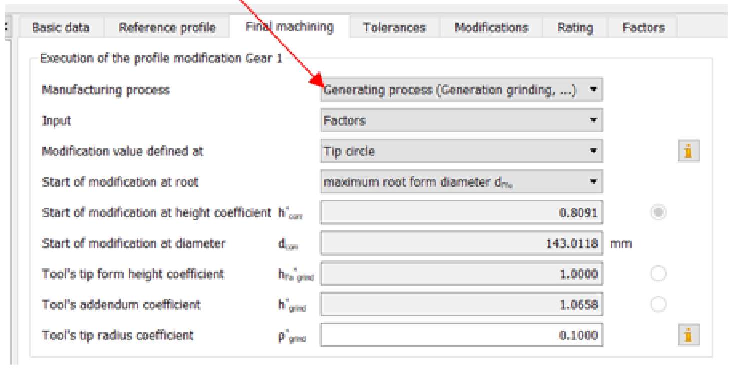
New Features in Gears
Part 1

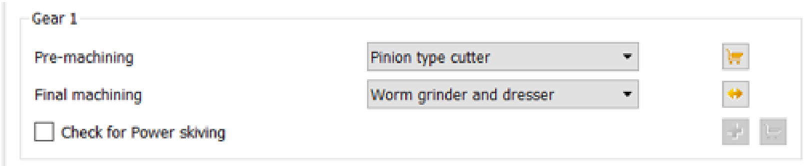
KUM International, October 23, 2019
U.Kissling

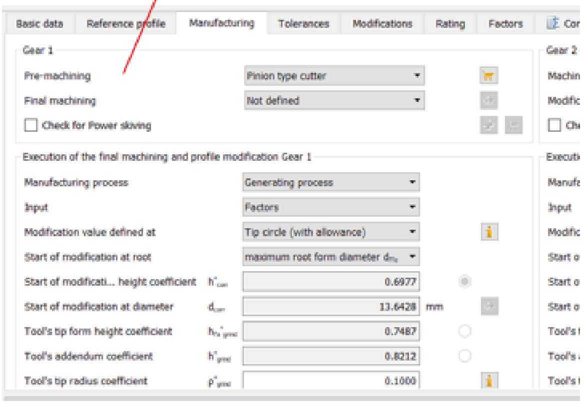
KISSsoft

Manufacturing knowhow in KISSsoft

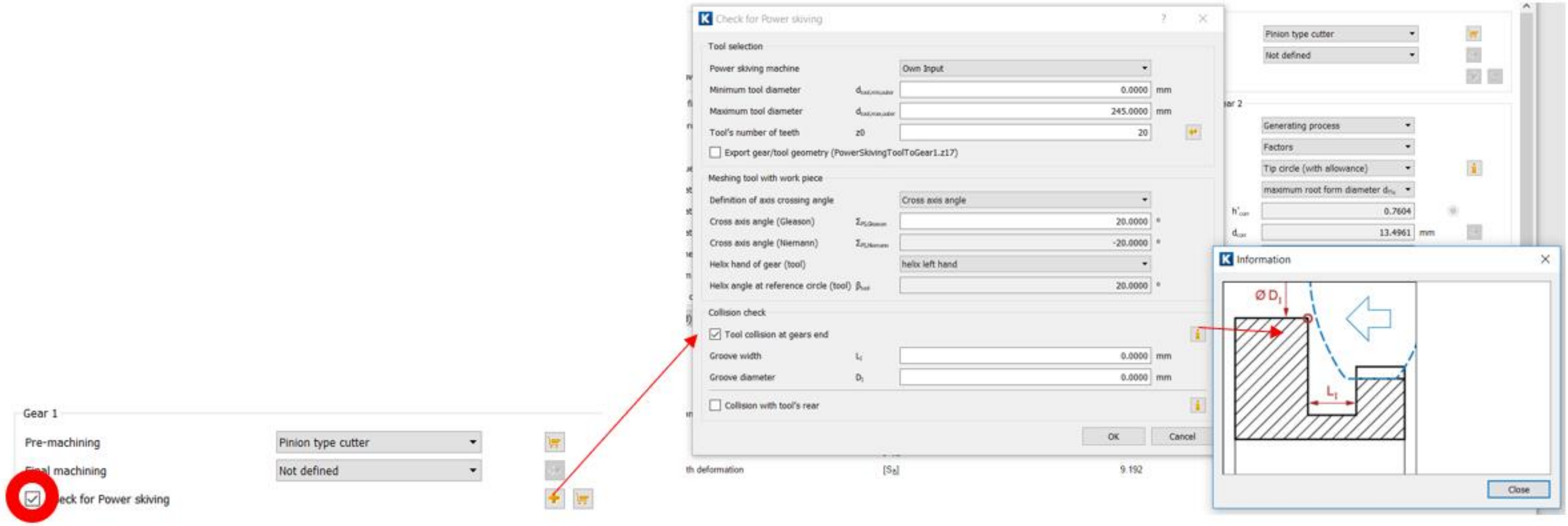
Tab 'Final machining' in 18 is moved into Tab 'Manufacturing' in 19!







Power Skiving Check added (Honing is planned)



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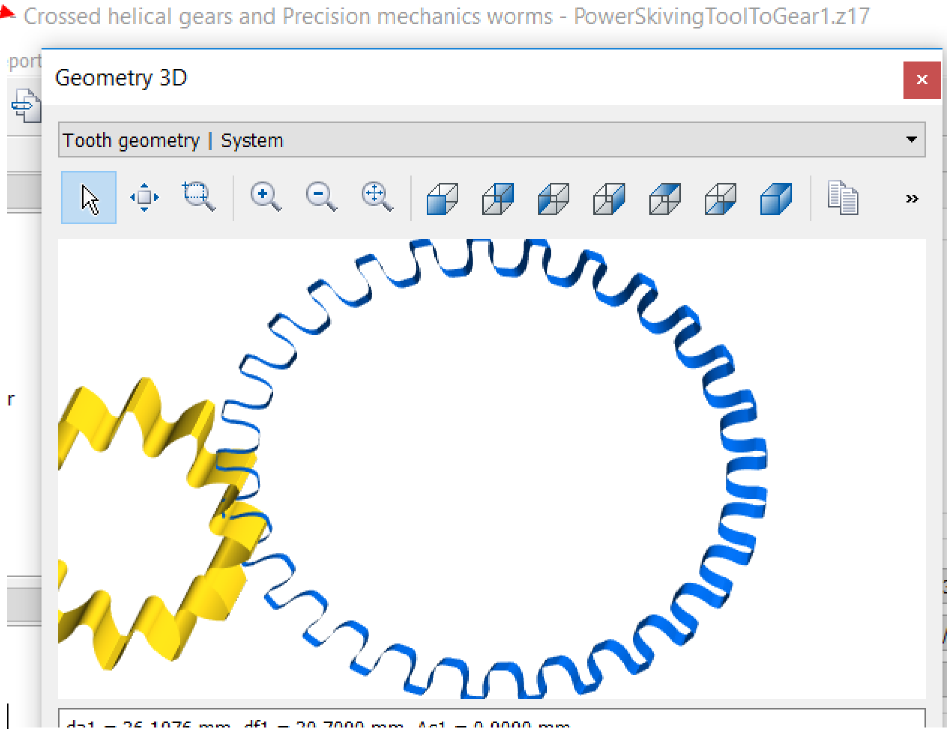
Manufacturing knowhow in KISSsoft : Power Skiving

Use the lay-out button!

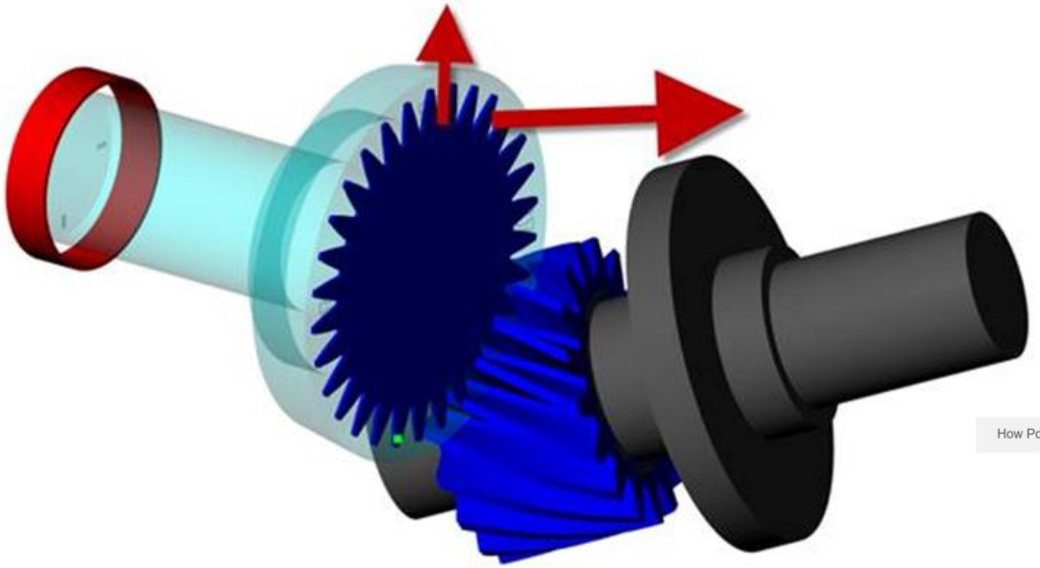
Tool's number of teeth z0 29

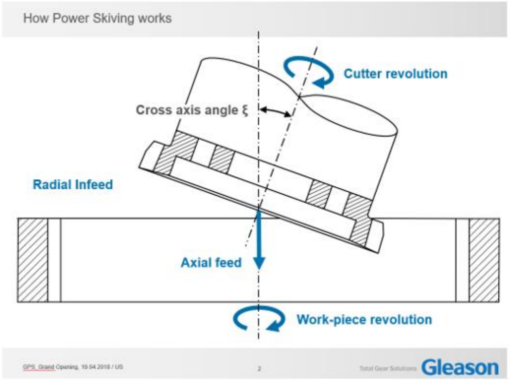
Visualization of Gear with Tool

☑ Export gear/tool geometry (PowerSkivingToolToGear1.z17)



Check with examples from Gleason in Studen





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Implemented in Fine-sizing

Fine Sizing

Conditions I | Conditions II | Conditions III | Results | Graphics

Nr.	m_n [mm]	α_n [°]	β [°]	z_1	z_2	x_1	d_{a2} [mm]	ε_α	ε_β	ε_γ	i	PSK_2	$PSKz_2$
1	0.600	22.500	0.000	32	-50	0.800	29.341	0.975	0.000	0.975	-1.562	Yes	21
2	0.600	22.500	0.000	33	-51	0.800	29.941	0.980	0.000	0.980	-1.545	Yes	21
3	0.600	22.500	0.000	34	-52	0.800	30.541	0.984	0.000	0.984	-1.529	Yes	21
4	0.600	22.500	0.000	35	-53	0.800	31.141	0.988	0.000	0.988	-1.514	Yes	21
5	0.600	25.000	0.000	30	-47	0.146	27.169	1.459	0.000	1.459	-1.567	Yes	21
6	0.600	25.000	0.000	31	-48	0.133	27.754	1.464	0.000	1.464	-1.548	Yes	21
7	0.600	25.000	0.000	32	-49	0.120	28.339	1.469	0.000	1.469	-1.531	Yes	21
8	0.600	25.000	0.000	33	-50	0.108	28.924	1.473	0.000	1.473	-1.515	Yes	29
9	0.600	27.500	0.000	30	-47	-0.005	26.988	1.408	0.000	1.408	-1.567	No	0
10	0.600	27.500	0.000	30	-47	0.095	27.108	1.378	0.000	1.378	-1.567	No	0
11	0.600	27.500	0.000	31	-48	-0.017	27.573	1.411	0.000	1.411	-1.548	No	0
12	0.600	27.500	0.000	31	-48	0.083	27.693	1.382	0.000	1.382	-1.548	No	0
13	0.600	27.500	0.000	32	-49	-0.030	28.158	1.414	0.000	1.414	-1.531	No	0
14	0.600	27.500	0.000	32	-49	0.070	28.278	1.386	0.000	1.386	-1.531	No	0
15	0.600	27.500	0.000	33	-50	-0.043	28.743	1.416	0.000	1.416	-1.515	No	0
16	0.600	27.500	0.000	33	-50	0.057	28.863	1.389	0.000	1.389	-1.515	No	0
17	0.600	30.000	0.000	30	-47	-0.147	26.817	1.358	0.000	1.358	-1.567	Yes	27
18	0.600	30.000	0.000	30	-47	-0.047	26.937	1.334	0.000	1.334	-1.567	Yes	27
19	0.600	30.000	0.000	30	-47	0.053	27.057	1.312	0.000	1.312	-1.567	Yes	27
20	0.600	30.000	0.000	31	-48	-0.159	27.402	1.360	0.000	1.360	-1.548	Yes	27
21	0.600	30.000	0.000	31	-48	-0.059	27.522	1.337	0.000	1.337	-1.548	Yes	27
22	0.600	30.000	0.000	31	-48	0.041	27.642	1.315	0.000	1.315	-1.548	Yes	27
23	0.600	30.000	0.000	32	-49	-0.170	27.989	1.361	0.000	1.361	-1.531	Yes	27
24	0.600	30.000	0.000	32	-49	-0.070	28.109	1.339	0.000	1.339	-1.531	Yes	27
25	0.600	30.000	0.000	32	-49	0.030	28.229	1.317	0.000	1.317	-1.531	Yes	27
26	0.600	30.000	0.000	33	-50	-0.182	28.575	1.362	0.000	1.362	-1.515	Yes	27

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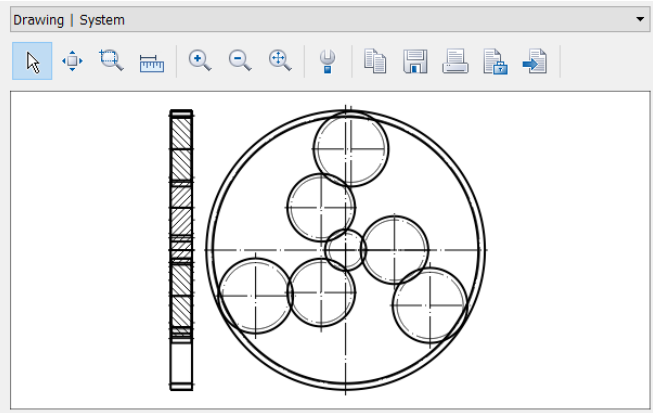
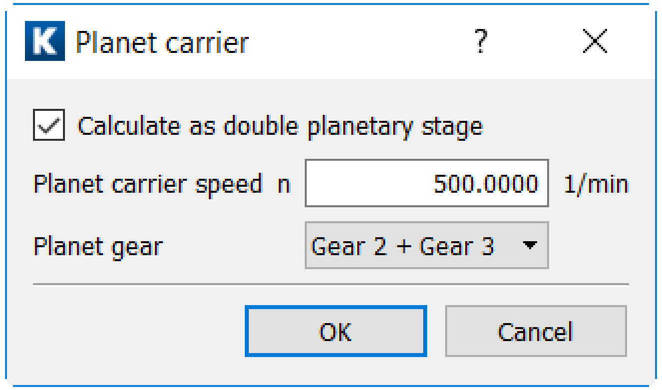
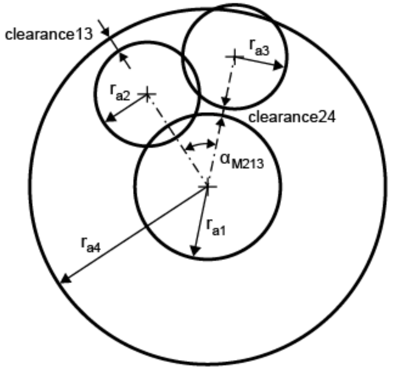
Double planetary stage in 4-Gear-Chain & Fine sizing for 4-Gear-Chain

Speed n_1 15000.0000 1/min







New example added: Double pinion PlanetarySet

New license: Z1c

In the report:

Supplementary data

This gear stage is suitable for a planet epicyclic stage with a sun in the center.

Angle between center point, gear2-gear1-gear3 (°)	[αM213]	33.128
Distance between tip circles gear1-gear3 (mm)	[clearance13]	64.152
Distance between tip circles gear2-gear4 (mm)	[clearance24]	74.856

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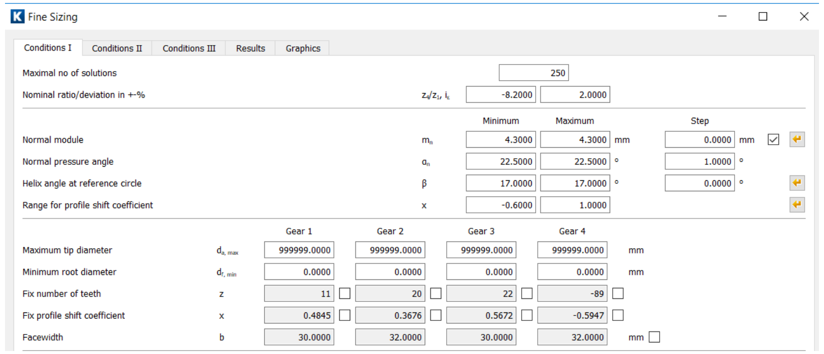
New: 4-Gear-Chain with Fine-Sizing

Center distances used are defined in the ‘Basic data’ tab.

Exception, when special feature for double planetary is activated. Then dv4 is given, center distances are varied.



☑ Size as double planetary stage (all center distances vary)

Nominal ratio z_3/z_2 — i_{23} 1.1000

V-Circle internal gear — d_{v4} 400.0000 mm — 3.0000 %

Additional results for double planetary:

αM_{213} [°]	CL_{13} [mm]	CL_{24} [mm]
12.284	**73.970**	**82.534**
12.284	73.110	83.394
25.162	70.204	77.454
25.162	69.344	78.314
25.162	68.484	79.174
33.368	65.579	73.243
33.368	64.719	74.103
39.917	60.954	69.048
39.917	60.094	69.908
45.548	56.328	64.856
45.548	55.468	65.716

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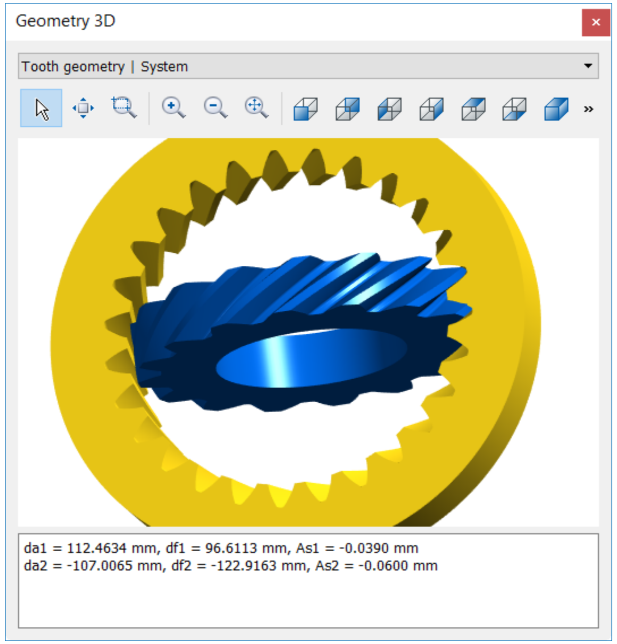
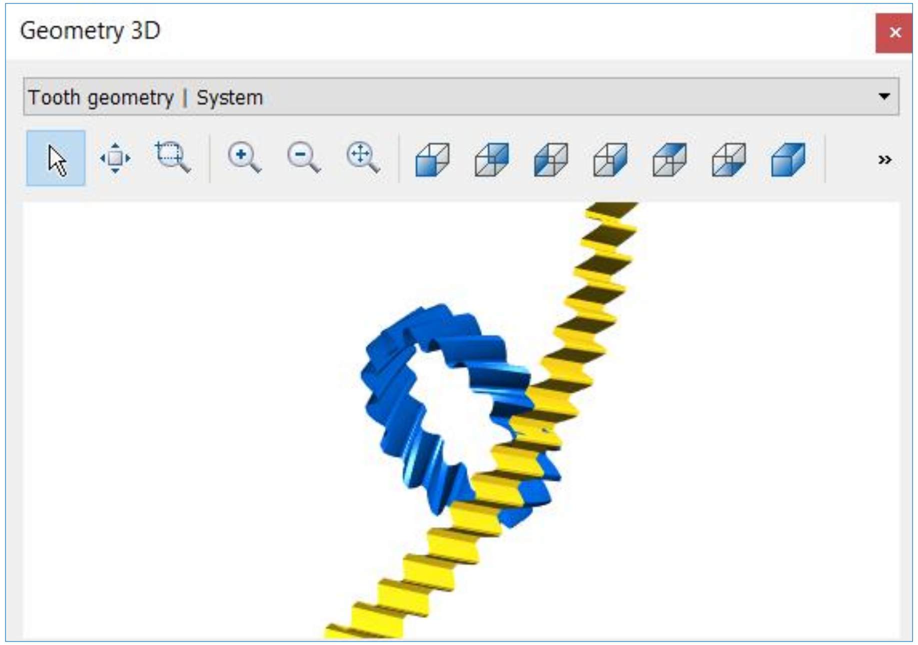
Crossed helical gear pairs with internal gear & with rack

Crossed helical gear pairs with an internal gear.

No strength calculation available (no known rule exists).

Pinion can also be a spur gear.





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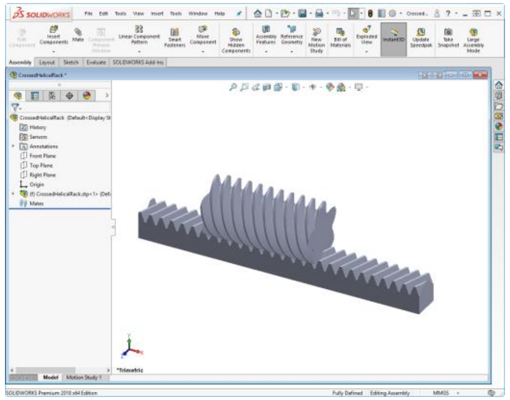
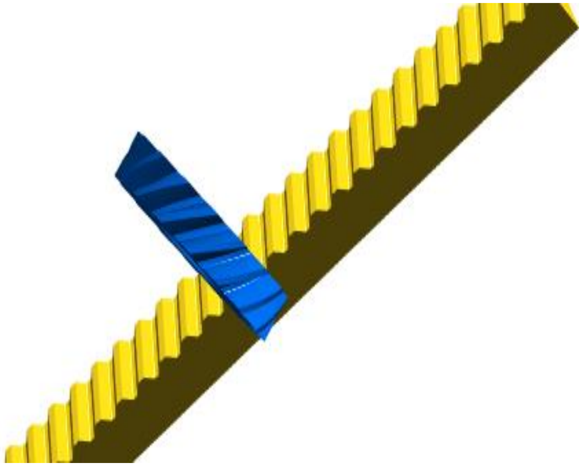
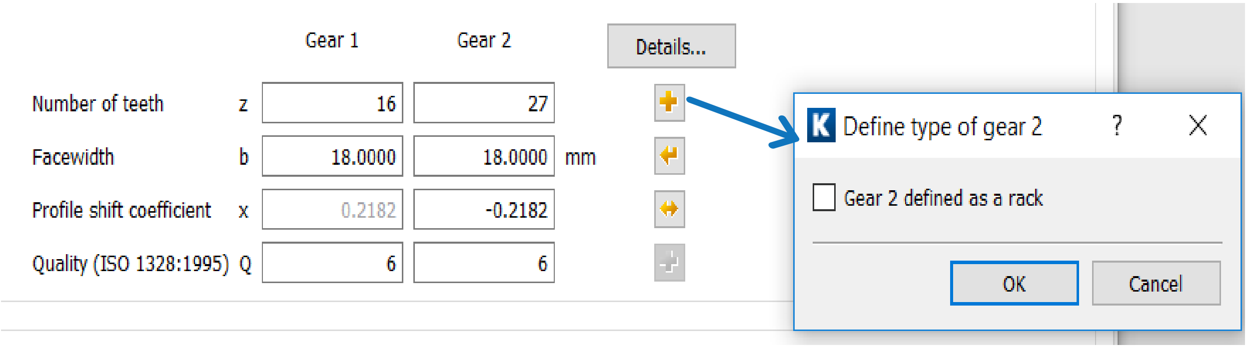
Pinion with Rack.
Strength as for a gear with >1000 teeth.







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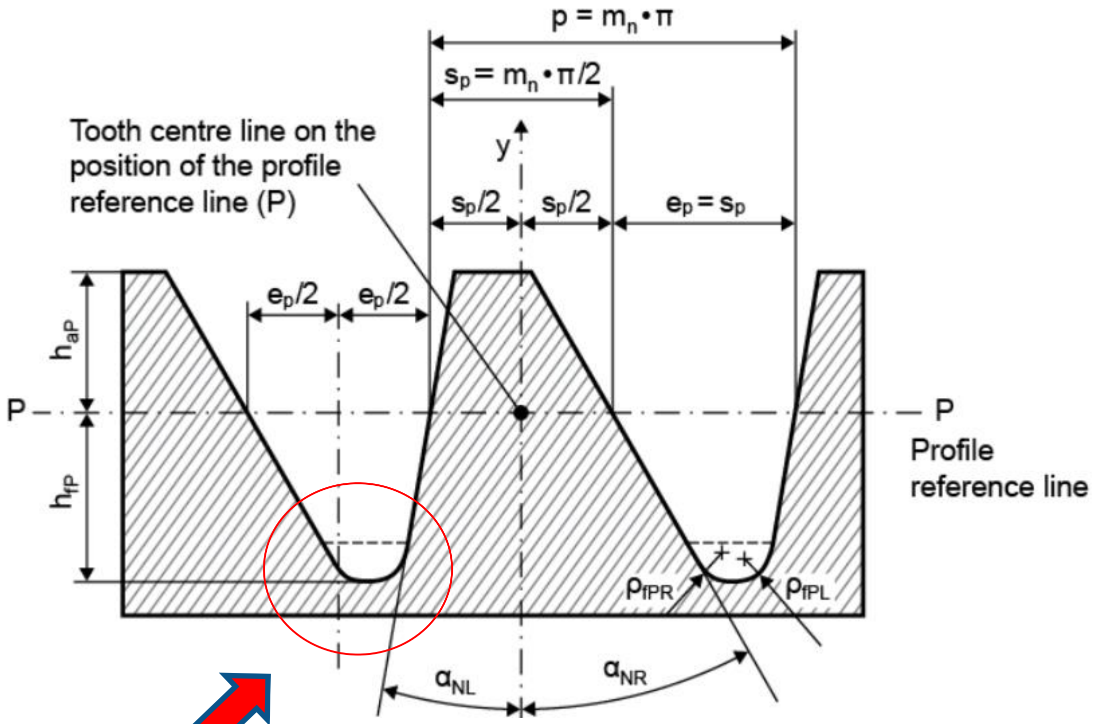
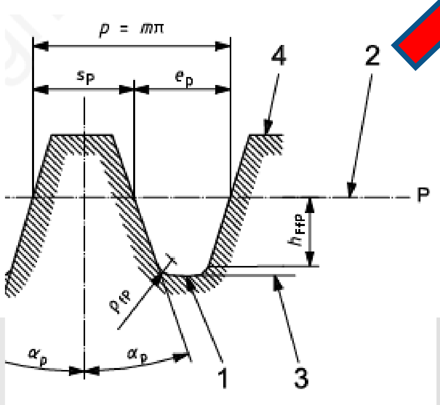
Asymmetric gears:
- LTCA (Stiffness acc. Weber-Banaschek adapted)
- A sizing function for the gear root radius / tool tip radius of asymmetric gears was added.

This module is no longer a beta version but some functionality is still limited for asymmetric gears:
- No premanufacturing
- Only for cylindrical gears
- Only ISO 6336 and VDI plastic calculation available
- No rough and fine sizing
- No operating backlash calculation
- No modification sizing





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New in DIN

Draft: Calculation of load capacity of cylindrical worm with globoid gear wheel with rectangular crossing axes

DEUTSCHE NORM *Entwurf* September 2018

DIN 3996 DIN

ICS 21.200

Entwurf

Einsprüche bis 2018-12-24
Vorgesehen als Ersatz für
DIN 3996:2012-09

Tragfähigkeitsberechnung von Zylinder-Schneckengetrieben mit sich rechtwinklig kreuzenden Achsen

Calculation of load capacity of cylindrical worm gear pairs with rectangular crossing axes

Calculation of the efficiency replaced
by a new method.

Oehler, M.: FVA-Forschungsvorhaben Nr. 729/I. Schneckengetriebewirkungsgrade. FVA-Heft Nr. 1226 (2017)

New in ISO

Calculation of load capacity of spur and helical gears	International Standard	Technical Specification	Technical Report
Part 1: Basic principles, introduction and general influence factors	X		
Part 2: Calculation of surface durability (pitting)	X		
Part 3: Calculation of tooth bending strength	X		
Part 4: Calculation of tooth flank fracture load capacity		X	
Part 5: Strength and quality of materials	X		
Part 6: Calculation of service life under variable load	X		
Part 20: Calculation of scuffing load capacity (also applicable to bevel and hypoid gears) — Flash temperature method (replaces: ISO/TR 13989-1)		X	
Part 21: Calculation of scuffing load capacity (also applicable to bevel and hypoid gears) — Integral temperature method (replaces: ISO/TR 13989-2)		X	
Part 22: Calculation of micropitting load capacity (replaces: ISO/TR 15144-1)		X	
Part 30: Calculation examples for the application of ISO 6336 parts 1,2,3,5			X
Part 31: Calculation examples of micropitting load capacity (replaces: ISO/TR 15144-2)			X

Cylindrical gears

Some ISO standards are renamed:

Scuffing ISO TR 13989-1/2 - > ISO TS 6336-20/21

Micropitting ISO15144 - > ISO TS 6336-22

Tooth flank fracture ISO DTR 19042 -> ISO TS 6336-4

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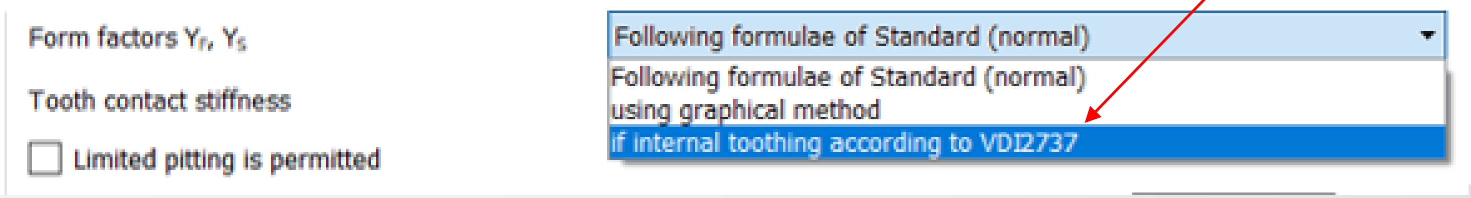
New edition of ISO6336-1, 2, 3 and 6 will be published at the end of 2019.
In V2019 of KISSsoft only on request available.

6336-3 (Bending):

- Tooth form factor YF always calculated with xE.i (smallest thickness)
- External gears, produced with a hob: No change
- For all internal gears, and external gears produced with a shaper cutter, method acc. VDI2737 is used.



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$$\sigma_{F0} = \frac{F_t}{b\, m_n} Y_F \cdot Y_S \cdot Y_\beta \cdot Y_B \cdot Y_{DT}$$

6336-3 (Bending):

$$Y_F = \frac{\frac{6\, h_{Fe}}{m_n} \cos\alpha_{Fen}}{\left(\frac{s_{Fn}}{m_n}\right)^2 \cos\alpha_n} \cdot f_\varepsilon$$

- Helix angle factor Yβ changed, much bigger for β > 10° : σF0 increased
- New: The factor *f*ε considers the influence of load distribution between the teeth (*f*ε = 0.63 … 1.0) : σF0 decreased

-> σF0 for β >= 20° significantly increased !
-> σF0 for β = 0..10° and ε_α >= 2.0 significantly decreased !

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Influence of manufacturing tolerances

- Example:

Right flank with tip relief Ca varied in 6 steps from 18 to 48 µm, cross varied with length factor in 6 steps from 0.5*mn to 5.5*mn. So 36 variants are checked.

Additionally torque is varied in 3 steps from 41.6 to 100 % of nominal torque. So 36*3 = 108 LTCA calculations are performed.

Modifications sizing

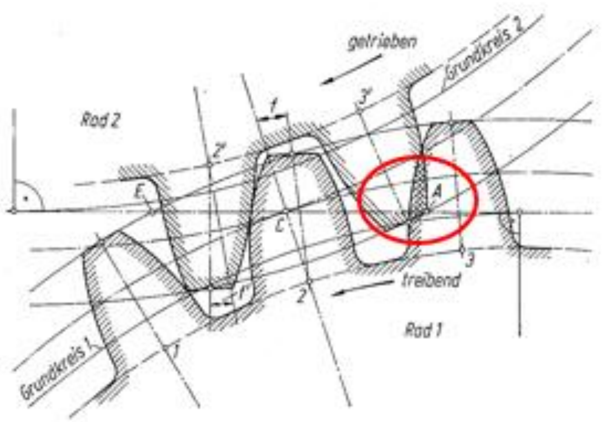
Conditions I | Conditions II | Results | Graphic I | Graphic II

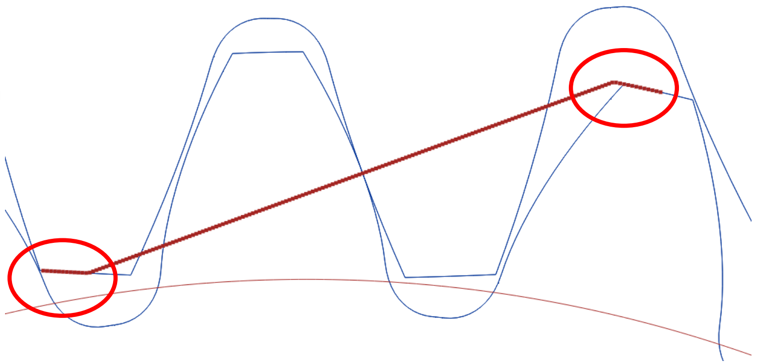
No.	Gear	Synchroı	Flank	Type of modification	Number of steps	Value (min) [µm]	Value (max) [µm]	Factor 1 (min)	Factor 1 (max)
1	Gear 1	1	right	Tip relief, progressive	6	18.0000	48.0000	0.5000	5.5000
2	Gear 2	1	right	Tip relief, progressive	6	18.0000	48.0000	0.5000	5.5000

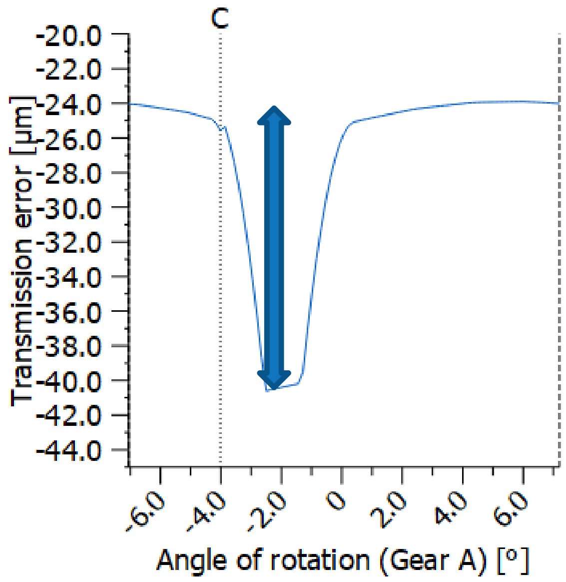
Example: Tooth number 30:43, module 4 mm, helix angle 17° and a pressure angle on the right flank of 31° (face width 40 mm, torque on pinion 1682 Nm, speed 2180 rpm).

Optimisation for noise

- Compensate primarily for tooth bending to avoid contact shock and to reduce the transmission error (PPTE).







Contact shock: $\varepsilon_{\alpha\_under\ load} > \varepsilon_{\alpha\_theoretical}$

PPTE
(Peak to peak transmission error)

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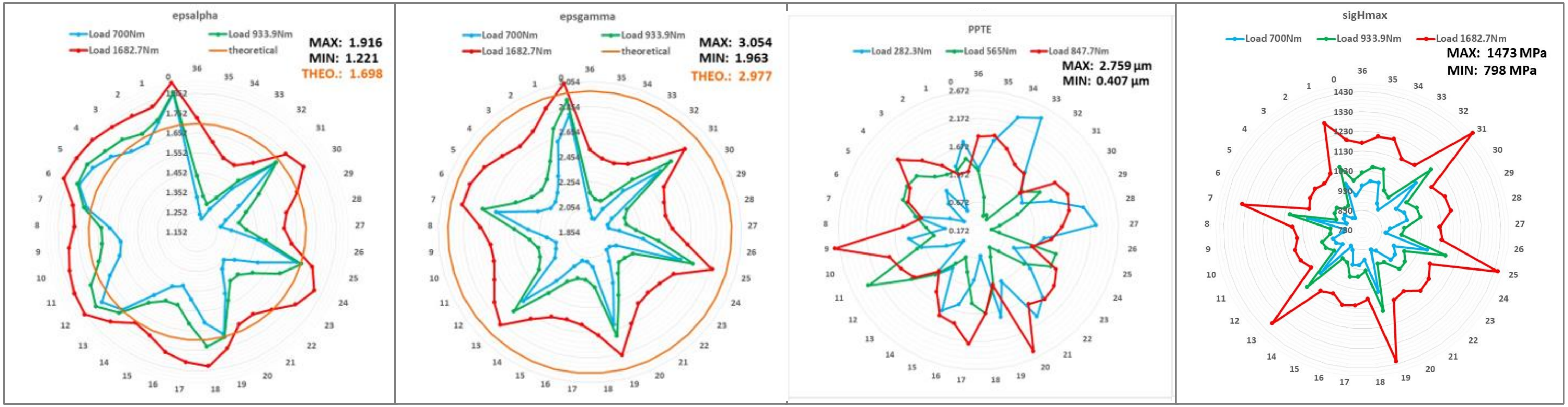
Overview of the main results for 36 profile modification variants at 3 torque levels.

Profile contact ratio under load ε_α | Total contact ratio ε_γ | PPTE | Maximum Hertzian pressure



Solution **8** can be a "good compromise" for min, mean and max load.

Influence of manufacturing tolerances

- Very important to consider manufacturing tolerances in the selection process of modifications
- Check of the stability of a chosen modification variant when profile and lead errors are added

Conditions I

Base modifications (are not varied)

No.	Gear	Flank	Type of modification	Value [µm]	Factor 1
1	Gear 1	both	Tip relief, arc-like	42.1000	1.9658
2	Gear 1	both	Crowning	10.0000	
3	Gear 2	both	Tip relief, arc-like	42.1000	1.9630
4	Gear 2	both	Crowning	10.0000	

Conditions I | Conditions II | Results | Graphic I | Graphic II

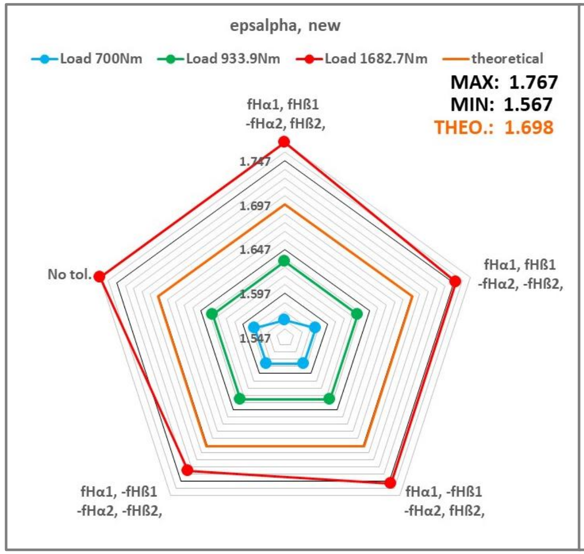
No.	Gear	Synchroi	Flank	Type of modification	Number of steps	Value (min) [µm]	Value (max) [µm]
1	Gear 1	1	both	Pressure angle modification (value)	2	-6.0000	6.0000
2	Gear 1	2	both	Helix angle modification, parallel (value)	2	-7.0000	7.0000

Inputs for the simulation of manufacturing errors to check the 'stability' of a proposed solution.

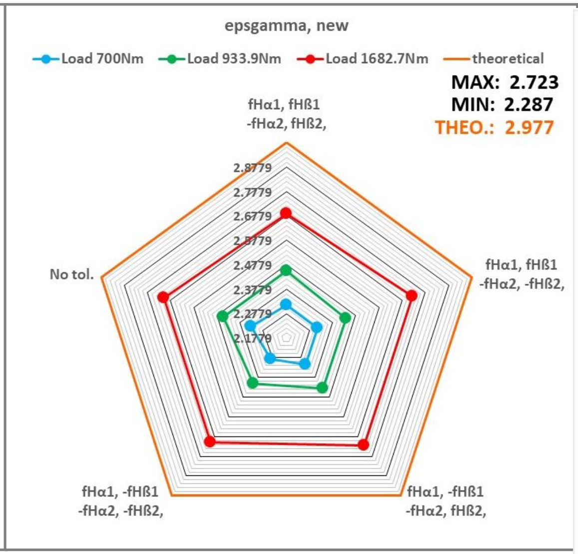
Influence of manufacturing tolerances

Simulation of manufacturing errors to check the ‘stability’ of a proposed solution. ‘No tol’ on the left side is the theoretical solution without any error.

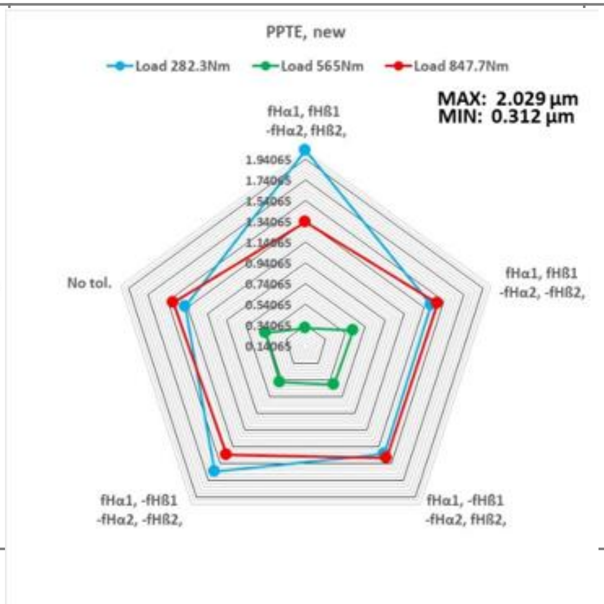
Profile contact ratio under load ε_α



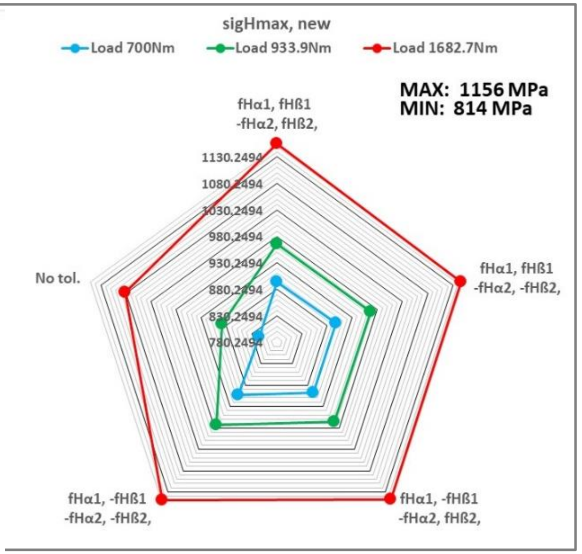
Total contact ratio ε_γ



PPTE



Maximum Hertzian pressure



Overall, the increase in the range of 10% of the critical parameters is acceptable. The proposed modifications can be considered appropriate for the manufacturing process.

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New papers about cylindrical gears

VDI-Conference 2019 (Munich)

- Combining gear design with manufacturing process decisions, U. Kissling, U. Stolz, A. Türich.
- Derivation of tooth stiffness of asymmetric gears for loaded tooth contact analysis, B. Mahr, A. Pogacnik, A. Langheinrich.
- Comparison of Strength Ratings of Plastic Gears by VDI 2736 and JIS B 1759, In Vision of Building a New International Standard, I. Bae, U. Kissling.

FTM-Meeting 2019 (Detroit)

- Sizing of profile modifications for asymmetric gears, U. Kissling.

Others

- Efficient layout process of cylindrical gears with manufacturing constraints, I.Tsikur.

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Thank you for your attention!

Sharing Knowledge

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