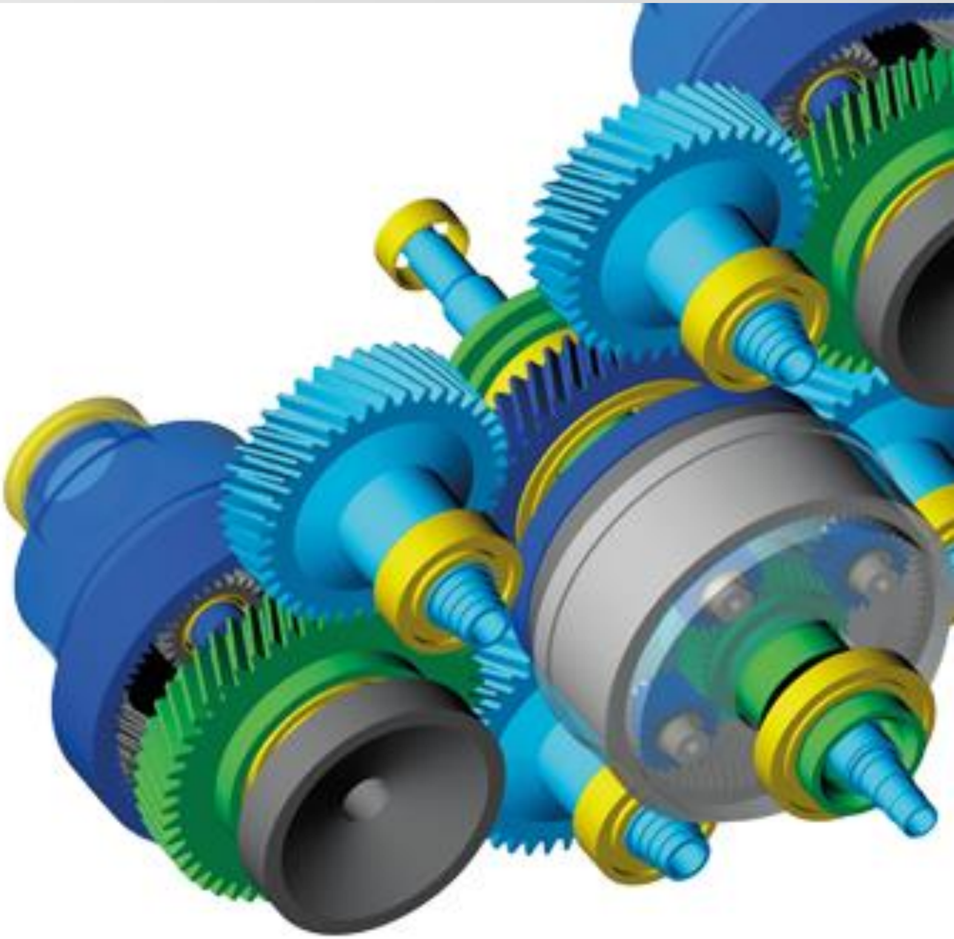
Cylindrical interference fit
DIN 7190



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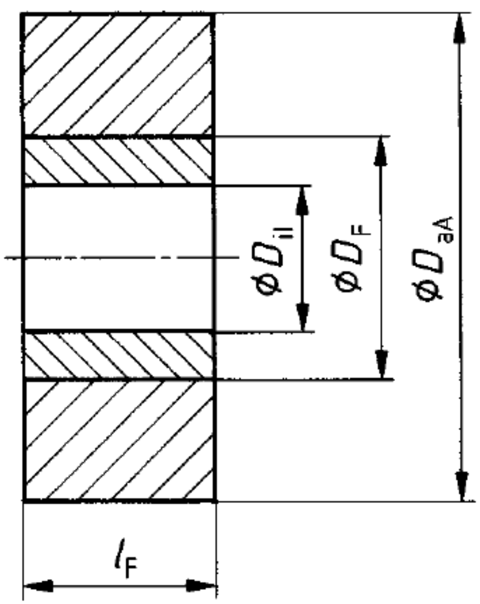
The connection is achieved by joining shaft and hub where the outer diameter of the shaft is bigger than the inner diameter of the hub.

Interference fits are used to connect:

- Planetary pins in the planetary carrier
- Connection of main shaft to gearbox (shrink disk)
- Connection of gears on shafts
- Connection of sleeves on shafts
- Bearings on shafts (to some extent)



Types of joining process:

- Longitudinal press fit (longitudinal pressing)
- Transverse press fit (warming and/or cooling parts)

Transmittable torque and axial force

- Loads are transmitted by friction on the circumference of the shaft.
- An interface contact pressure and friction are required.
- Transmittable torque T

$$T = \frac{\pi}{2} D_F^2 \, l_F \, \nu_{ru} \, \frac{p}{S_r}$$

- Transmittable axial force F_{ax}

$$F_{ax} = \pi \, D_F \, l_F \, \nu_{rl} \, \frac{p}{S_r}$$

- Symbols

D_F	Nominal diameter
L_F	Length of connection
ν_{ru}	Coefficient of friction – circumferential
ν_{rl}	Coefficient of friction – longitudinal
p	Interface contact pressure
S_r	Safety factor against sliding

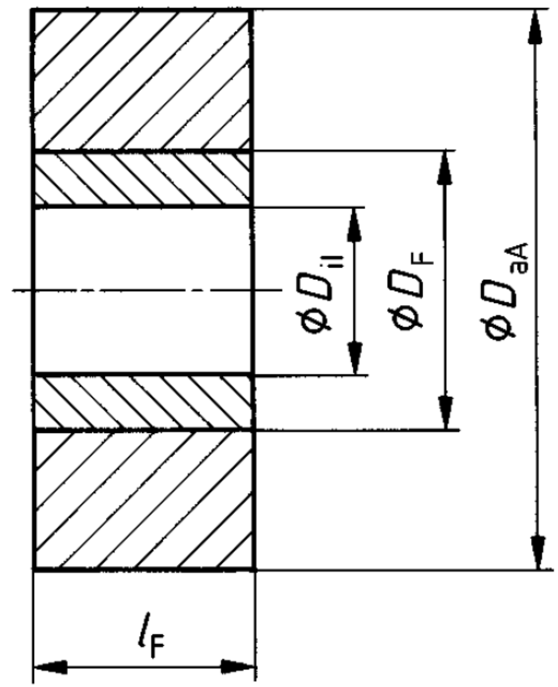
Calculation of interference fits (DIN 7190)

- **Calculation case a)** Given interface pressure *p*
- **Calculation case b)** Given oversize *U* (KISSsoft)

0,4 (changed in 2017)

$$U_w = U - \not{0{,}8}\,(R_{zA} + R_{zI})$$

Effective oversize — Fit oversize — Smoothing (embedding)



- Auxiliary values

$$\xi_w = \frac{U_w}{D_F}$$ referential effective oversize

$$Q_I = \frac{D_{iI}}{D_F} \qquad Q_A = \frac{D_F}{D_{aA}} \qquad K = \frac{E_A}{E_I}\left(\frac{1+Q_I^2}{1-Q_I^2} - \mu_I\right) + \frac{1+Q_A^2}{1-Q_A^2} + \mu_A$$

Interface pressure for purely elastically stressed interference fits

To guarantee the reference safety against plastic strain S_p

	Hollow shaft	Full shaft and $E_I = E_A = E$, $\mu_I = \mu_A = \mu$
Shaft	$\xi_w \leq K \dfrac{1 - Q_I^2}{\sqrt{3}\, S_{PI}} \dfrac{R_{eLI}}{E_A}$	$\xi_w \leq \dfrac{4\, R_{eLI}}{\sqrt{3}\,(1 - Q_A^2)\, S_{PI} \cdot E}$
Hub	$\xi_w \leq K \dfrac{1 - Q_A^2}{\sqrt{3}\, S_{PA}} \dfrac{R_{eLA}}{E_A}$	$\xi_w \leq \dfrac{2\, R_{eLA}}{\sqrt{3}\, S_{PA} \cdot E}$
Interface pressure	$p = \dfrac{\xi_w\, E_A}{K}$	$p = \dfrac{1 - Q_A^2}{2}\, E\, \xi_w$

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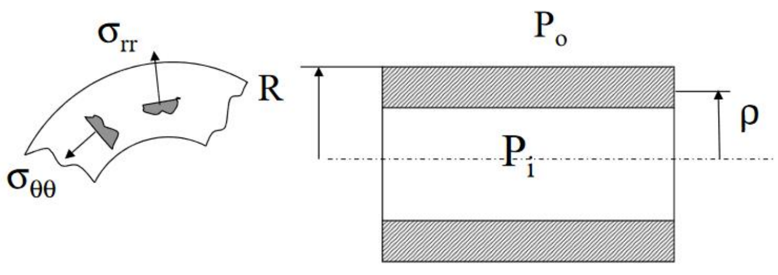
Stress profiles for purely elastically stressed interference fits

- Radial and tangential stresses

$$\sigma_{\theta\theta} = \frac{p_i . r^2 - p_o . R^2}{R^2 - r^2} + \frac{p_i - p_o}{\rho^2} . \frac{r^2 . R^2}{R^2 - r^2}$$

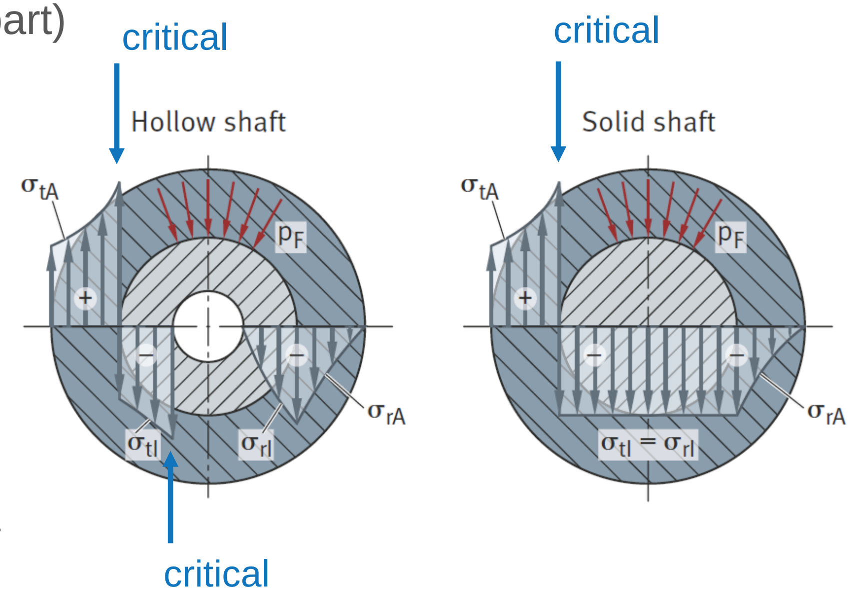
$$\sigma_{rr} = \frac{p_i . r^2 - p_o . R^2}{R^2 - r^2} - \frac{p_i - p_o}{\rho^2} . \frac{r^2 . R^2}{R^2 - r^2}$$



- Stresses on the inner edge of the hub (outer part)

Tangential stress	$\sigma_{tAi} = p_F \frac{1+Q_A^2}{1-Q_A^2}$
Radial stress	$\sigma_{rAi} = -p_F$
Equivalent stress (DEH)	$\sigma_{vAi} = \sqrt{\sigma_{tAi}^2 + \sigma_{rAi}^2 - \sigma_{tAi} \cdot \sigma_{rAi}}$
	$\sigma_{vAi} = \frac{2 \cdot p_F}{1-Q_A^2} < \sigma_{per}$

S. Wartzack, *Technical Pocket Guide*. Schaeffler Technologies AG & Co. KG, 2021.



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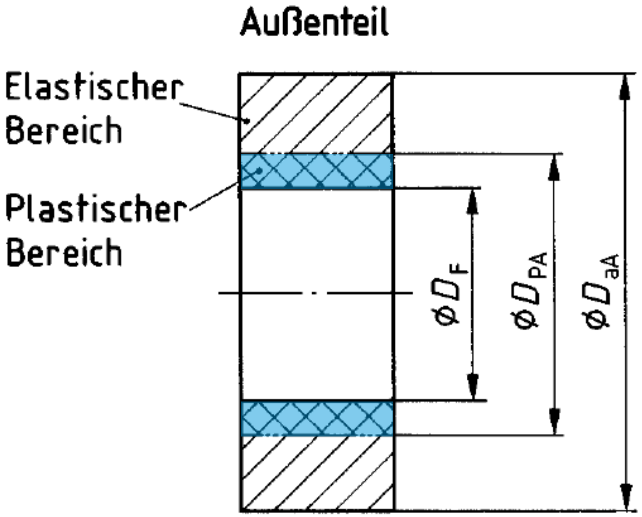
Calculation of elastic-plastic stressed interference fits

- The following limitations apply for calculation according to DIN 7190:
  - I. The inner part (shaft) must be full ($Q_i = 0$)
  - II. Both, inner and outer parts (shaft and hub) must have the same elasticity constants, i.e. $E_I = E_A = A$ and $\mu_I = \mu_A = \mu$

- In an outer part an interior plasticized zone up to diameter D_{PA} is formed, while a full inner part is either purely elastic or full-plastic stressed.
- An elastic-plastic design of the interference fit is not possible if inner part becomes fully plastic while the outer part is still subjected to purely elastic stress, i.e.:

$$\left(1 - Q_A^2\right) \frac{R_{eLA}}{2} \geq R_{eLI}$$



$$\zeta = \frac{D_{PA}}{D_F}$$

ζ … specific plasticity diameter

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Interface pressure for elastic-plastic stressed interference fits

- Specific plasticity diameter ς_{zul} of the outer part is calculated from transcendental eq.:

$$2\ln\zeta - (Q_A\zeta)^2 + 1 - \sqrt{3}\,\frac{p}{R_{eLA}} = 0 \qquad \begin{cases} p = \dfrac{p_{PI}}{S_{PI}} & \text{for } \dfrac{p_{PI}}{S_{PI}} \le \dfrac{p_{PA}}{S_{PA}} \\ p = \dfrac{p_{PA}}{S_{PA}} & \text{for } \dfrac{p_{PA}}{S_{PA}} < \dfrac{p_{PI}}{S_{PI}} \end{cases}$$

- Referential effective oversize ξ_w must be within:

Purely elastically stressed outer part

$$\frac{2}{\sqrt{3}}\frac{R_{eLA}}{E} < \xi_w < \frac{2}{\sqrt{3}}\zeta_{zul}^2\frac{R_{eLA}}{E}$$

Elastic-plastic stressed outer part

- Interface pressure

$$p = \frac{R_{eLA}}{\sqrt{3}}\left[1 + 2\ln\zeta - (Q_A\zeta)^2\right]$$

- Less than 30% of outer ring can be plasticized: $\dfrac{q_{PA}}{q_A} \le 0{,}3$ where $\dfrac{q_{PA}}{q_A} = \dfrac{(\zeta^2 - 1)Q_A^2}{1 - Q_A^2}$

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- Consideration of centrifugal expansion due to rotating speed

Operating data

Nominal torque	T_n	400.0000	Nm	Axial force	F_A	200.0000	N
Bending moment	M_B	0.0000	Nm	Radial force	F_R	0.0000	N
Application factor	K_A	1.0000		Speed	n	0.0000	1/min

- Consideration of temperature differences

Temperatures

Service temperature shaft	θ_B	20.0000	°C	Service temperature hub	θ_B	20.0000 °C

Longitudinal interference fit

Coefficients of friction ratio (press on)	μ_e/μ_a	1.3000		
Coefficients of friction ratio (loosening)	μ_{ll}/μ_a	1.6000		
		Shaft	Hub	
Assembly temperature (press on)	θ_M	20.0000	20.0000	°C

Calculation of joining temperature (lateral interference fit)

Depends on joint diameter, per thousand of df (acc. DIN 7190)	1		◉
Constant mounting clearance of	0.1000	mm	○
Temperature of shaft for joining	20.0000	°C	

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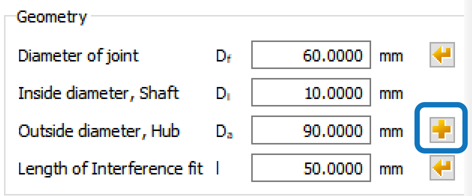
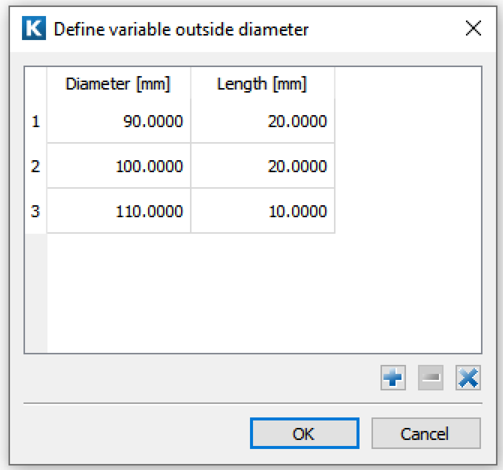
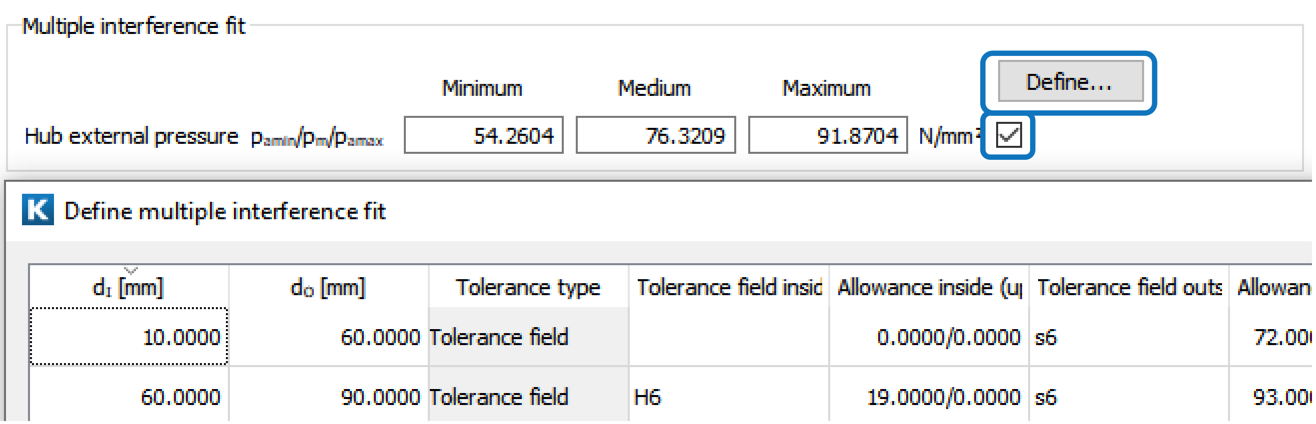
- Stepped hubs

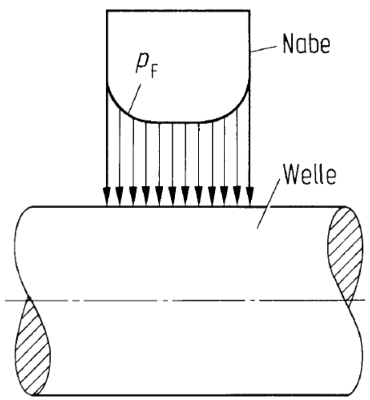


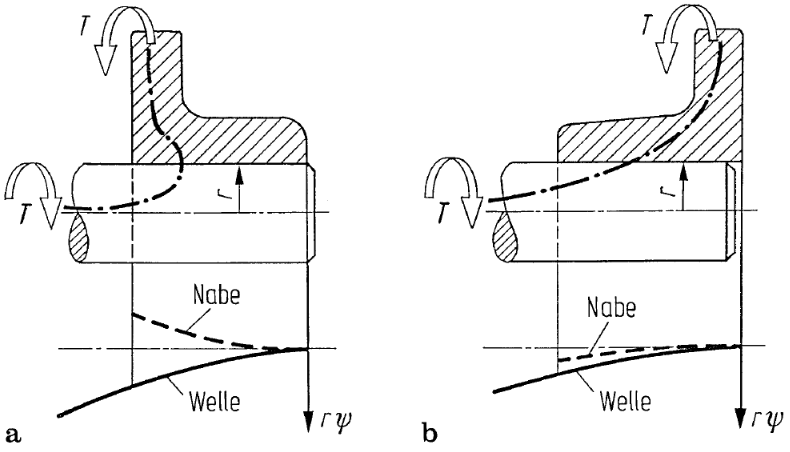


- Simulation of external pressure acting on the hub (via multiple interference fit)



- Pressure is not evenly distributed along length of connection. Some areas may have some movement between shaft and hub while the whole connection does not yet move → risk of fretting corrosion and weakening of shaft, especially under fatigue loads.
- At the ends of the hub, the contact pressure typically increases, resulting in a stress raiser on the shaft.
- Torque should be passed through the whole hub (Figure b).
- If necessary, hub material should be torsionally softer than shaft material.





G. Niemann, H. Winter, and B. R. Höhn, *Maschinenelemente 1*. Springer Berlin Heidelberg, 2005.

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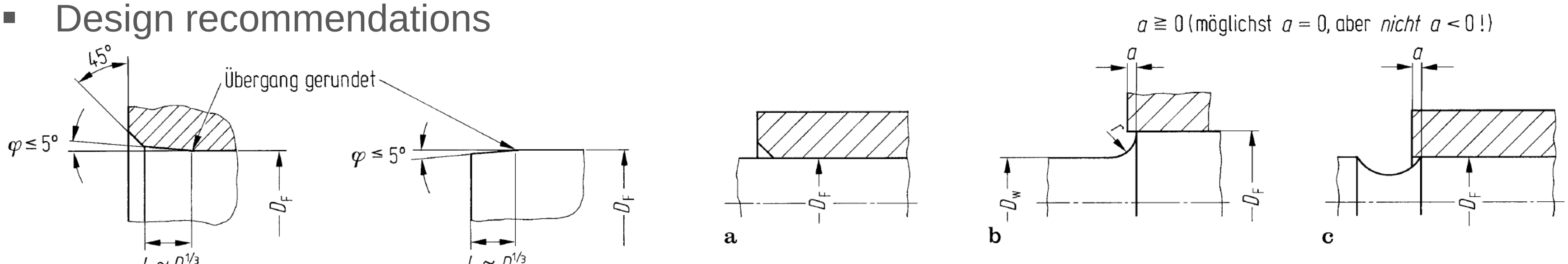
- The interference fit should not be combined with a keyway/key as the keyway will seriously disturb the stress state.
- Highest torque can be transmitted using a solid shaft and a thick hub
- If the load is introduced from one side, an uneven torque distribution along the length of the connection will result. Therefore, it does not make sense to use very long connections. Recommended ratio between width/diameter
    - Alternating torsion load L_F / D_F = 0.5…1.0
    - Torsion and bending, static L_F / D_F = 1.0…1.5
    - Alternating bending L_F / D_F = 1.5…2.0
  - Design recommendations



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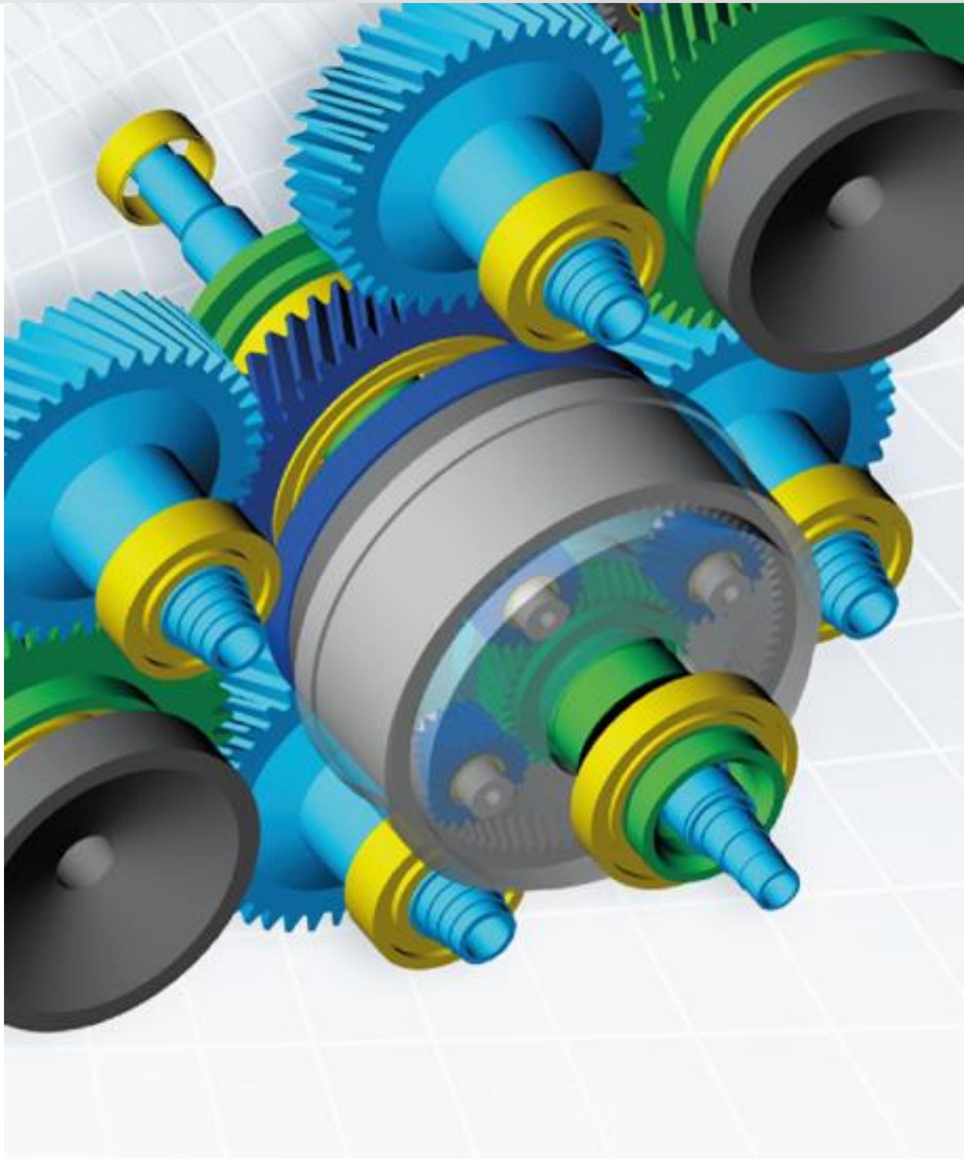
Thank you for your attention!



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