

## Bevel Gear Production Software



For Use With 5-Axis Machines For Low-Cost,  
Efficient, and Flexible, Production As Part of  
Industrial Revolution 4.0

## Presentation Contents

- Overview the DS Bevel software
- Current Software preview
  - Gear Design Pro - Bevel
  - Load Analysis Model – Bevel
  - Machine Centre (Manufacturing Simulation 5 Axis / G-Code)
  - Inspection Centre
  - Optimal Calculation
- Development of a Heat Treatment Model

## Overview of Dontyne Systems Bevel Software

- The Gear Design Pro has ISO/AGMA calc for sizing while Generic bevel gear design option produces the complex gear tooth surface data including micro-geometry
- The Load Analysis Model shows contact region of the gear pair under no load and transmission error under load
- The Machine Centre can design tooling and calculate machine path G-code for 5-axis as well as hobbing, grinding, shaping, shaving and even
- Measured data can be evaluated by Inspection Centre module
- Measured data can be used for tool optimisation by Optimal calculation

## Gear Design Pro - ISO/AGMA Design and Rating

Types Milled, Hobbed, Gleason, Klingelnberg, and Oerlikon can be sized and rated

The image displays two windows from the Dontyne Systems software interface for ISO 23509 Bevel Gear Design.

**Left Window: ISO 23509 Bevel Gear Geometry**

- ISO 23509 Input Method: Method 0 (Spiral bevel) Milling
- Shaft Angle: 90.000
- Hypoid Offset: -0.000 (Above/Below)
- Number of Teeth: 17
- Wheel Mean Pitch Diameter: 163.614
- Wheel Outer Pitch Diameter: 196.896
- Wheel Face Width: 23.384
- Mean Spiral Angle: 47.400
- Cutter Radius: 90.733 to 94.817
- Number of Blade Groups: 1
- Cutter Tip Radius: 1.000
- Additional Data for Dimensions (Data Type II):
  - Nominal Design Pressure Angle (Drive): 20.000
  - Nominal Design Pressure Angle (Coast): 20.000
  - Influence Factor of Limit Pressure Angle: 1.000
  - Mean Addendum Factor: 0.283
  - Depth Factor: 2.000
  - Thickness Factor: 0.059
  - Clearance Factor: 0.125
  - Outer Normal Backlash: 0.200
  - Addendum Angle of Wheel: 1.662
  - Dedendum Angle of Wheel: 3.434

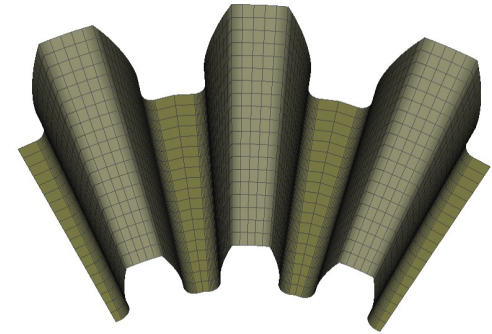
**Right Window: ISO 23509 Bevel Gear Sizing**

- Depthwise Taper: Standard
- Addendum Angle of Wheel: 1.662
- Dedendum Angle of Wheel: 3.434
- Sum of Dedendum Angles: 5.097
- Cutter Radius (max): 94.817
- Cutter Radius (min): 76.774
- Cutter Radius (standard inch): 3.5" 88.9 mm

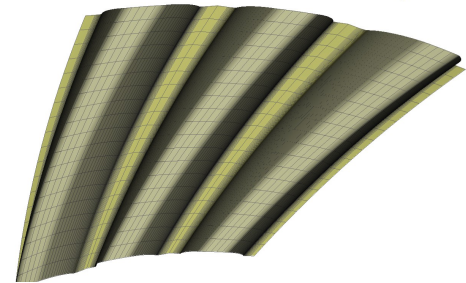
The Sizing window also features diagrams illustrating different taper and slot width options: Standard Taper, Uniform Taper, Constant and Modified Slot Width, and Root Line tilt.

## Types of Gear That Can be Exported

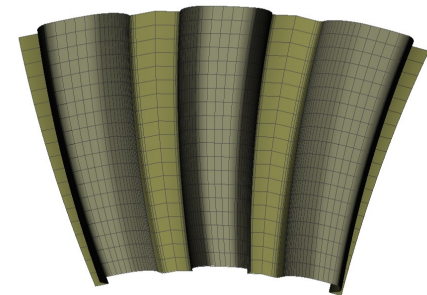
Straight bevel



Spiral Bevel

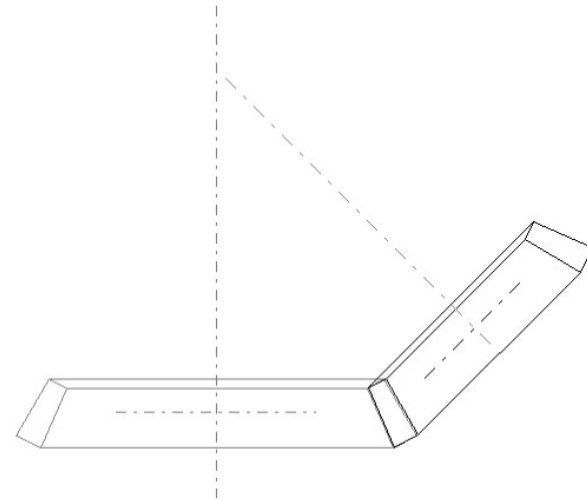
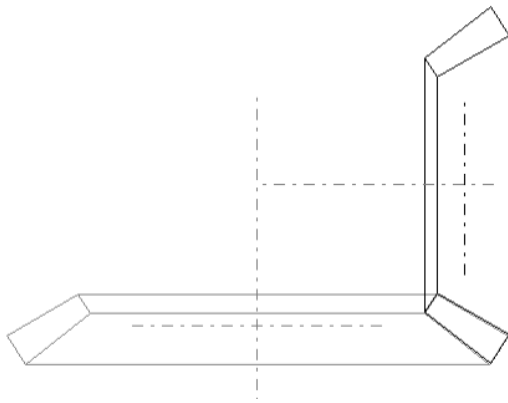


Zerol Bevel

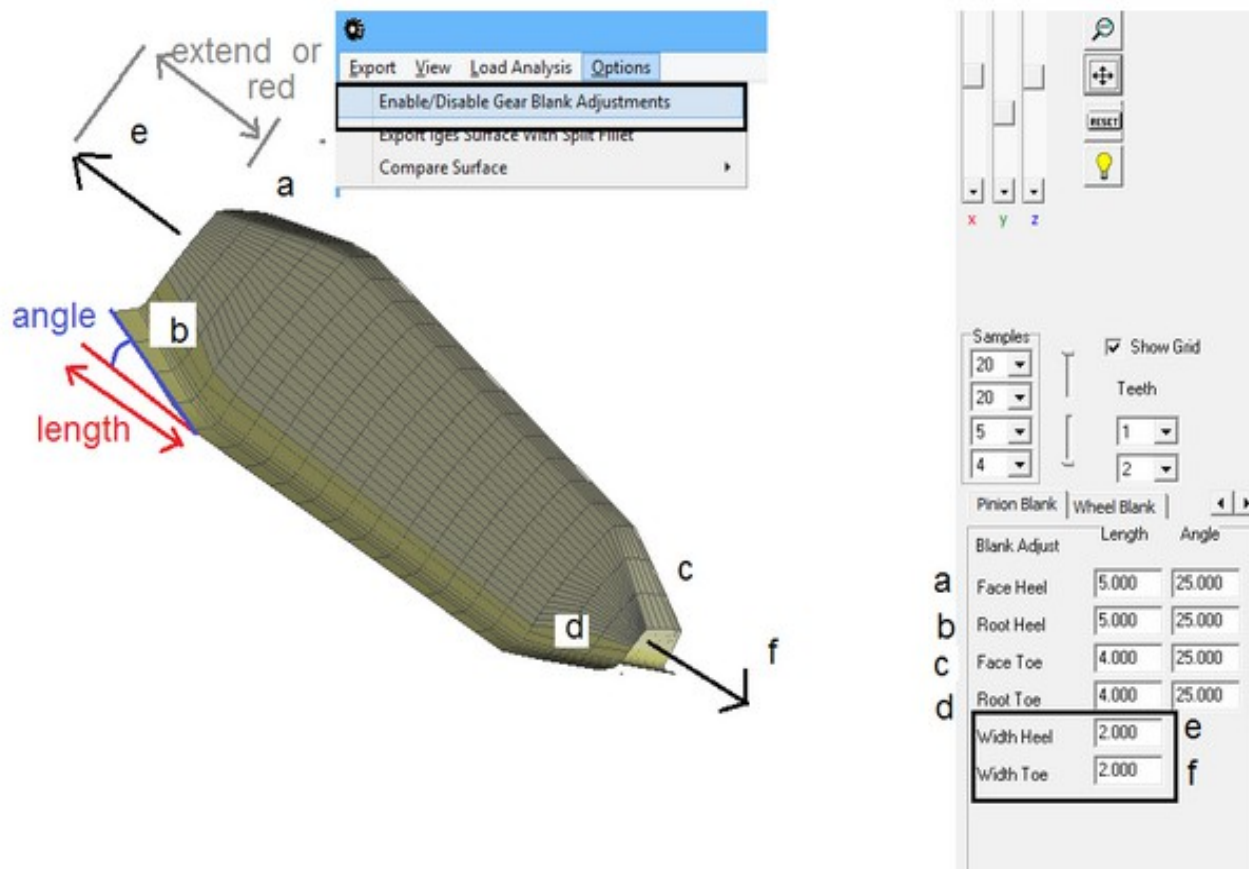


# Types of Gear That Can be Exported

90 degree shaft angle or other



## Gear Design Pro



Design tooth can be cropped (a,b,c,d) or extended at toe or heel in Gear Production Suite pair editor reducing potential for error after reworking in export to CAD

## Gear Design Pro

The screenshot displays the 'Generic Spiral Bevel Gear Geometry' software interface. The left panel contains input fields for PINION and WHEEL parameters. The right panel lists various gear geometry parameters. A 3D model of a gear tooth is shown on the right, with red boxes highlighting the fillet coefficients at the toe and heel.

**Software Parameters:**

Parameter	Value
Name	Item_6
Shaft Angle	90.000
Number of Teeth	21
Module (mean normal)	3.444
Pitch Diameter (mean)	72.333
Face Width	22.225
Pressure Angle	20.000
Spiral Angle (mean)	0.000
Radius for Spiral	
Pitch Angle	45.000
Face Angle	48.853
Root Angle	40.550
Circ. Thickness (mean norm)	5.411
Backlash (mean normal)	-0.000
Outer Addendum	4.193
Outer Dedendum	4.849
Root Fillet Coeff. (rhof/m_mn)(Toe)	0.200
Root Fillet Coeff. (rhof/m_mn)(heel)	0.200

**Geometry Parameters:**

Parameter	Value
Shaft Angle	
Number of Teeth	
Outer Transverse module	
Outer Pitch Diameter	
Nom. Press. Ang.	
Mean Spiral Angle	
Face Width	
Pitch Angle	
Face Angle	
Root Angle	
Outer Addendum	
Outer Dedendum	
Outer Whole Depth	
Outer Trans Circ Thickness	
Outer Pitch Cone Distance	
Mean Normal Module	
Mean Pitch Dia	
Mean Cone Distance	
Mean Addendum	
Mean Dedendum	
Mean Whole Depth	
Mean Norm Circ Thickness	
Mean Trans Circ Thickness	
Normal Chordal Thickness	
Mean Chordal Addendum	
Addendum Modification Coeff.	
Inner Addendum	h <sub>ai</sub> 2.696
Inner Dedendum	h <sub>fi</sub> 3.119
Inner Whole Depth	h <sub>i</sub> 5.815
Inner Pitch Cone Distance	R <sub>1</sub> 40.035

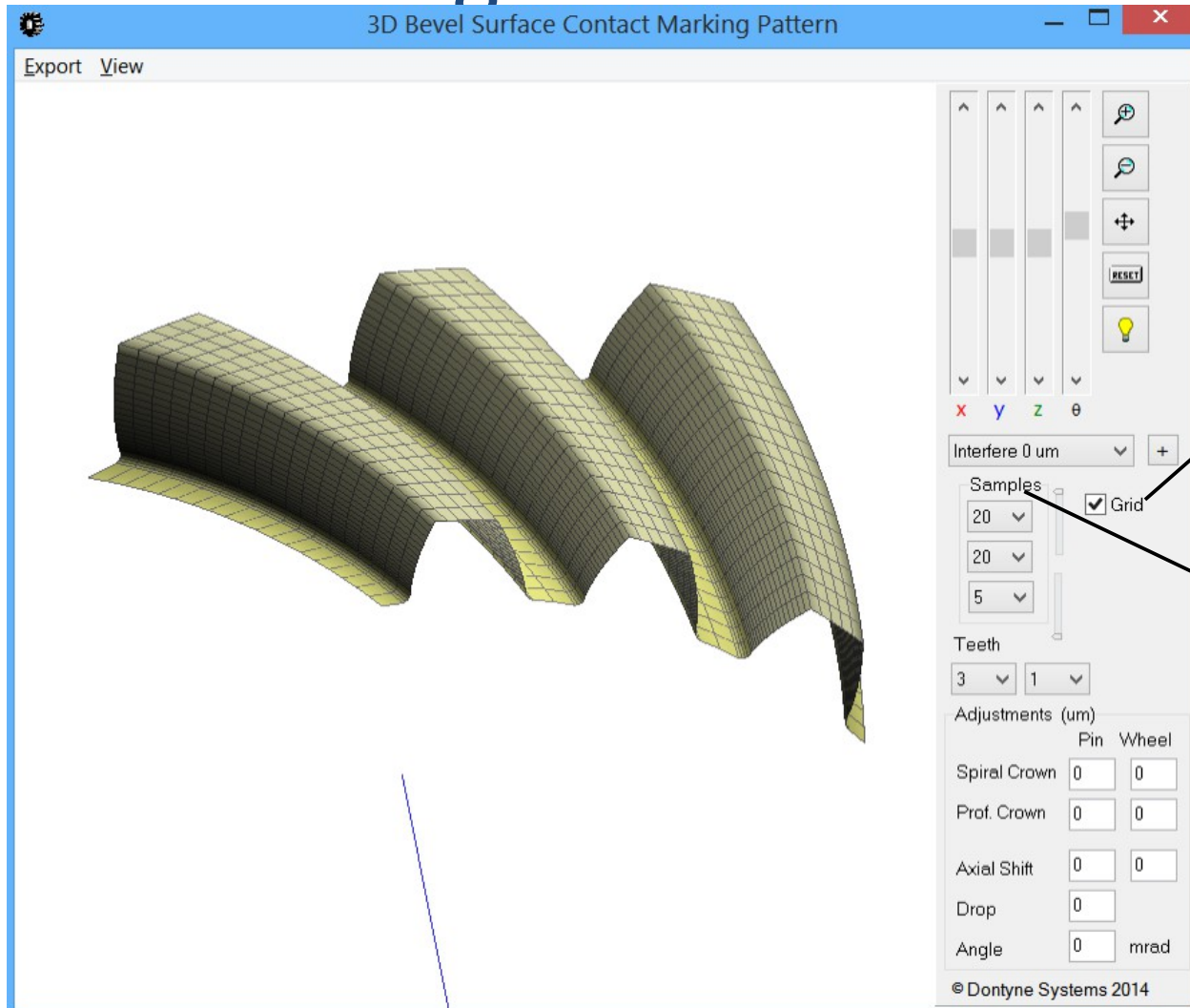
**Root Fillet Coefficients:**

Location	Value
Root Fillet Coeff. (rhof/m_mn)(Toe)	0.482
Root Fillet Coeff. (rhof/m_mn)(heel)	5.030

Gleason Strength Factors included in report - Flexible root design for optimum root strength – constant or variable from toe to heel



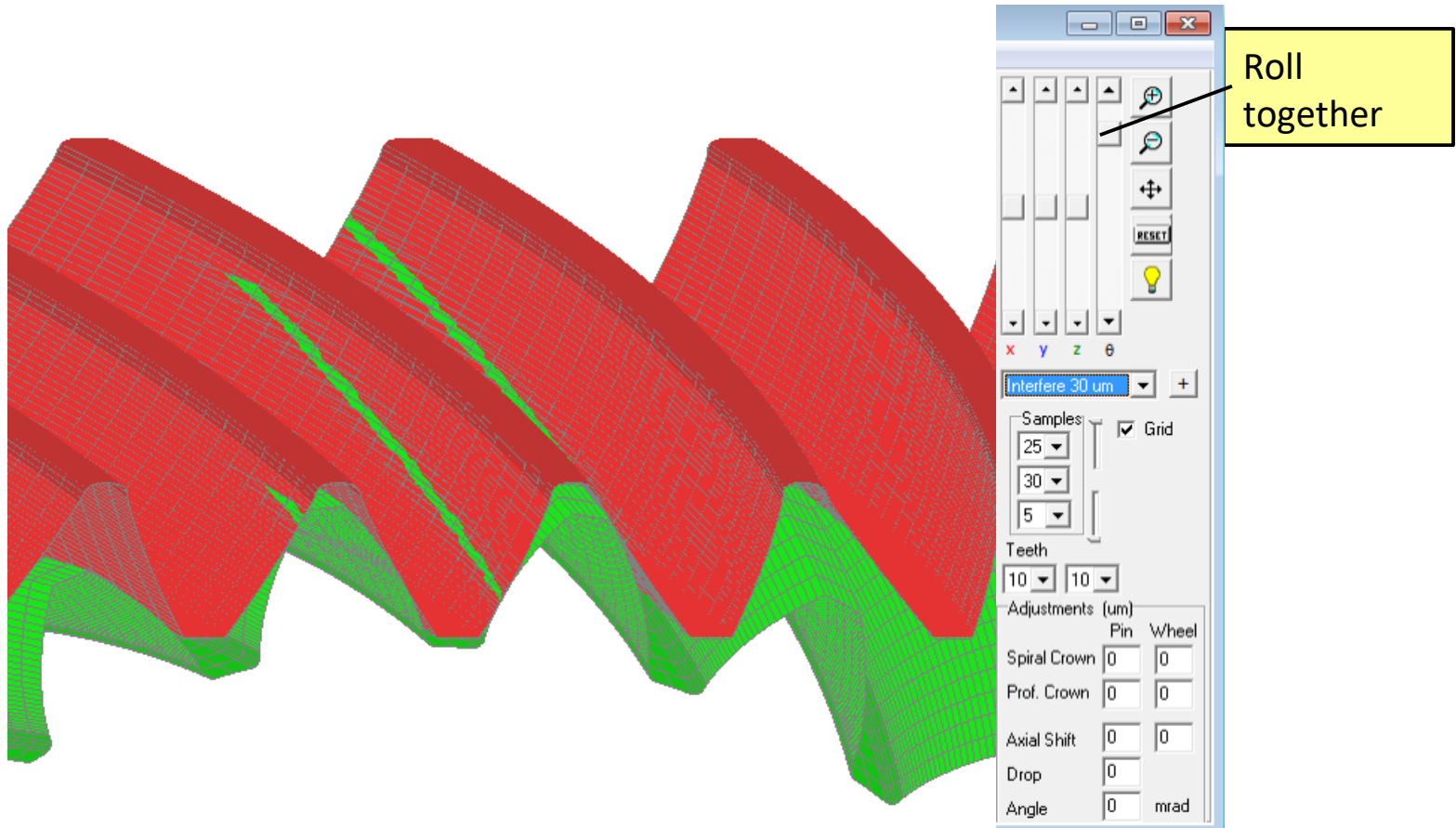
## Gear Design Pro - Generic



Grid

Samples

## Gear Design Pro - Generic



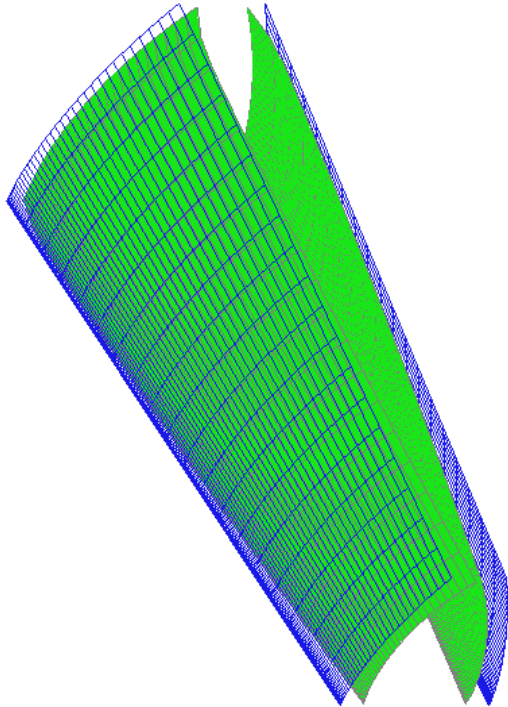
## Gear Design Pro – Micro Geometry

3D Bevel Surface Contact Marking Pattern

Export View

Modifications overlay pinion x 10

No load 0



Interfere 0 um

Samples: 20, 40, 0, 0

Grid

Teeth: 1, 1

Adjustments (um)	Pin	Wheel
Spiral Crown Heel	40	0
Spiral Crown Toe	60	0
Ctr Offset %	40	0
Prof. Crown Tip	20	0
Prof. Crown Root	20	0
Ctr-Ht Offset %	0	0

Calculate

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## Gear Design Pro – Micro Geometry

Calculate mirco-geometry values from definition of required marking

3D Bevel Surface Contact Marking Pattern

No Load Marking Pattern Pinion  
Thickness 10 um

Calculate

Run Analysis For Current Settings

Call Window to Define Required Marking Pattern

Adjustment (m)	Pin	Wheel
Spiral Crown Seal	17	0
Spiral Crown Toe	12	0
Cr Offset %	0	0
Prof. Crown Tip	12	0
Prof. Crown Root	18	0
Cr-Hi Offset %	0	-0

Use Measured Data

Desired Marking Pattern (PINION)

A B

C D

Thickness 10 um

A= 15% B= 15%

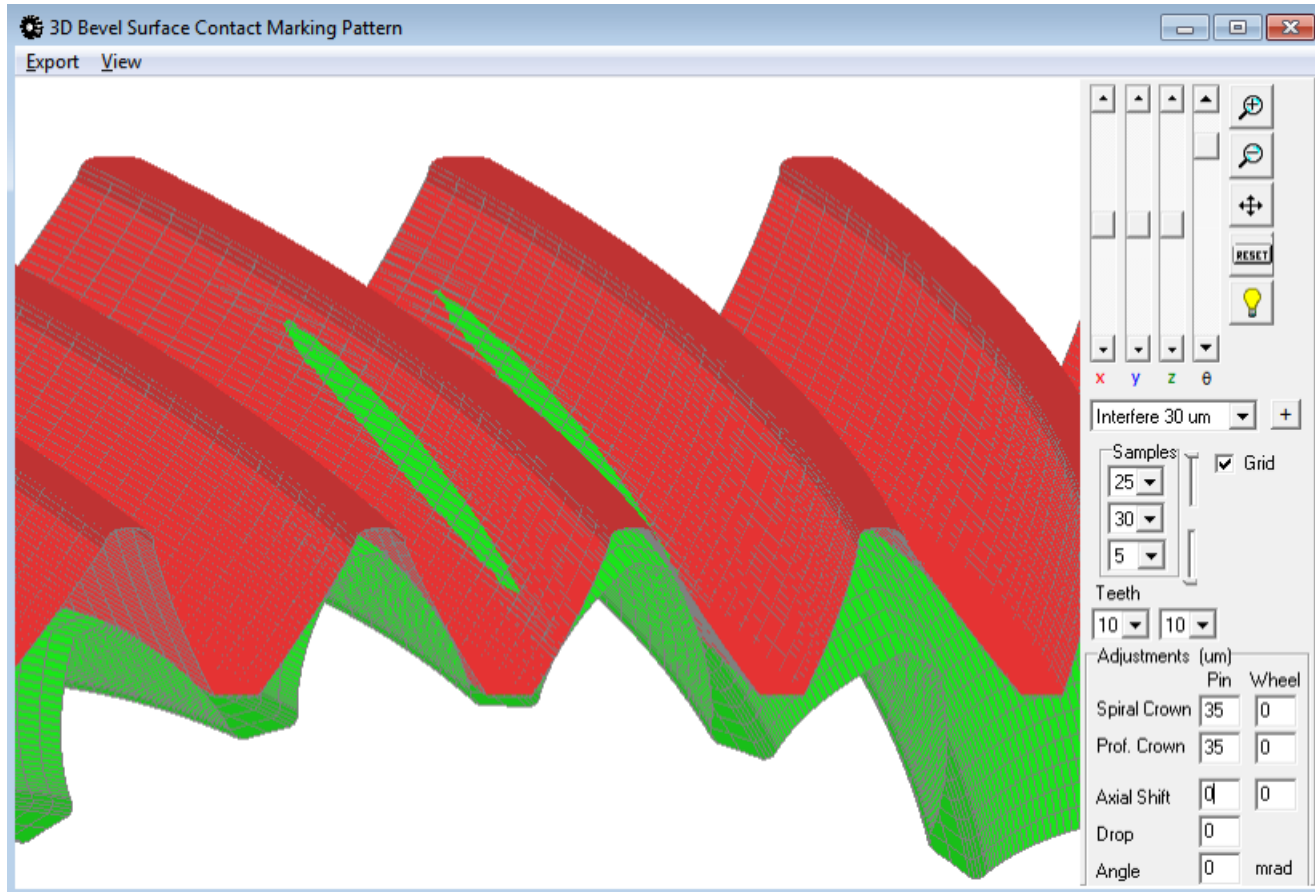
Apply To  
 Pinion  Wheel  Both

C= 15% D= 15%

OK Cancel

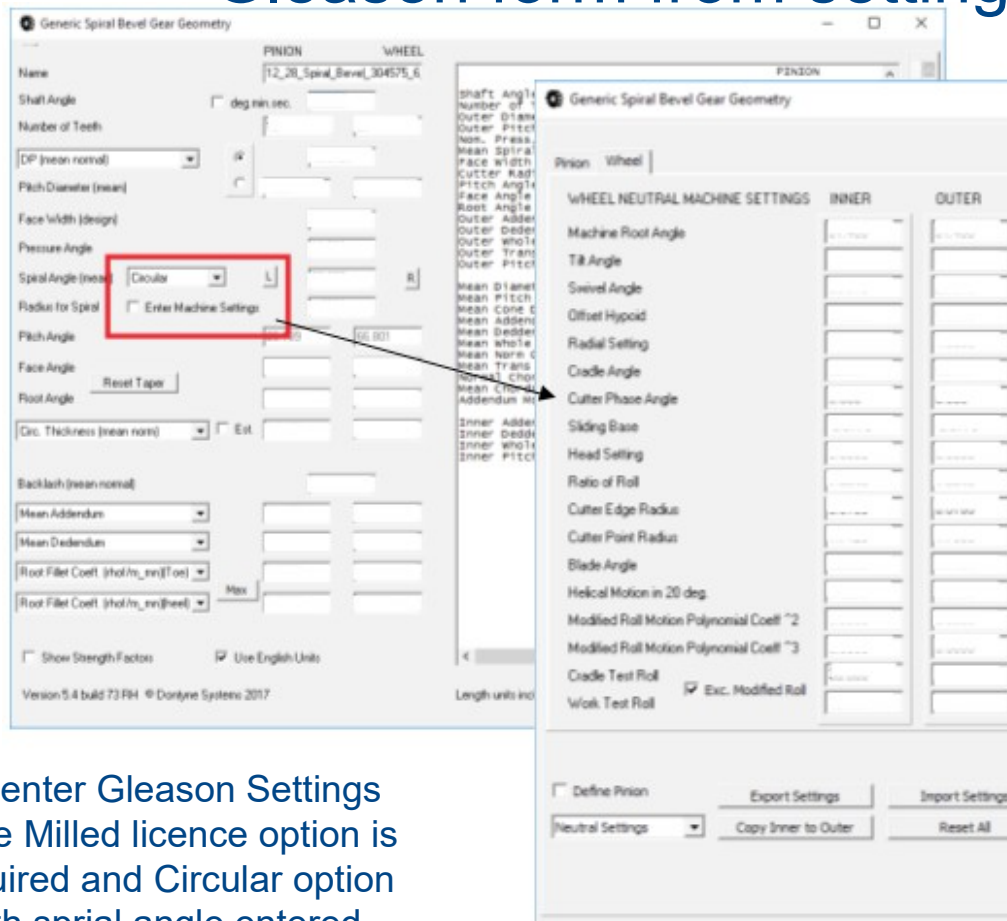
Calculated Mirco Geometry Settings Returned To Load Model For Analysis

## Gear Design Pro – Micro Geometry





## Gear Design Pro – Micro Geometry Gleason form from setting sheet



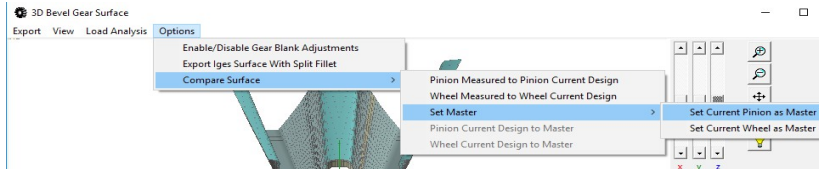
### IMPORTANT!

1. The software does not calculate settings required to achieve a design, but calculates tooth form based on parameters entered
2. The nominal values are often changed from those the issued documents by production to achieve specific customer contact conditions

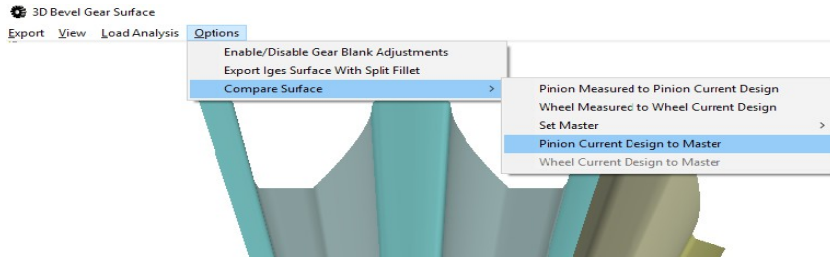
To enter Gleason Settings Face Milled licence option is required and Circular option with spiral angle entered

## Gear Design Pro – Micro Geometry

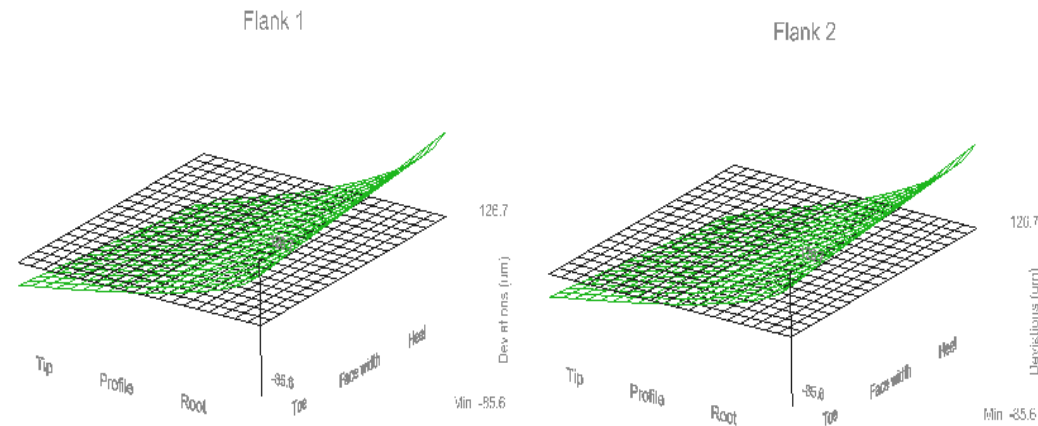
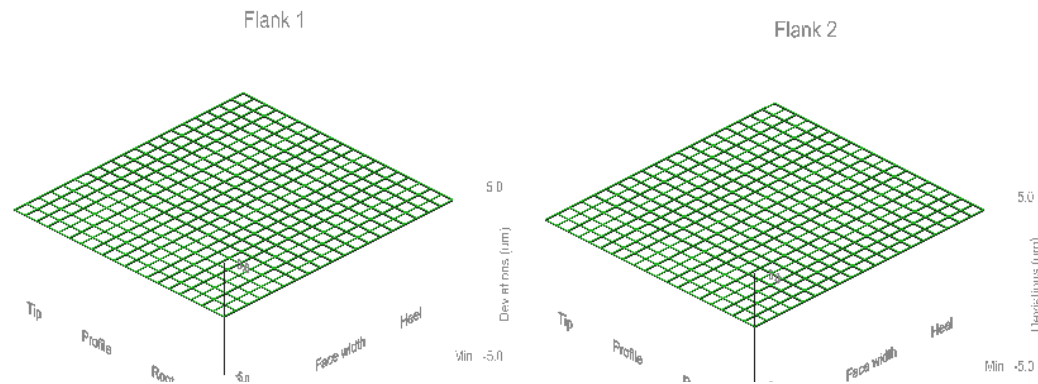
Determine changes due to changes in design or machine settings



Choose the set as master from the menu to set current design or measured surface as reference



Any changes in micro-geometry due to design, machine settings, and measured data relative to stored reference can be viewed

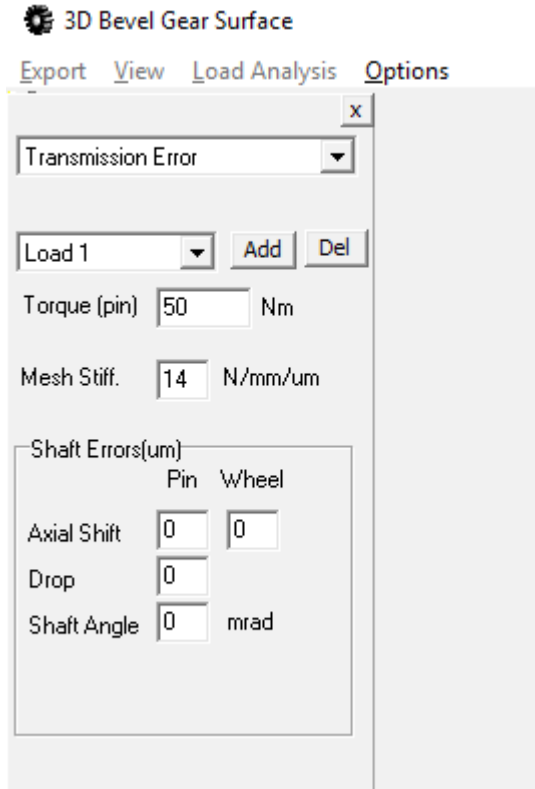


# Tooth Contact Analysis

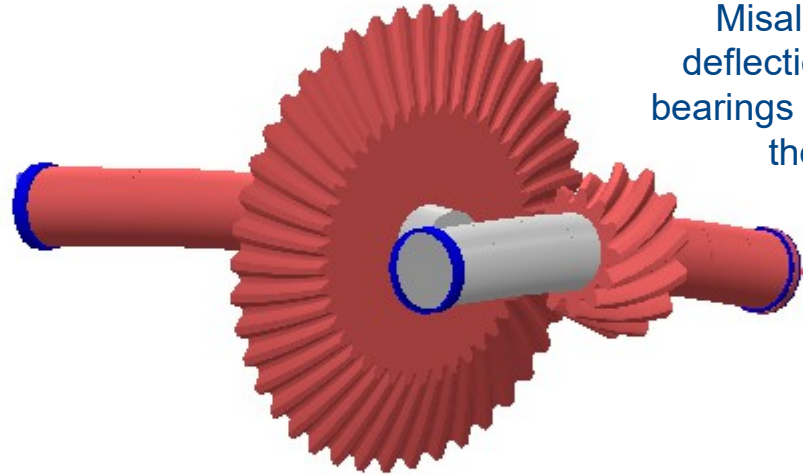
- No-Loaded and Loaded tooth contact analysis
- Transmission error calculations
- Alternative root fillet shapes other than circular
- Consideration of tooling
- Direct links measurement data



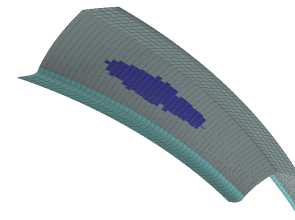
## Tooth Contact Analysis



Load Analysis (Standard) can model deflections in 4 axes at several different load cases



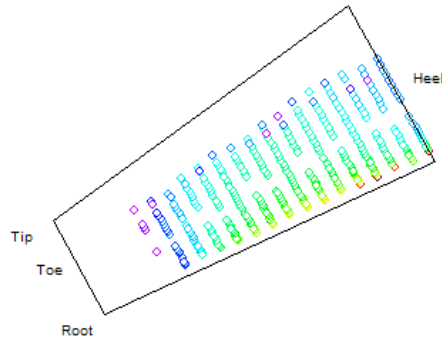
Misalignment is caused by deflection in casing, shaft, and bearings as well as deformation of the tooth under load



Micro-geometry (small changes to the theoretical surfaces) are designed to avoid tooth edge contact or noise and vibration otherwise due to deflection under load

## Tooth Contact Analysis

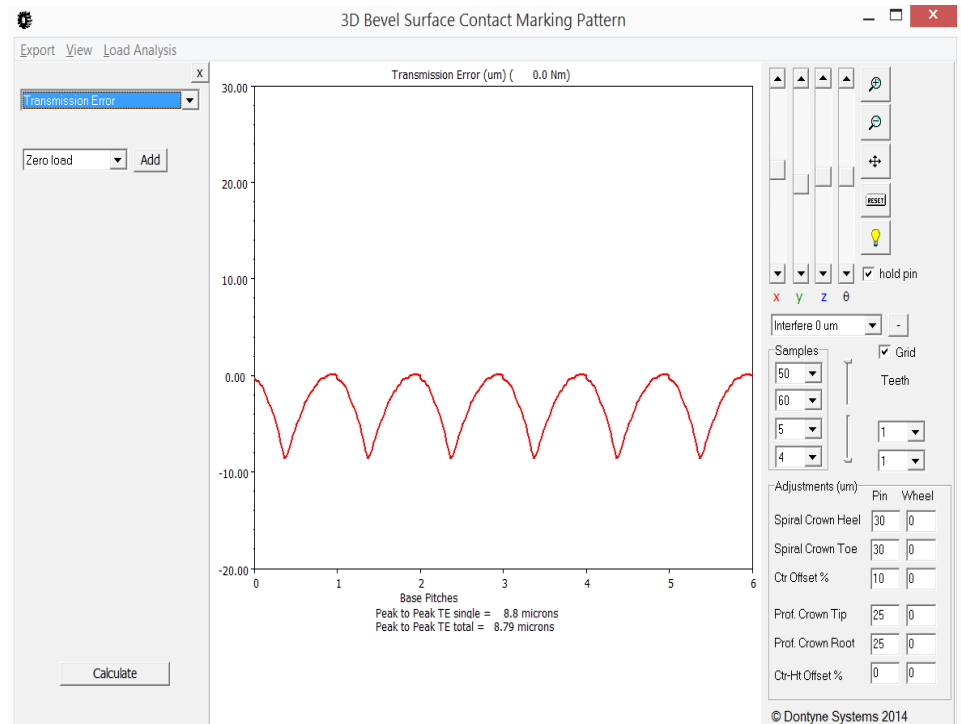
Contact Stress (MPa) (load1 100.0 Nm)



Effect of Shaft alignment on loaded stress results

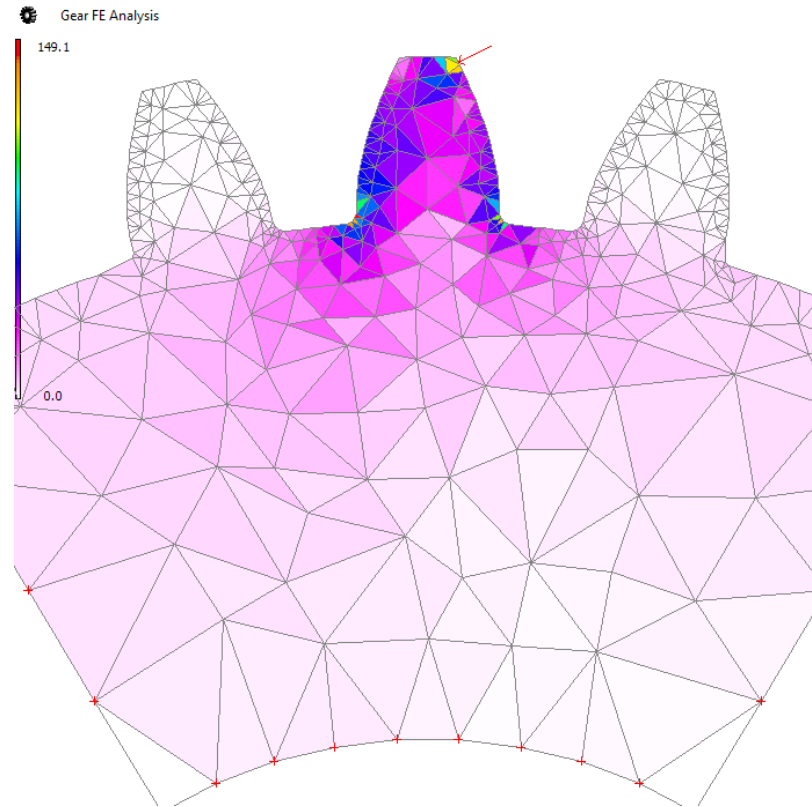
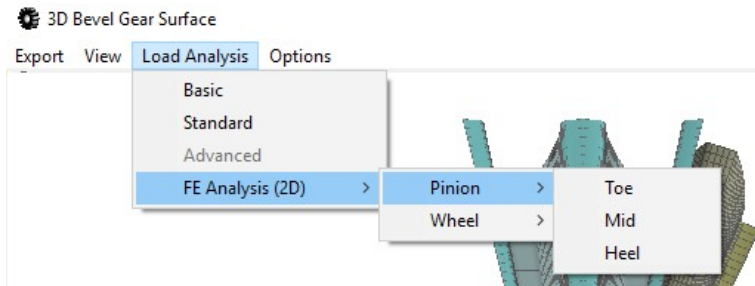


Contact Stress



Transmission Error

## Tooth Contact Analysis



Bending Stress can be analyzed in normal plane through toe, middle, or heel (straight bevel only)

## Gear Design Pro - Data Export

DXF 3D line grid

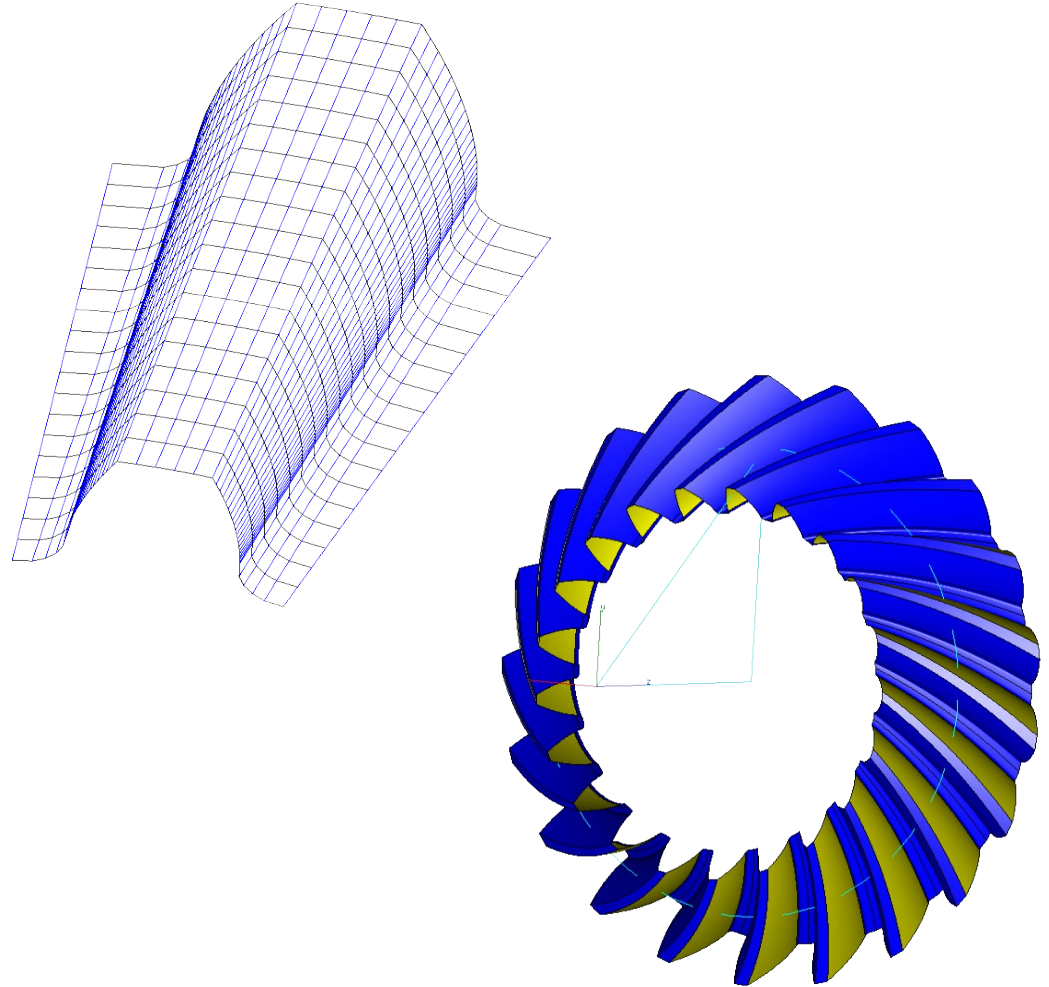
ASCII X,Y,Z N

IGES B-spline surface

G-Code (Mazak, Okuma,  
Makino, etc)

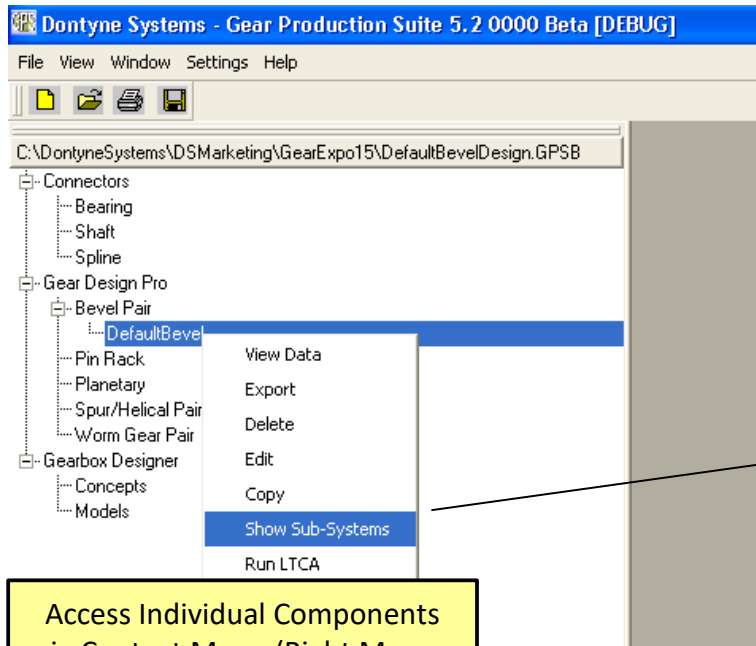
Inspection Systems CMM  
(Carl Zeiss, Mitutoyo, IMS,  
Renishaw, etc)

Gear Checker (Osaka  
Seimitsu, Klinglenberg)

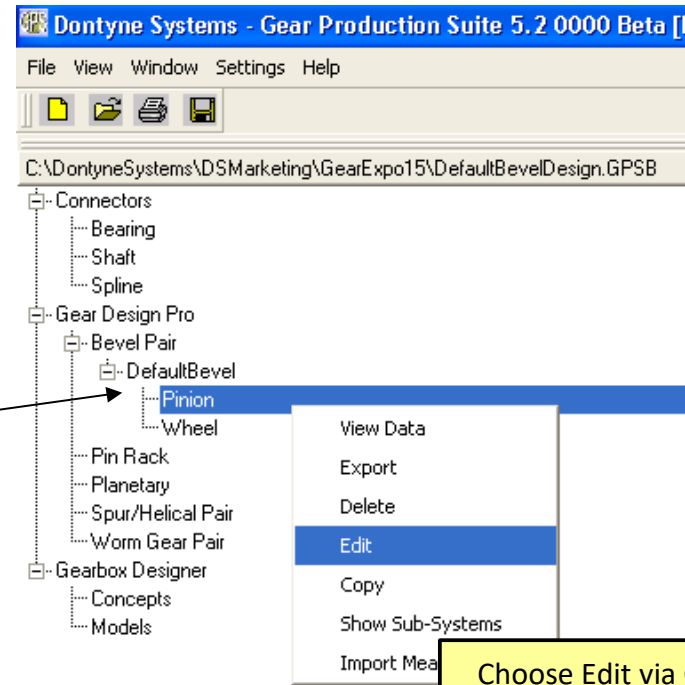


## Tool Design

Die tool for forging - Tool Definitions can be derived from gear



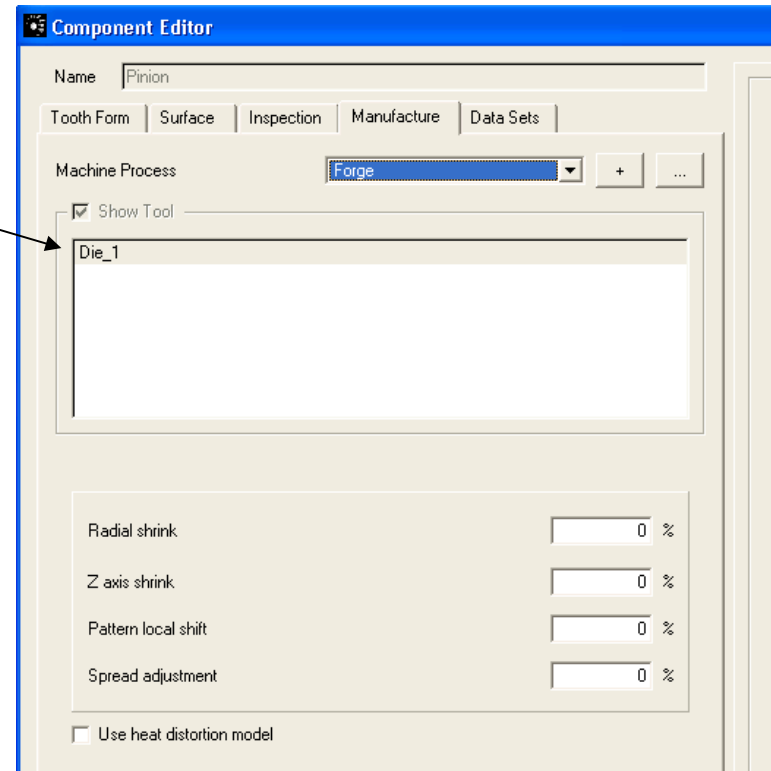
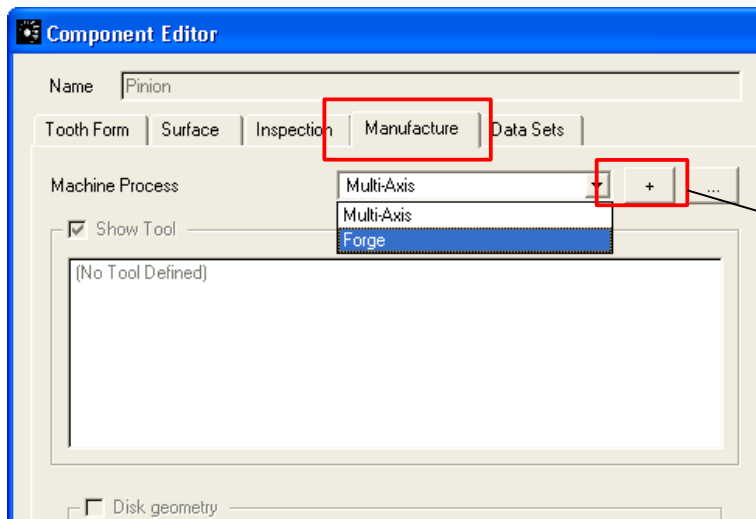
Access Individual Components via Context Menu (Right Mouse Click)



Choose Edit via Context Menu (Right Mouse Click) To Access Component Details

## Tool Design

Choose process available for gear type and create tool



## Tool Design

Choose process available for gear type and create tool

The image displays two screenshots of the 'Component Editor' software interface, illustrating the steps to create a tool for a gear type.

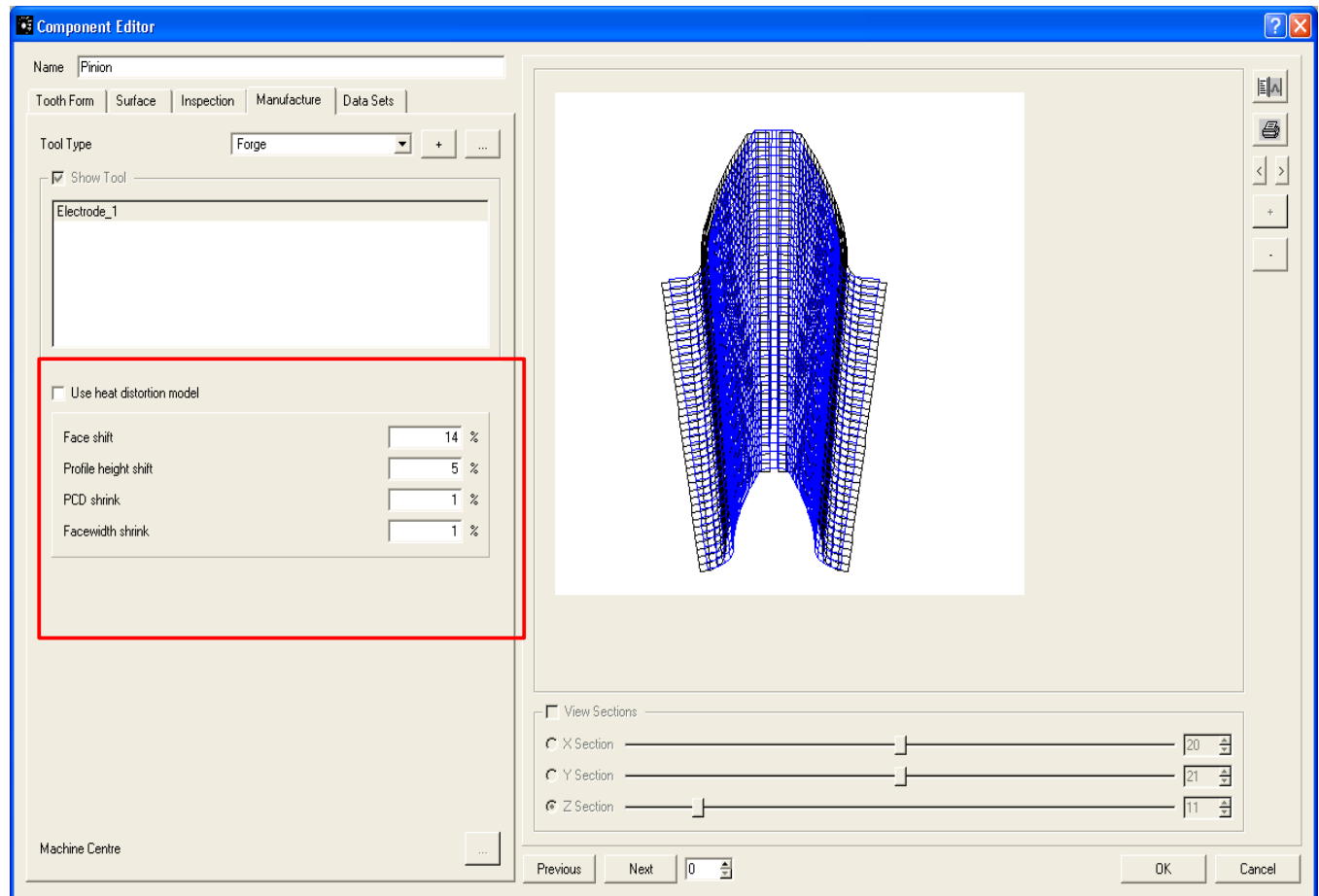
**Left Screenshot:** The 'Manufacture' tab is selected in the 'Machine Process' dropdown menu. A red box highlights the '+' button next to the dropdown. A yellow callout box states: "Select 'Manufacture' Tab To Access Process Options".

**Right Screenshot:** The 'Forge' process is selected. A default tool named 'Die\_1' is created. A red box highlights the tool design options, which include: Radial shrink (0%), Z axis shrink (0%), Pattern local shift (0%), Spread adjustment (0%), and a checkbox for 'Use heat distortion model'. A yellow callout box states: "Pressing '+' Creates a Default Tool Based on Gear Geometry".

**Bottom Callout:** A yellow callout box states: "Tool Design Options for Given Tool Type Are Shown".

## Tool Design

Die tool for forging - tool definitions can be derived from gear

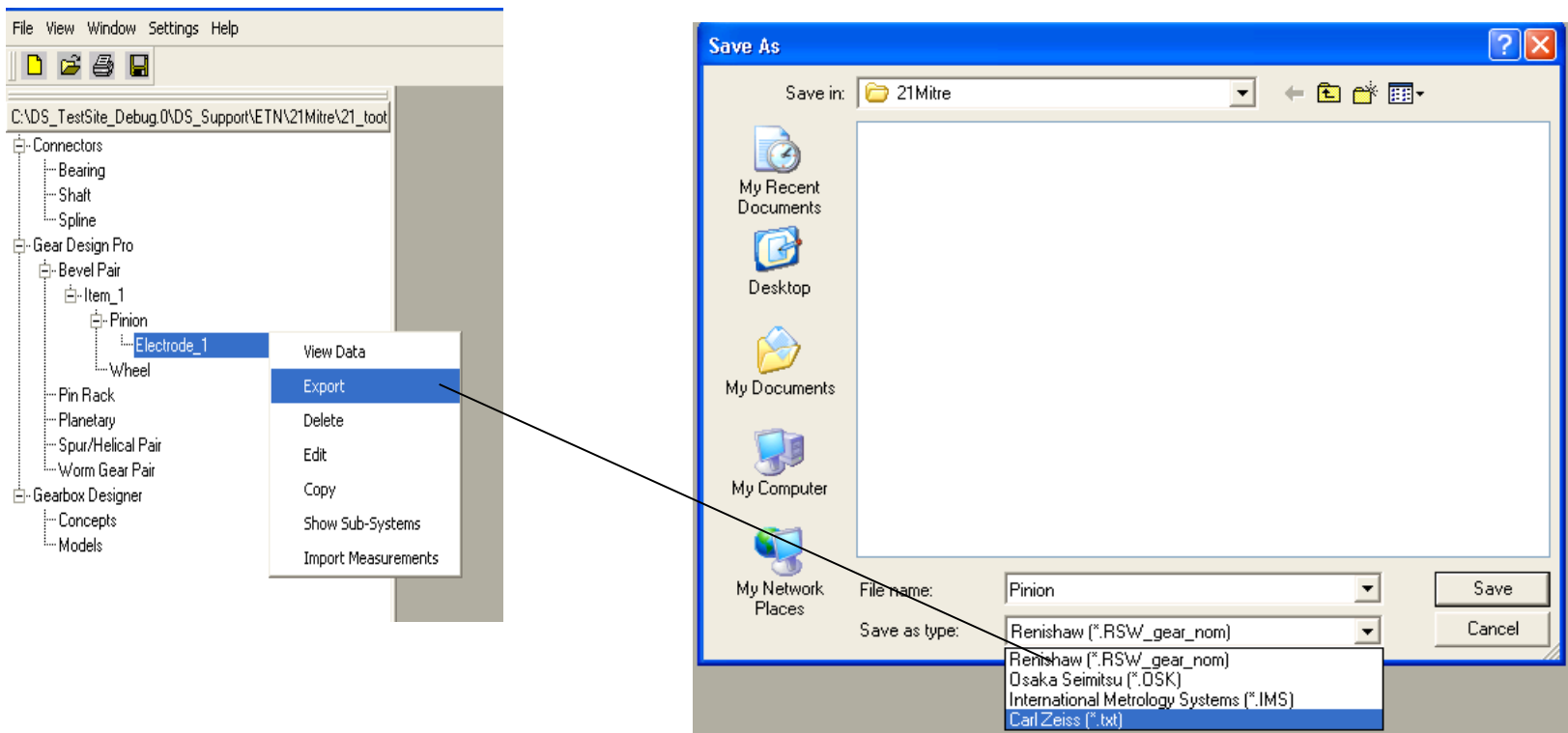


Factors applied to gear form to define die which can also compensate for heat shrinkage



## Tool Design

Tool can be exported from different formats



Gear and tool data can be exported to various inspection machines

## Machine Centre

Virtual 5-Axis simulation defines various machines, tools, and cutting options

Simulation of 5-Axis process to cut tooth using end mill, fast flexible production of prototypes and small batch

Export G-Code to file

Rotary Axis Designation Letter  
 A  B  C

CutterTilt Axis Designation Letter  
 A  B  C

Rotary Table Axis Rotation  
 CW  CCW

Cutter Head Axis-A Rotation  
 CW  CCW

Cutter Head Axis-A Datum  
 X-Zero  Z-Zero

Rotary Table Axis Datum  
 Fixed  Rot. with Table

Tooth Position  
 0 deg.  180 deg.

Rotary Table Angle Definition  
 +180 to -180  
 0 to 360 (M115 M116)

Swap X Axis  
 X  Y  Z  
 -X  -Y  -Z

Swap Y Axis  
 X  Y  Z  
 -X  -Y  -Z

Swap Z Axis  
 X  Y  Z  
 -X  -Y  -Z

Mean Cone Distance	51.147
X distance to Mean Point	36.166
Z Mean Point to Pitch Cone	36.166
Z Pitch Cone from Datum	0.000
Z mean Point from Datum	-36.166

Linear 5.dp    Angle 5.dp

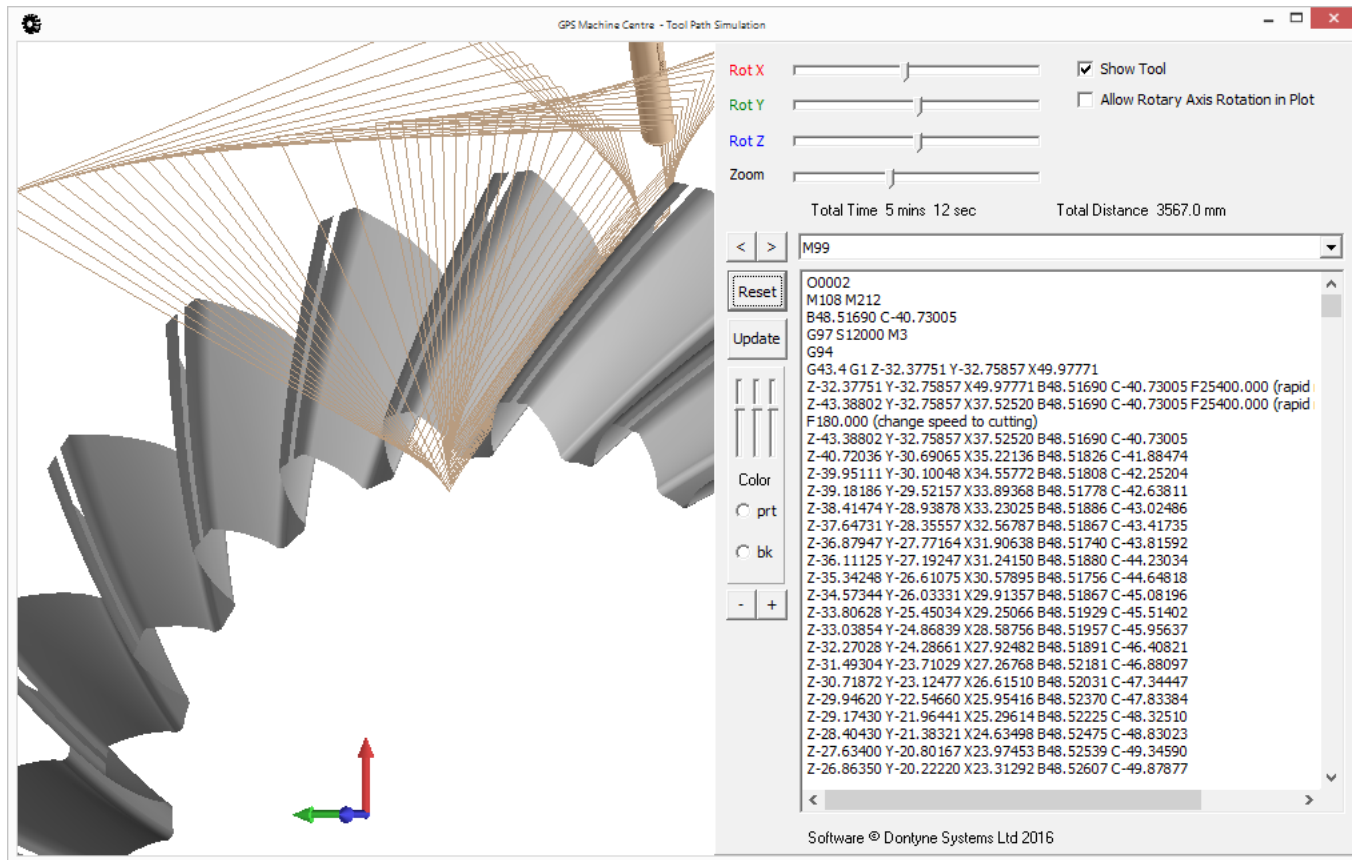
4 Axis (Mount Angle)

Restore Default Co-ordinate Setup

All length units in mm unless stated otherwise

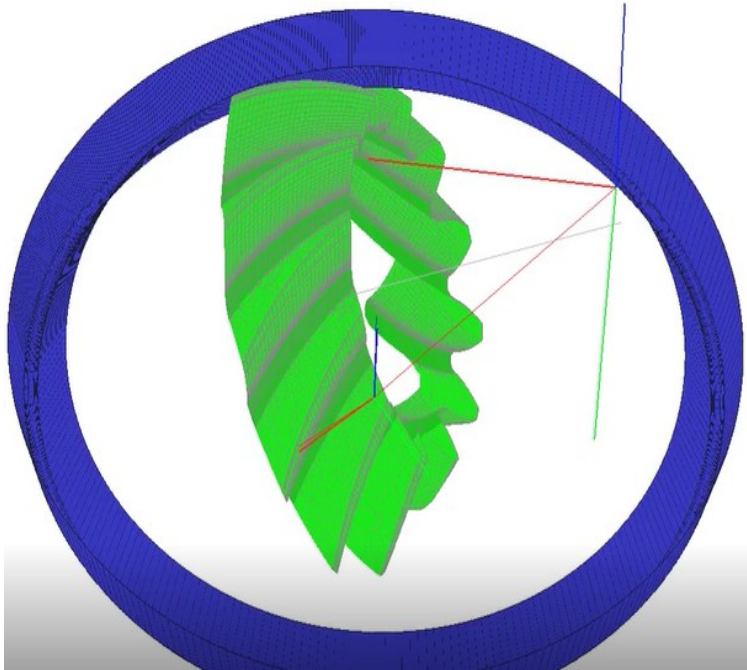
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## Machine Centre



G-Code Calculation can be exported to \*.EIA file

## Machine Centre



Generic Spiral Bevel Gear Geometry

Pinion Wheel

WHEEL NEUTRAL MACHINE SETTINGS

Machine Root Angle

Tab Angle

Swivel Angle

Distal Hipad

Radial Setting

Grade Angle

Outer Phase Angle

Sliding Base

Head Setting

Ratio of Roll

Cutter Edge Radius

Cutter Point Radius

Blade Angle

Helical Motion in 20 deg

Modified Roll Motion Polynomial Coef. "2"

Modified Roll Motion Polynomial Coef. "3"

Grade Test Roll

Work Test Roll  In - Modified Roll

INNER OUTER

46.146 46.146

Pinion Wheel

	PINION	WHEEL
Shaft Angle	SIGMA	21
Number of Teeth	z	21
Outer Transverse module	m_et2	4.193
Outer Pitch Diameter	d_e	88.048
Nom. Press. Ang.	alpha_n	20.000 (R)
Mean Spiral Angle	beta_m	20.000 (L)
Face width	b	22.225
Cutter Radius	r_co	30.000
Pitch Angle	delta	45.000
Face Angle	delta_a	48.853
Root angle	delta_r	40.550
Outer Addendum	h_ae	3.985
Outer Dedendum	h_fe	4.101
Outer Whole Depth	h_e	8.087
Outer Trans Circ Thickness	s_et	6.586
Outer Pitch Cone Distance	R_e	62.260
Mean Normal Module	m_nm	3.237
Mean Pitch Dia	d_m	72.333
Mean Cone Distance	R_m	51.147
Mean Addendum	h_am	3.237
Mean Dedendum	h_fm	3.236
Mean Whole Depth	h_m	6.473
Mean Norm Circ Thickness	s_nm	5.084
Mean Trans Circ Thickness	s_mt	5.411
Normal Chordal Thickness	s_mnc	5.083
Mean Chordal Addendum	h_mnc	3.275
Addendum Modification Coeff.	x_m	0.0001
Inner Addendum	h_ai	2.489
Inner Dedendum	h_fi	2.372
Inner Whole Depth	h_i	4.860
Inner Pitch Cone Distance	R_i	40.035

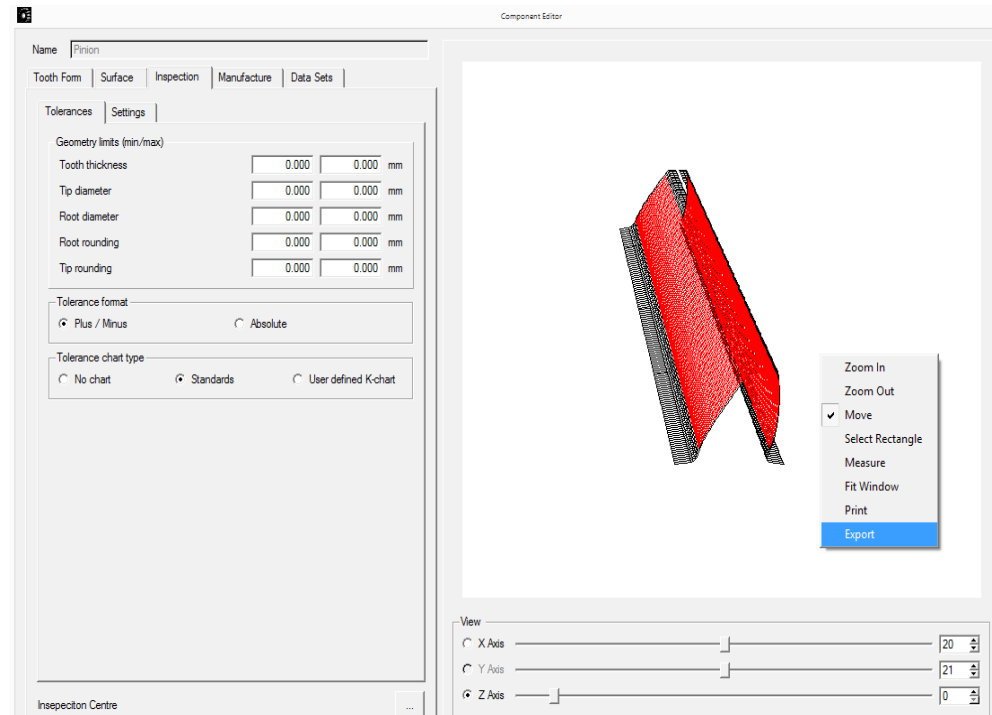
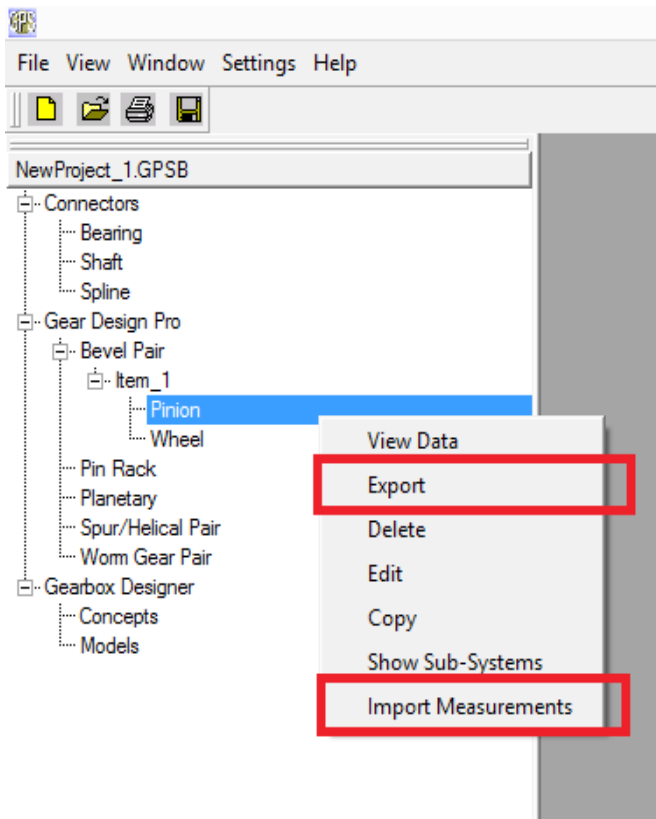
Length units are unless stated otherwise

OK Cancel

Face Milled option calculates tool form and G-code for production on 5-axis for medium and large batch sizes

## Inspection Centre

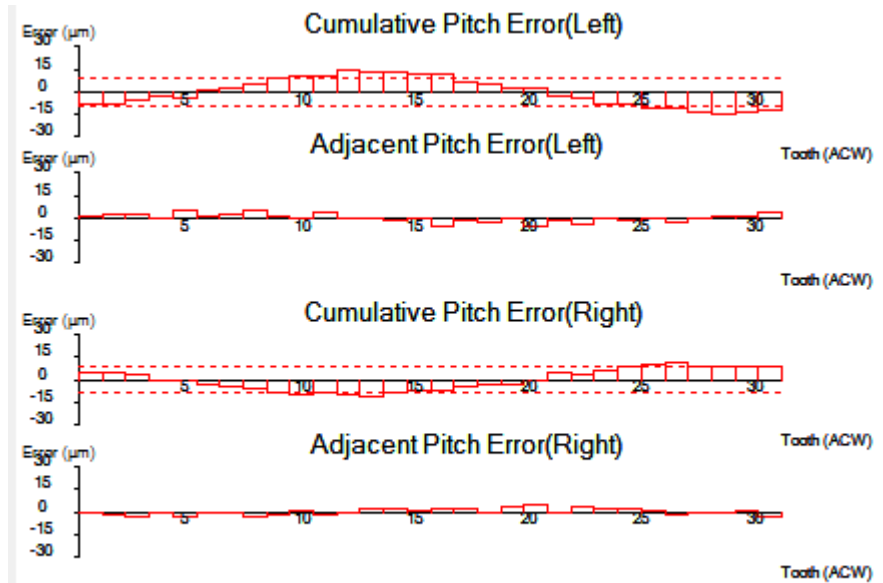
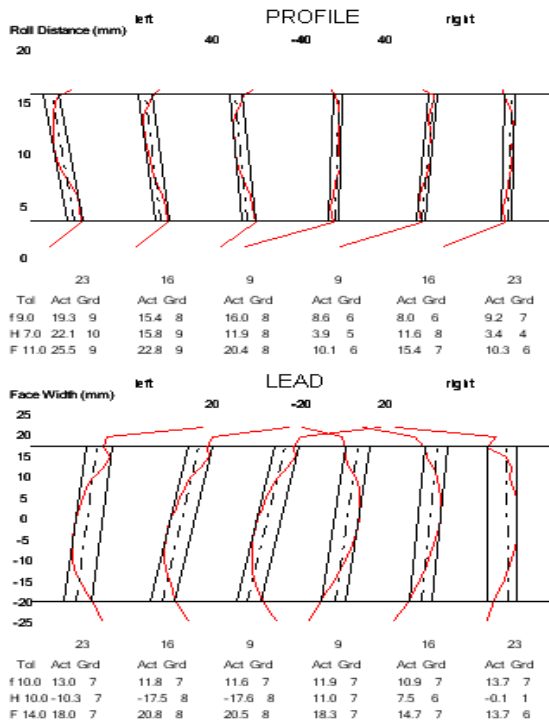
### Export Target Data / Import Measurement File



Inspection tab on single component window can be used to select inspection range even on cropped teeth and adjust reference plane with inspection machine datum

## Inspection Centre

Measured data can be imported and evaluations of profile, flank line, pitch, thickness and run-out to ISO and AGMA



## Inspection Centre

### Tooth Surface Measurements

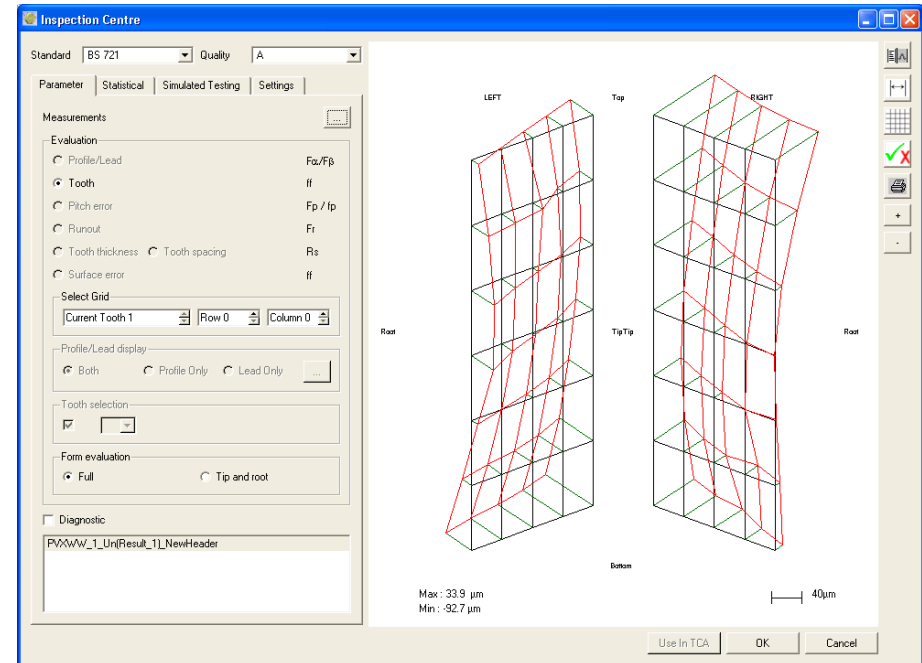
Data can be imported and used for:

Statistical analysis of several teeth

Creating master tooth form

Tooth contact analysis

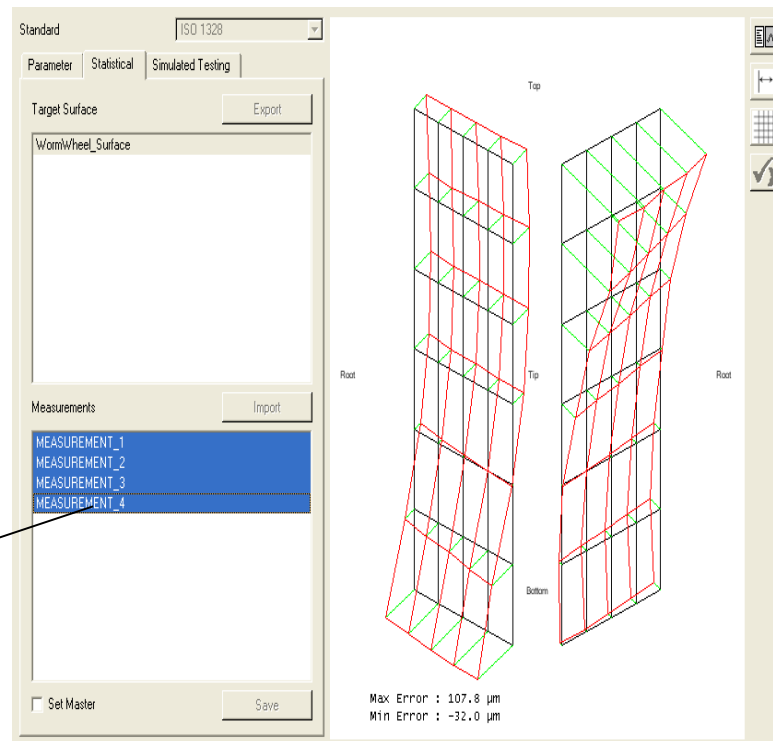
Tool and process correction



## Inspection Centre

Import and evaluate tooth measurement data for a component or tool

Several measurement files can be imported into Inspection Centre



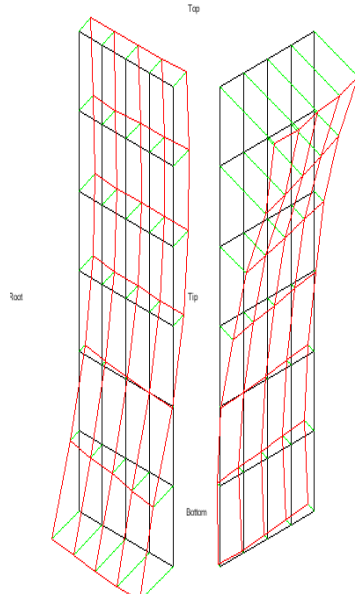
Create Average from Multiple Measurements



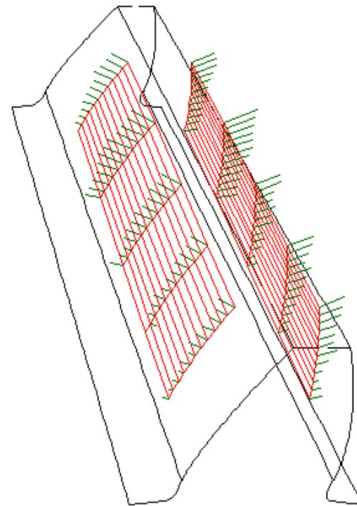
## Inspection Centre

Import and evaluate tooth measurement data for a component or tool

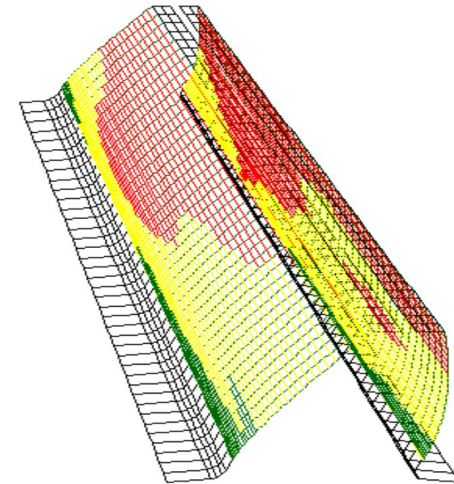
Isometric Projection



Surface Projection



Heat Map



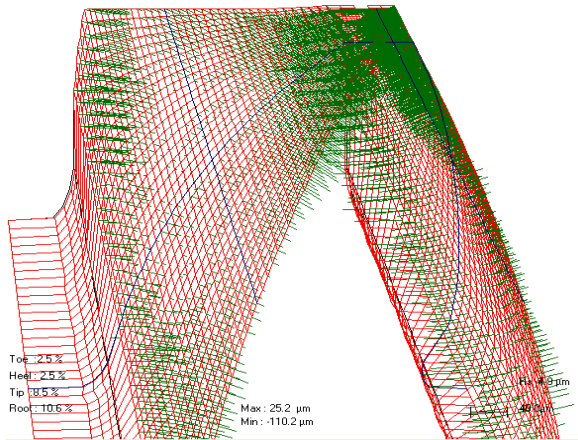
Different formats for surface display

New Heat-Map format showing areas of correct form to given tolerance (green) marginal (yellow) and error (red)

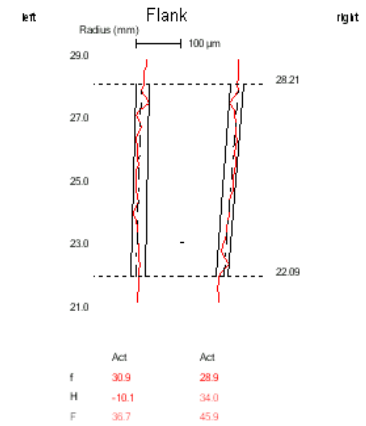
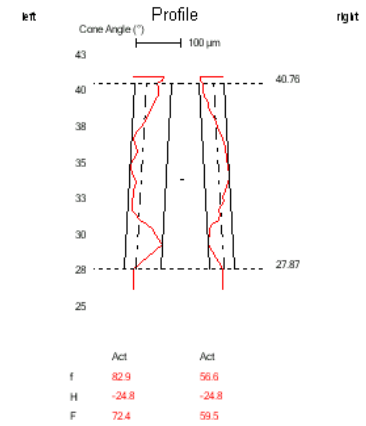
## Inspection Centre

Import and evaluate tooth measurement data for a component or tool

Twist Pattern



Current Profile/Flank selection indicated in blue



Different formats for surface display

## Inspection Centre

Import and evaluate tooth measurement data for a component or tool

Target surface can be smoothed to make generation by 5-axis possible

Select "Set Master" to create a surface definition for comparison

The screenshot shows the 'Inspection Centre' software window. On the left is a 'Diagnostic' panel with a table of parameters. On the right is a 3D visualization of a tooth surface with a red wireframe and a green mesh. At the bottom right of the 3D view, surface roughness statistics are displayed:  $R_s 17.5 \mu m$ ,  $Max: 20.0 \mu m$ , and  $Min: -87.6 \mu m$ . A scale bar indicates  $40.0 \mu m$ . The 'Diagnostic' panel includes a 'Standard' dropdown set to 'ISO 17485' and a 'Quality' dropdown set to '6'. Below the table is a 'Datasets' section with a 'Tabulate' button. At the bottom of the interface are buttons for 'Machine Centre', 'Optimal', 'Save', and 'Close'.

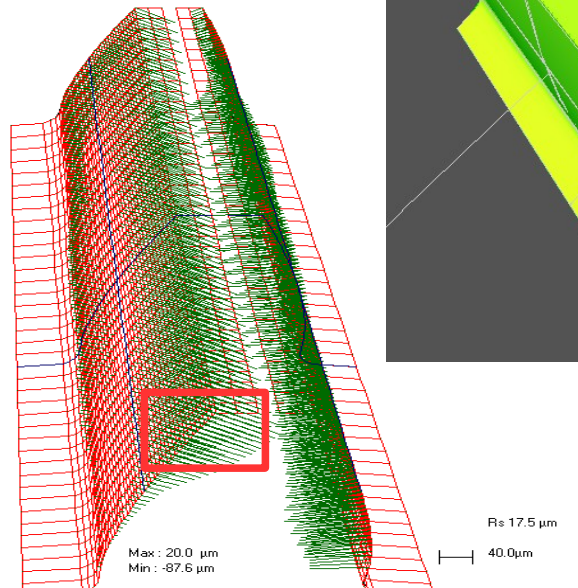
Parameter	Value 1	Value 2	Value 3	Value 4	Unit
Crown Heel	0.00	-24.19	0.00	-14.23	$\mu m$
Crown Toe	0.00	-20.07	0.00	-16.15	$\mu m$
Ctr Offset	0	0	0	0	%
Prof Barrel Tip	0.00	18.03	0.00	-56.54	$\mu m$
Prof Barrel Root	0.00	-63.44	0.00	6.82	$\mu m$
Ctr Height Offset	0	0	0	0	%
Lead Taper	0.00	0.00	0.00	0.00	$\mu m$
Profile Taper	0.00	0.00	0.00	0.00	$\mu m$
Bias	0.00	0.00	0.00	0.00	$\mu m$

Target surface can be exported to machining or inspection equipment

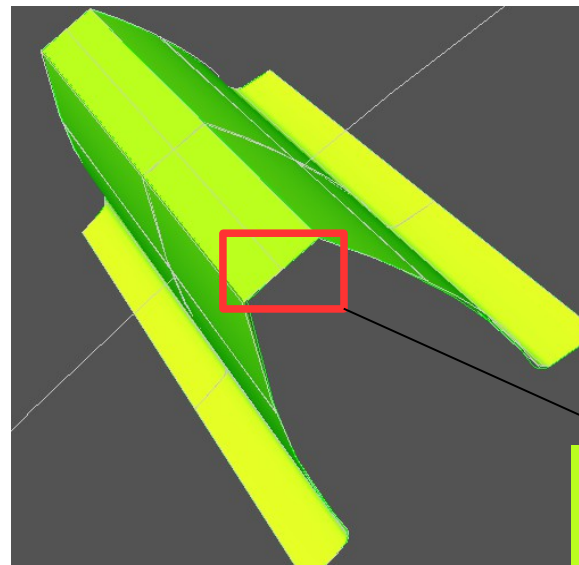
Create Target Surface For Future Production

## Inspection Centre

### Create Master Or Optimised Surface



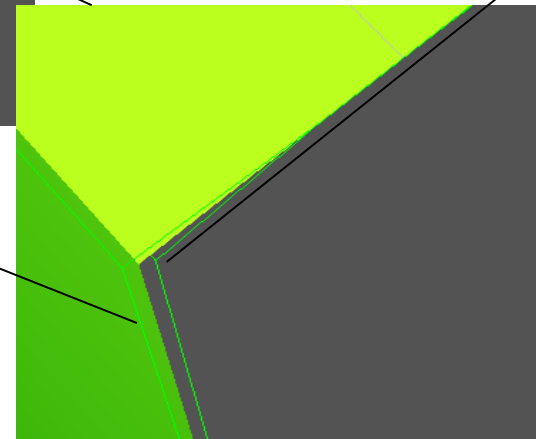
Region shows  
minus metal



Solid surface is nominal tooth form

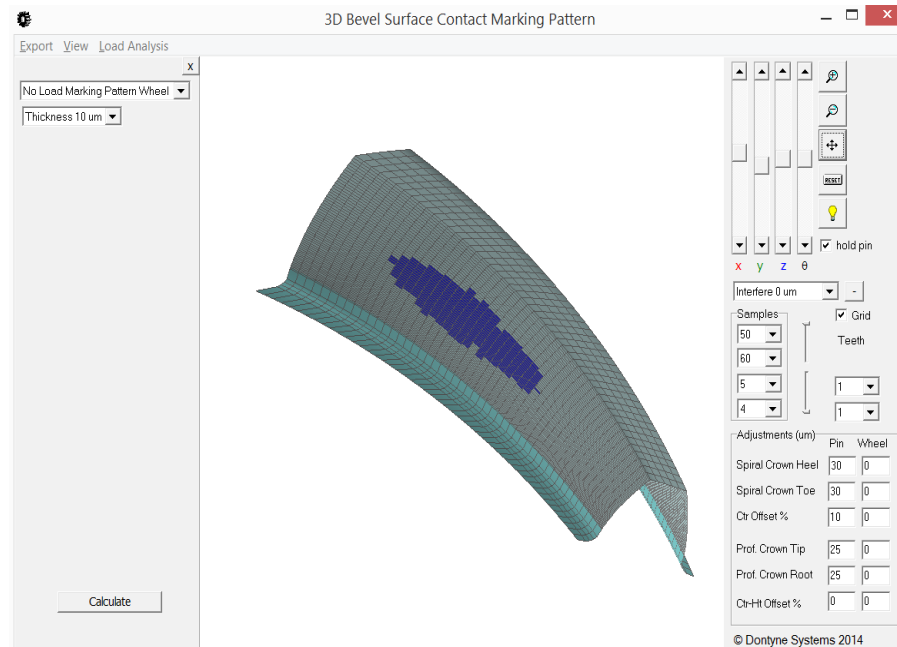
Select "Set Master" to  
define a surface as new  
nominal which can be  
exported in IGES or G-  
Code, and Inspection  
file formats

Optimal exports  
surface with  
opposite  
deviations to  
measured



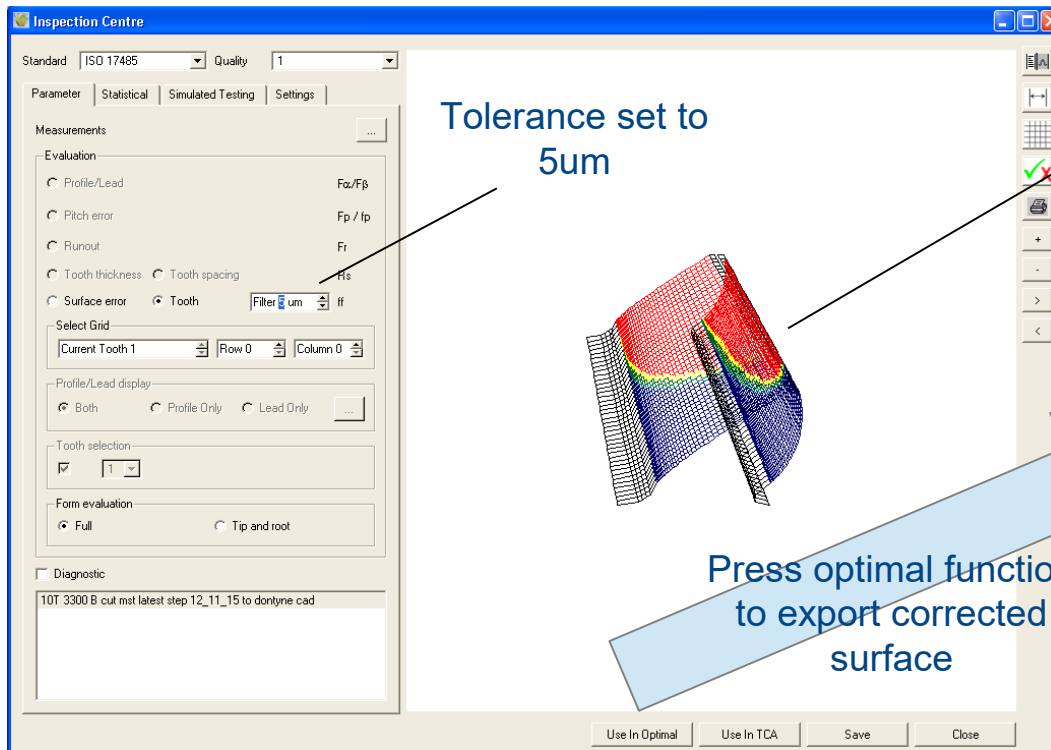
## Inspection Centre

Tooth measurement data can be used to simulate a marking pattern

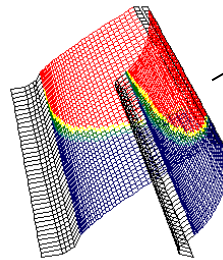


Simulation of marking pattern using measurement data on one or both components

## Optimal - Tool Optimisation Using Measured Data

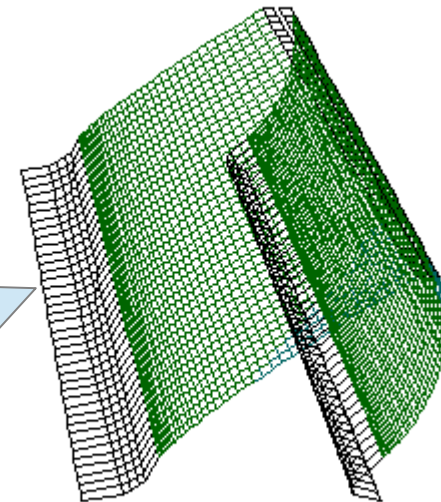


Tolerance set to 5um



Press optimal function to export corrected surface

First attempt indicates small area within 5um tolerance (red and blue outside plus and minus material respectively)



Most areas of gear now show within 5um tolerance (green) after re-machining

## Future Development

- Full 3D FE of tooth form
- Efficiency in Load Model
- Database for heat distortion

## Deformation Model For Heat Treatment Compensation

- Appropriate for pre-finished form and for die production in forging and injection moulding
- Factors such as design parameters, material, force, and temperature will form model
- Requires contribution from customer to develop initial model based on experience
- Model will be compared to existing data for validation (propose correct 50% as initial target)
- Considerable savings in time if avoidance of iteration to tool surface



Thank You