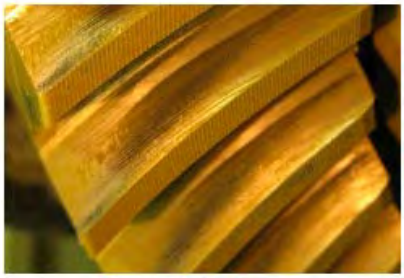
Using the VH>> function, the above values were entered in HyGEARS, a new pinion Summary was obtained and used to cut the pinion, and the following contact patterns were obtained on the gear:



Concave Flank **Convex Flank**

Clearly, the contact patterns went where desired by the developer at the 1st iteration.. The fact that the gear member was not cut to target does affect the precision of the solution, but does not prevent obtaining a good solution. Doing a 2nd iteration yielded the following result:

Concave Flank



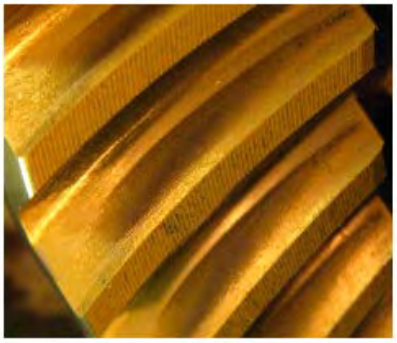
Convex Flank

Here, what would be needed is to :

- Reverse Engineer the gear to the CMM data using the HyGEARS *R.E.* function,
- develop the contact pattern by modifying the pinion machine settings using the HyGEARS *BPat* function,
- use the HyGEARS *VH>>* function as explained above.

Doing so, the results shown below are obtained after 1 iteration. Clearly, the results converge very quickly. A 2nd iteration could be applied in order to improve a bit more the contact pattern on the Concave flank.

Concave Flank



Convex Flank

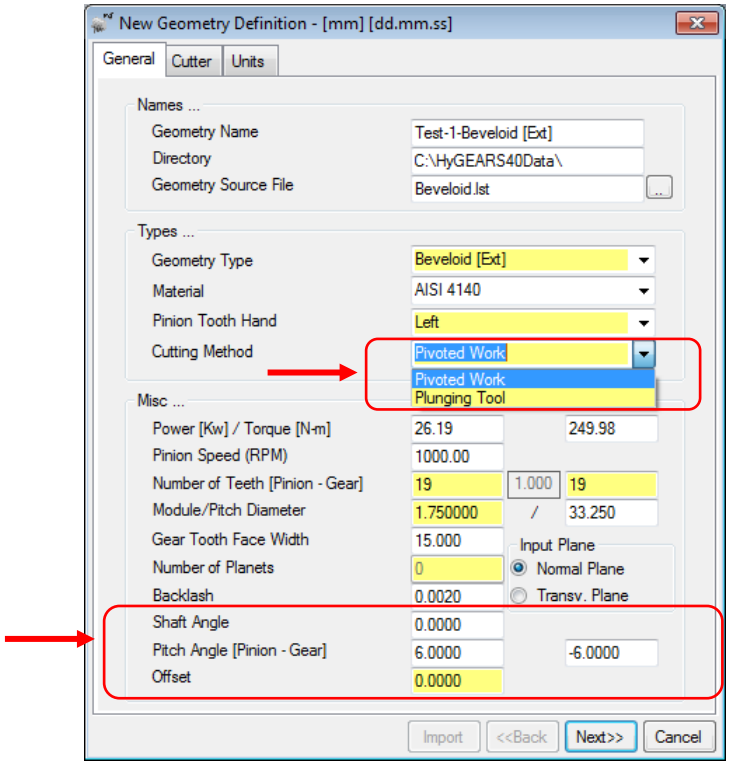
28) Addition of a 2nd manufacturing method for Beveloid gears [external].

Up to HyGEARS Build 405.80, [external] Beveloid gears were based on a *Pivoted Work*, i.e. the work piece axis would be pivoted by the specified pitch angle such that the tool would move in a straight direction that would be at an angle to the axis of the work.

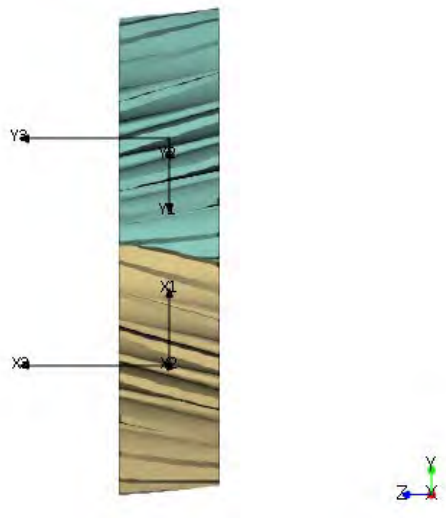
From Build 405.90, figure below, the *Plunging Tool* option is also offered where the axis of the work is installed in the machine as if cutting a spur gear, but the tool plunges progressively as the tool advances along the face width: in effect, the *Profile Shift* factor changes continuously as the tool moves along the face width.

The *Pivoted Work* approach produces a gear set which is slightly not-conjugate. In both cases, *Pivoted Work* and

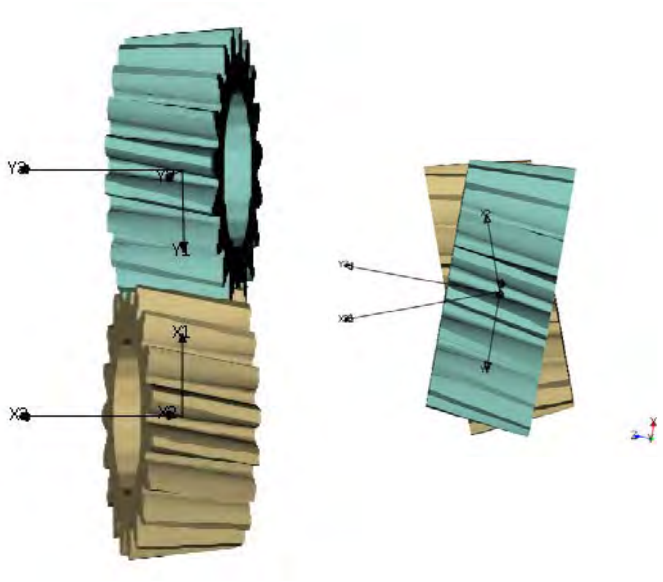
Plunging Tool, the helix and blades angles of the pinion are adjusted in order to center the Contact Pattern.



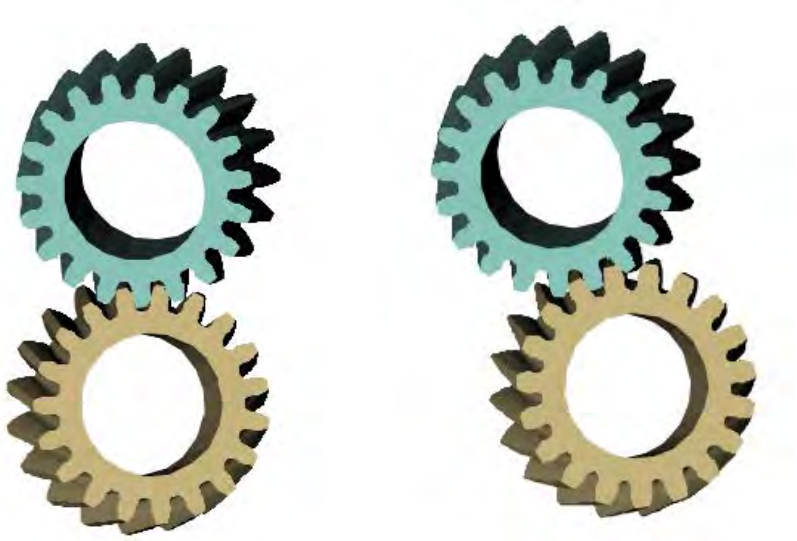
In addition, the Pitch Angle of both the Pinion and Gear can now be entered such that both members, or only 1, can be Beveloid, and can be of same value but opposite signs such that the axes of the Pinion and Gear are //, as is shown in the figure below.



Finally, a Shaft Angle and a Pinion Offset can be imposed. For example, figure below, the Pinion and Gear Pitch Angles are respectively +6 and -6 deg, and a 20 deg. Shaft Angle is imposed. The resulting parts have // axes in one plane (left, below), and non // axes in the perpendicular plane (right, below).



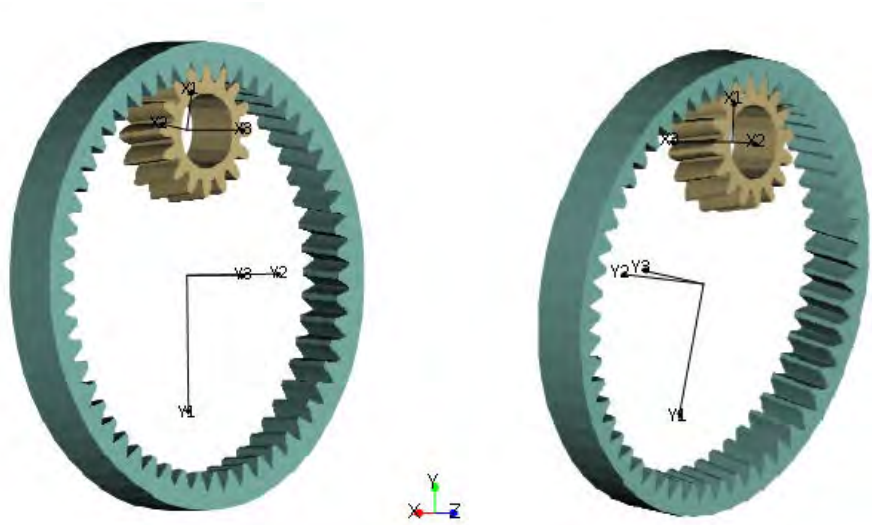
As another example, for the same Pinion and Gear Pitch Angles and Shaft Angle, the left gear set below has no Pinion Offset while the right gear set has a 10mm Pinion Offset.



0 mm Pinion Offset **10 mm Pinion Offset**

29) Introduction of *Internal Beveloid* gears [new HyGEARS option] where either the Pinion, Gear or both can be Beveloid, and cut either with a *Pivoted Work* or *Plunging Tool* like external Beveloid gears.

For example, left figure below, the Pinion has a -5 deg. Pitch Angle while that of the Gear is +5 deg. The end result is a gear set with // axes where shifting the Pinion axially allows backlash control. By contrast, right figure below, both the Pinion and Gear have the same Pitch Angle, and the result is a gear set where the axes are not //; however, shifting the pinion axially still allows backlash control.


X1
X2
X3
Y3
Y2
Y1
Y
X
Z