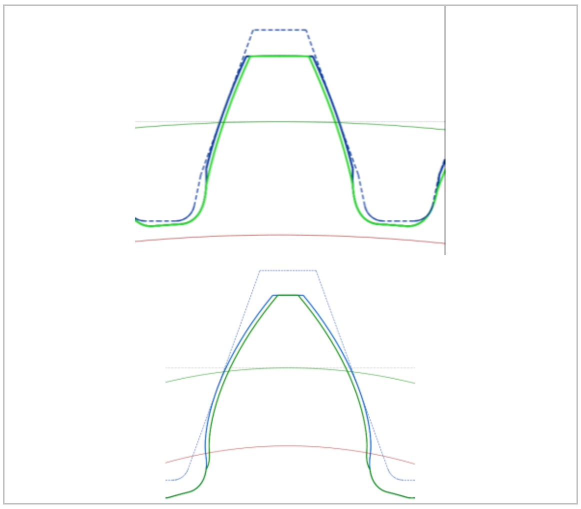
Functions related to cylindrical gear manufacturing

Pre-machining tool

- How to define the tool addendum length, to achieve the required gear dedendum?
- Which protuberance amount is needed to avoid the grinding notch with certainty?
- Can I use any existing tool for pre-manufacturing a new gear?

When pre-machining is applied, the tool addendum needs to be enlarged to compensate the manufacturing profile shift. To avoid grinding notches, the protuberance is applied on the pre-machining tool, to avoid the increased stress concentration.



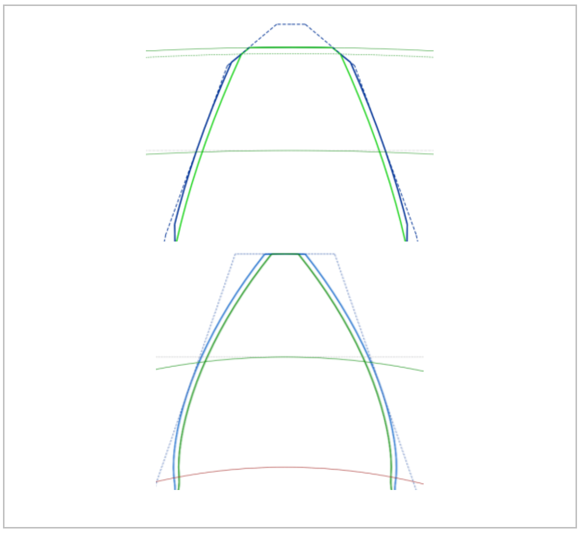
The root radius is applied as large as possible to reduce the root stresses ("full fillet" design), but to be checked for root form diameter.

Chamfering and topping tools

- What is the contact ratio change due to a chamfer?
- Is the noise behavior still ok with the reduced contact ratio due to chamfer?

The chamfering of the gear when pre-machining requires an individual tool.

KISSsoft allows the definition of the ramp angle and chamfer size.

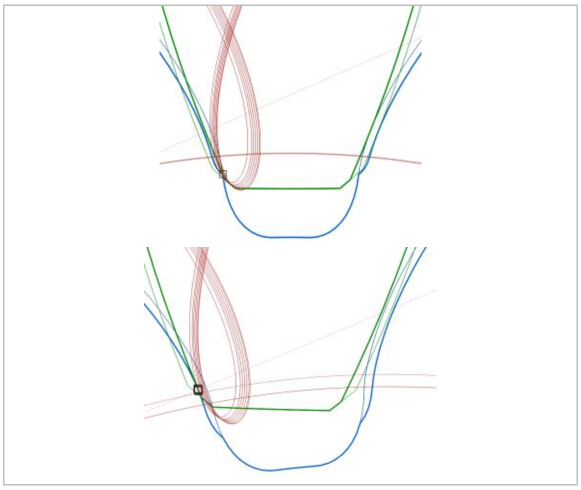


As a result, the tip form diameter is shown. Also, the reduced contact ratio is shown, what affects also both the noise and strength rating of the gear and has to be documented for further processing. As pre-machining tools, hobs and pinion type cutters are available.

Grinding depth

- What minimum grinding depth (root grinding, flank grinding) is required?
- Is the grinding depth sufficient to avoid interference / collision when meshing?
- What is the trace of tooth tip when meshing?

The addendum of the hard-finishing tool is calculated for required minimum active root diameter, maximum root form diameter or to avoid grinding the root etc.



Top: Tool workpiece interference,
Bottom: No interference

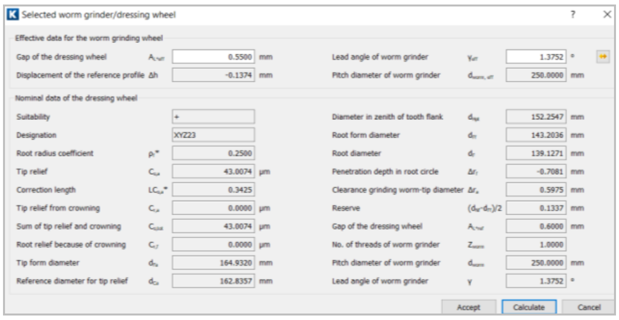
The simulation of rolling the gears shows interference for several tolerance conditions. The trace curve of the tooth tip shows the potential collision clearly.

Grinding dresser

- Can we reuse a grinding dresser for another workpiece?
- What is the effect on the gear design if we use an existing grinding dresser?

KISSsoft checks whether, for a given gear design, an existing grinding dresser can be used or re-used.

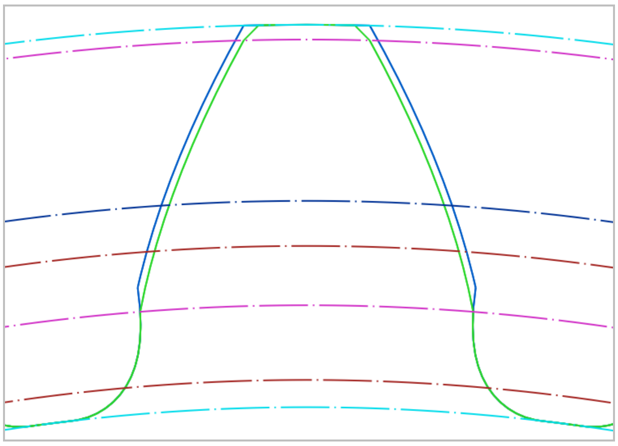
The software shows the resulting gear modifications if an existing grinding dresser is used, reducing tool costs and eliminating tool lead time. The difference between the designed modifications and the machined modifications is evaluated and the effect can be checked using KISSsoft functionality.



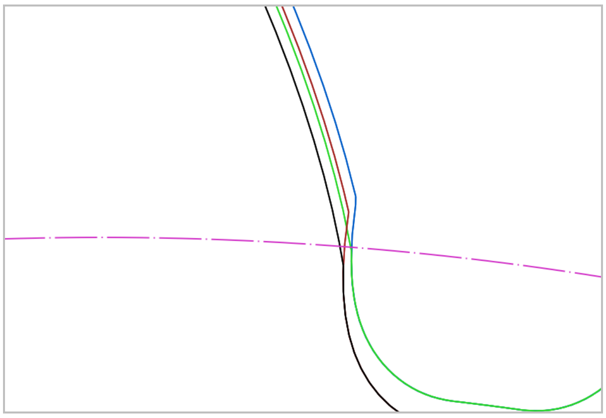
Diameters, meshing interference and collisions

- How does the tooth thickness tolerance range affect the range for dFf, dFa and df?
- What is the influence of machining stock and tool tip shape on the upper root form diameter?

The manufacturing profile shift of the pre-machining and final machining tool affect the form diameters and thereby the available involute length. A display of all relevant diameter, for different tolerance conditions, and for different machining steps visualizes the calculated values. Meshing interferences, safety distances and collisions may be detected in high resolution graphics with animation functions.



Form diameters, active diameters, tip and root diameter, reference circle / base circle, operating pitch diameter and diameter for DOP measurement.



Influence of tooth thickness on dFf (green / blue: tooth form, pre- and final machining, highest xE value, red / black: lowest xE value).

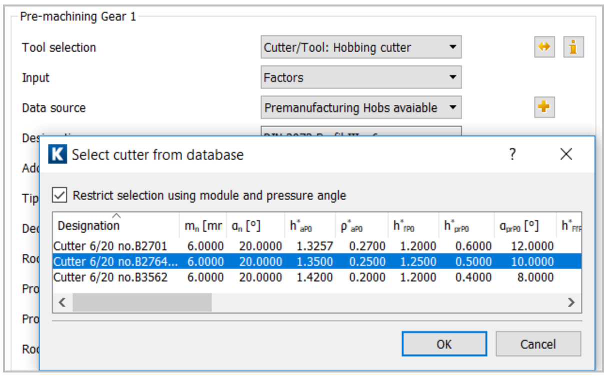
Hob database

- How can we ensure that gear designers consider existing tools when choosing a workpiece design?
- How can I request for a new tool based on the current gear design?

The reference profile, pressure angle, module and a tool reference number can be imported into KISSsoft

database from a text file. The tool inventory is then reflected in the gear design software.

Gear designers may then check on the availability of a suitable tool for a gear design and reducing the number of new tools needed. If a new tool is required, the gear profile data can be exported and sent to Gleason tool manufacturer on one click.

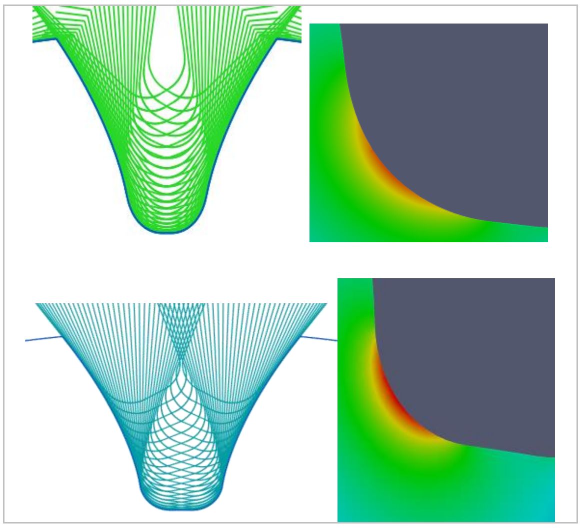


Hob and shaping cutter data imported in KISSsoft

Short lead hob

- What is the influence of the hob module on the workpiece root shape?
- How does a short lead hob affect the gear strength?

Short lead hobs create a different root shape resulting in different stress levels that cannot be assessed using DIN, ISO or AGMA gear rating standards. When using a short lead hob, it is then recommended to use the FEM calculation in KISSsoft considering the root geometry and curvature as manufactured. A comparison of stress levels for different hob modules allow for an approval of a certain hob design.



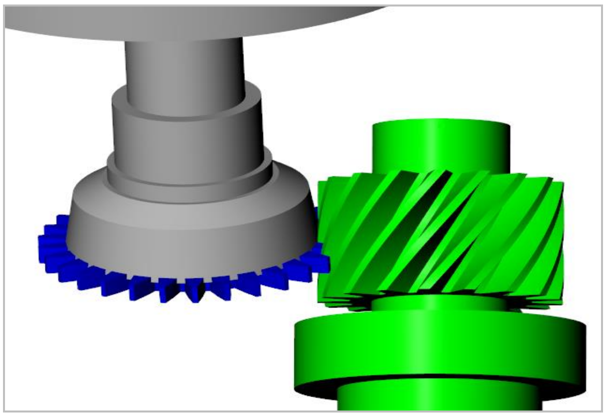
Upper image: Root shape hobbed with standard hob. Lower image: Root shape hobbed with short lead hob.

Power skiving

- Can a tooth profile be manufactured with power skiving?
- Is there sufficient runout for the tool regarding the shaft shoulder?

KISSsoft allows to estimate the manufacturability of gears using power skiving. On one hand, the tooth geometry is checked regarding machine and tool limitations, on the other hand, the gear can optionally also be checked for collisions with the tool. Collisions scenarios which shall be checked can be activated.

In addition, it is also possible to export the corresponding tool-gear helical calculation as a KISSsoft file which can then be opened separately and may be used for visualization or problem-solving purposes.

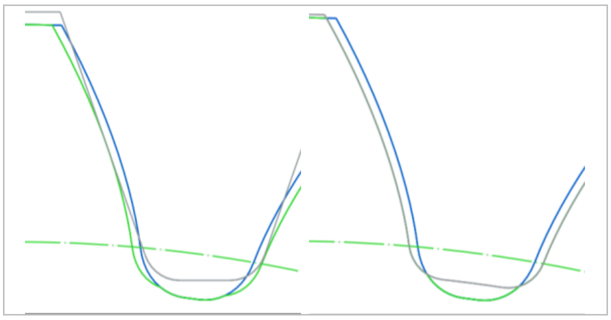


Forming and generating final machining

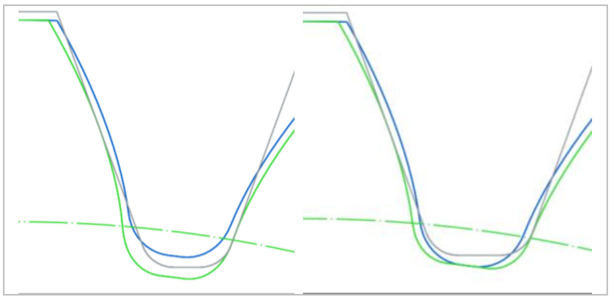
- How can we avoid grinding notches for generating and forming grinding operation?
- For a given final machining stock on the flank, how can we achieve a desired material removal in the root?

In different industries, different grinding techniques and strategies are used. While in industrial gears, the root is typically not ground, it is ground in most cases for aerospace gears. For large gears, a forming final machining process (e.g., hard hobbing with form cutter) may be used whereas for e.g., car transmission gears, a generating grinding process is common.

Grinding notches should be avoided for high performance application while they may be found in gears produced with small batches. KISSsoft allows to tune the stock removal on the flank and root separately and final machining tool runout is checked.



Left: Generating grinding with grinding notch. Right: Form grinding with grinding notch.

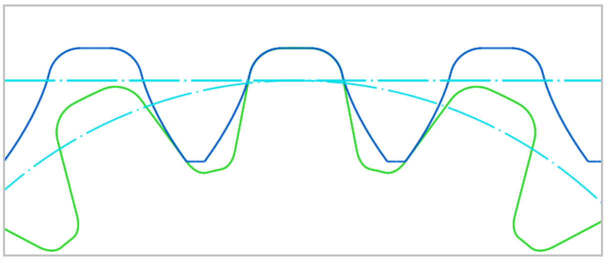


Left: Root and flank both ground. Right: Grinding depth = hobbing depth. Blue: gear after pre-machining, gray: tool

Tool profile for non-involute gears

- How can we determine the tool profile for non-involute gears?
- Is the workpiece profile manufacturable with a generating process?

Non involute gears with positive radius of curvature on the flank can typically be manufactured in a generating process using rack type or pinion cutter type tools. KISSsoft calculates the gear reference profile through a reverse generating process. The rack profile may then be exported as 2D *.dxf for tool production.



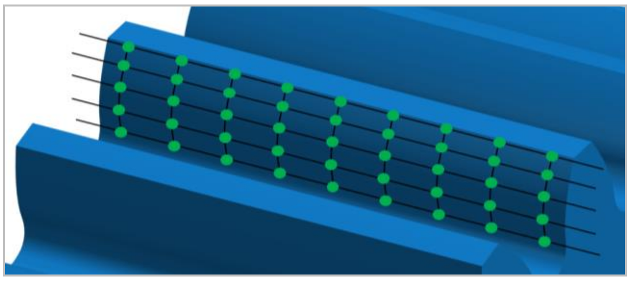
Green: Non-involute gear with circular tip area
Blue: Basic rack of tool

Measurement and quality

Measurement grid coordinates

- 3D models as STEP and measurement grid
- Data export in GDE and GAMA® format
- Including microgeometry and tolerances

To control a CMM or for the sake of verification, the measuring grid coordinates, and the normal vectors are calculated and reported in KISSsoft for a user defined number of flank points.

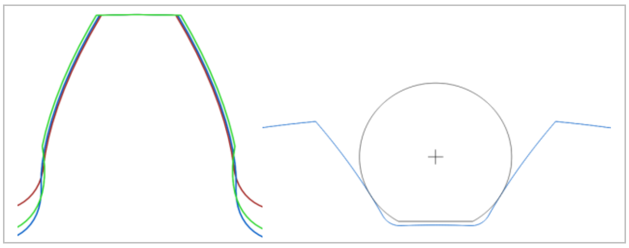


The export formats for GDE and GAMA® are available. They allow for a fast and safe data transfer between various manufacturing and measurement machines.

Tooth thickness and span width

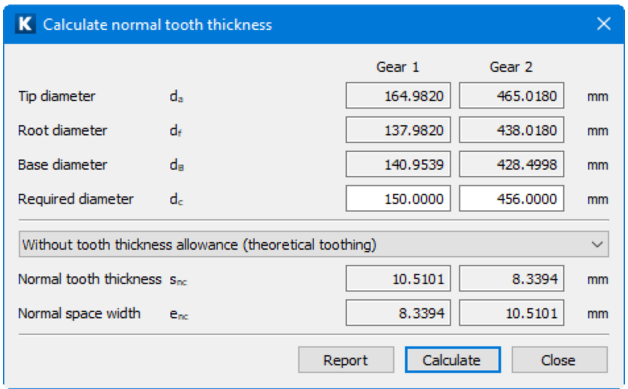
- What are the required tooth thickness values for pre-machining and final machining?
- What are the permitted tooth thickness values including the tolerances?
- Flattened ball for splines

The gear tooth thickness and span width can be determined for any manufacturing step. Using the tooth form analysis in KISSsoft, the analysis of tooth thickness at any position of tooth height is possible.



For involute splines, flattened ball needs to be applied to avoid the touching of the gear root.

Tooth thickness is calculated for a given diameter, for theoretical gear or considering tooth thickness allowances.

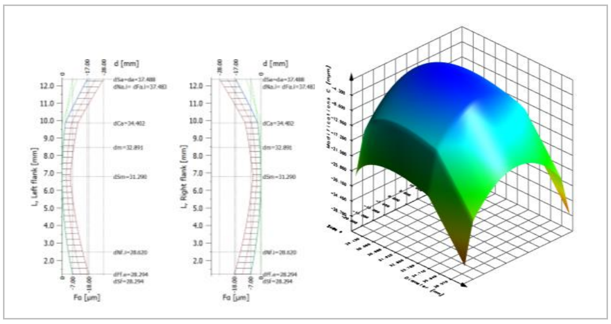


Calculated diameter over pin for theoretical, mean, upper and lower value may then be compared to measured DOP using Gleason over pins gauges.

Profile and tooth trace modification

- Lead, profile and combined modifications
- Topological modifications
- Tabular, graphical data for manufacturing drawings

Various gear modifications can be defined for right and left flanks independently for optimum running performance for each flank.



The K-charts are provided in KISSsoft for reference of the measurement machine. Also, the cumulated modifications per flank are available in 3D graphics.

GDE format for data exchange

- How do we communicate gear data easily and error free between different departments or companies?
- How do we get relevant gear geometry data that is missing on a drawing?

A unique, simple, accurate and flexible way to describe gear geometry and manufacturing data is implemented in KISSsoft based on VDI/VDE 2610 guideline. The data exchange between design department, production and quality inspection group, or with customers, is thereby simplified and accelerated. It serves as a digital gear table and is used in parallel to a drawing.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Master gears

- Can we use an available master gear or is a new one required?
- Which area of the involute is checked?

Based on a given workpiece design and the required diameters to be in contact with a master gear, the suitability of a given master gear is checked. Alternatively, a new master gear design is calculated considering workpiece diameter tolerances. Master gears may then be used on Gleason and other testers.

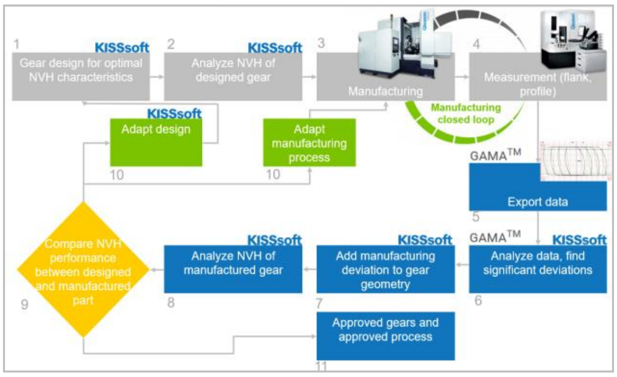
MASTER GEAR CALCULATION FOR DOUBLE FLANK TEST	(for Gear 1)		
Check of introduced Master Gear with da	228.3600 mm		
Master gear:	[zM]	36.0000	
	[Q]	3	
	[betaM]	0.0000	°
	[dM]	216.0000	mm
	[xM]	0.0300	
	[x.eM]	0.0254	
	[x.iM]	0.0254	
Data when pair gear/master gear is running (no backlash situation):			
Center distance	[aMin]	184.4047	mm
	[aMax]	184.4956	mm
Restrictions for Master gear tip diameter da:			
Optimum diameter (for dNf of gear)	[daopt.e]	229.5148	mm
	[daopt.i]	229.2804	mm
Maximal diameter (for dFf of gear)	[damax]	230.5777	mm
Maximal diameter for tip clearance 0.0060 mm	[damax-cl]	231.0764	mm

Lower image: Calculated master gear properties for a given workpiece, considering tip and root form diameter tolerances.

Analysis of manufactured gears

Design-manufacture-measure

- What is the vibration characteristic of the machined gear compared to the designed gear?
- How do machining errors influence the contact pattern under load?

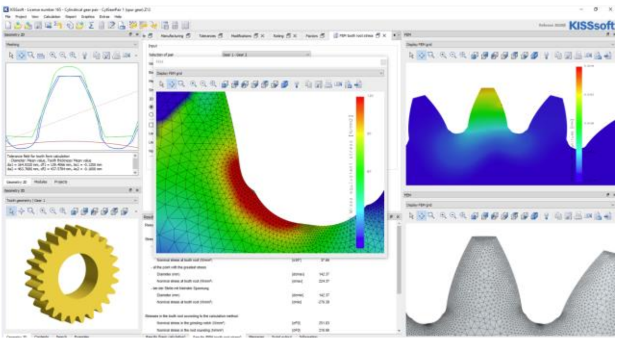


The design-manufacture-measure loop integrates KISSsoft, Gleason gear machines and metrology solutions. Machining errors may result in elevated noise levels or poor contact patterns in operation. To predict if the performance characteristics of a machined gear are satisfactory, the measured flank deviations are imported into KISSsoft. There, the designed and the measured geometry are analyzed (contact pattern under load, transmission error, force excitation, …) and performance characteristics are compared in parallel. Based on this, the manufacturing process with its deviations may be approved or the need for a more accurate or stable process may be identified.

Root radius and tooth root stresses

- What is the stress concentration due to a grinding notch?
- How can we assess root stresses for non-trochoidal root shapes?

Gear root strength is usually assessed using applicable DIN, ISO or AGMA rating standards. However, in the case of nonstandard root shapes or grinding notches, a FEM calculation is required.

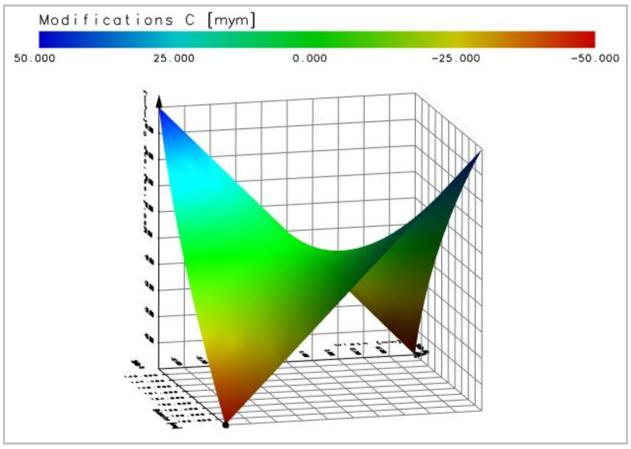


When grinding notches or other machining errors are created, KISSsoft provides a 2D FEM calculation where the stress increase is shown. Based on the stress level, gears may be safe for operation or need to be scrapped.

Natural and designed twist

- What amount of natural twist results from threaded wheel grinding?
- What are the resulting deviations from the designed flank geometry?

In threaded wheel grinding process for helical gears with lead modifications, a natural twist results (unless it is compensated). Its effect on the contact under load and the vibration excitation may be assessed using KISSsoft. Furthermore, a desired twist amount to mitigate the negative effect of gear misalignment under load may be designed and optimized.

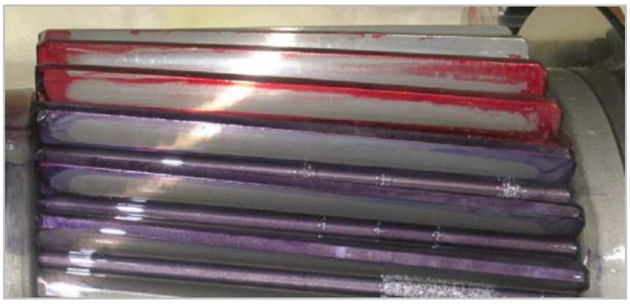


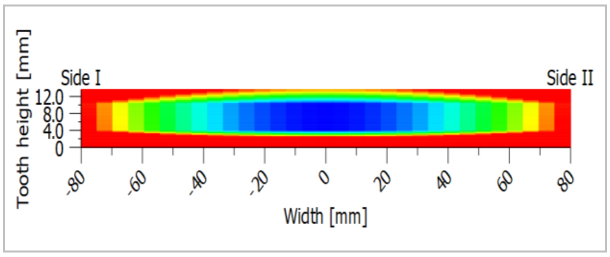
Sizing functions in KISSsoft automatically find the optimal flank twist amount to achieve optimal contact pattern under load. It then needs to be checked by the production engineers whether the calculated twist amount can be manufactured.

Assembly contact pattern

- How can we check that a contact pattern after assembly is as required?
- How do bearing play and assembly tolerances influence the contact pattern?

No load contact patterns after assembly are typically available towards the final phase of the gearbox assembly only. The contact pattern at no load, but considering bearing clearances, can be predicted with KISSsoft. It then serves as a basis for the acceptance of the unit under assembly. The marking compound thickness may be given in the calculation as an additional parameter.





Above: Contact pattern after spin test during gearbox assembly
Below: predicted contact pattern considering gear microgeometry and bearing clearance influence.