IMPROVED CALCULATION OF LOAD-DEPENDENT GEAR LOSSES BY CONSIDERATION OF SO FAR DISREGARDED INFLUENCES

T. Jurkschat[a*], T. Lohner[a], K. Stahl[a]
*Corresponding author: jurkschat@fzg.mw.tum.de
[a]Gear Research Centre (FZG), Technical University of Munich (TUM)
Boltzmannstraße 15, 85748 Garching b. München, Germany

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ABSTRACT
The topic of this study identifies potentials for improving the efficiency calculation of gearboxes. In drive technology, spur gears are frequently used for transformation of torque and speed. Power transmission always involves power losses.Particular interest has to be given to the load-dependent gear loss as it often accounts for a large share of the total loss.Hence, precise calculation proceduresfor the load-dependent gear loss are required for gear box design.

Systematic and comprehensive experimental investigations at the FZG efficiency test rig (Figure 1)have been carried out to investigate the load-dependent gear losses of spur and helical gears with and without flank corrections(Jurkschat et al. [1]). The experimental results have been incorporated into a calculation procedure, where a distinction is made between tribological(μ_{mz}) and geometrical (H_{VL}) influence factors.

$$P_{VZP} = \mu_{mz} \cdot H_{VL} \cdot P_A$$

Additional experiments have been conducted to improve the calculation of load-dependent gear losses by so far disregarded influences. On the one hand, the influence of the driving direction is investigated. Thereby, the considered driving and driven gears showed high differences of the specific sliding at tooth root and tooth tip. On the other hand, the influence of the change of contact ratio under load is investigated. Both influences show considerable influence on the load-dependent gear losses.

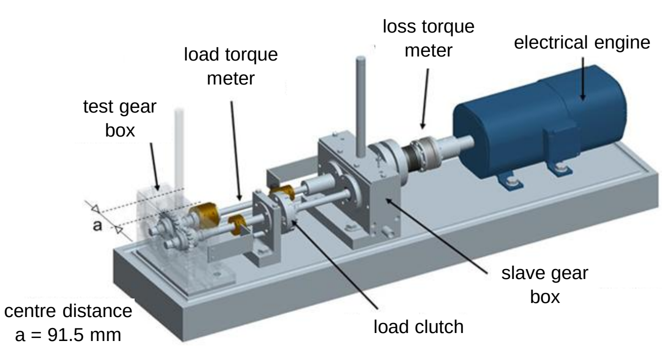

Fig.1 FZG efficiency test rig

The improved calculation of the mean coefficient of friction $\mu_{mz|opt}$ is based on a calculation approachaccording to Doleschel[2], which distinguishes between the solid coefficient of friction in asperitycontacts $\mu_{mz,s}$and the fluid coefficient of friction $\mu_{mz,f}$.Depending on the fluid load portion ξa regression analyses of allexperimental results was made.Thereby, the influence of the driving direction is considered by thelength of addendum path of contact of the driven and driving gear$g_{\alpha a1}/g_{\alpha a2}$, whichaffects only the boundary and mixed lubrication regime ($\xi < 1$).

$$\mu_{mz|opt} = \begin{cases} \left((1-\xi)\cdot\mu_{mz,s|opt} + \xi\cdot\mu_{mz,f|opt}\right) & \xi \geq 1 \\ \left((1-\xi)\cdot\mu_{mz,s|opt} + \xi\cdot\mu_{mz,f|opt}\right)\cdot\left({g_{\alpha a1}}/{g_{\alpha a2}}\right)^{0,04} & \xi < 1 \end{cases}$$

The local mesh and contact conditions along the plane of action are considered by the numerically calculated local gear loss factor. Thereby, the local gear loss factor $H_{VL|opt}$ is extended to include the influence of the change of contact ratio under load.

$$H_{VL|opt} = \frac{1}{p_{et}} \cdot \int_{y=0}^{b} \int_{x=A'}^{E'} \frac{f_N(x,y)}{F_{bt}} \cdot \frac{v_g(x,y)}{v_{tb}} \cdot dx \cdot dy$$

A comparison of the improvedcalculation procedure with the state of the art shows improved accuracy when determining the load-dependent gear loss of gear boxes.

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