STRESS CALCULATION IN WORM GEARS USING ELASTIC MULTIBODY MODELS

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Modern *electric power steering systems* (EPS) excel at a high energy efficiency compared to hydraulic systems. In addition, extra features like lane departure warnings, parking assistance and other autonomous driving functions are directly applicable with these systems. In all EPS concepts, the steering support is generated by an electric drive, whose force is applied into the system by a servo gear unit, see [1]. Two common EPS concepts are the EPS *dual pinion* (EPSdp) and the EPS *column* (EPSc). They both use a worm drive to transmit a motor torque. In EPSc concepts this torque acts on the steering column directly. In EPSdp it powers a second servo pinion which acts on the rack, see Figs. 1 and 2. The parts in such gear drives must meet defined load and durability specifications.

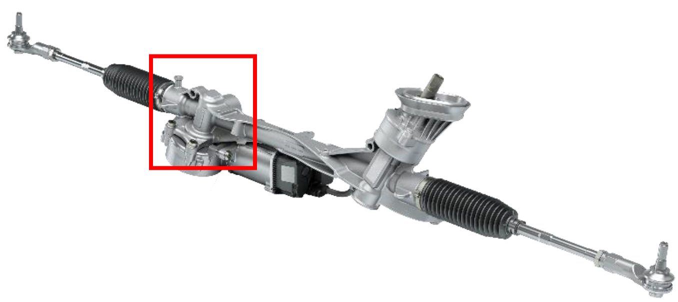

Fig. 1: EPSdp system with servo pinion

Fig. 2: Worm wheel drive in the servo gear unit

Common approaches for the dimensioning of worm gears rely on finite element analyses (FEA), but cover mainly static load cases due to commonly high simulation times. The applied loads within these calculations are determined in preceding multibody system (MBS) simulations. One drawback of this workflow is, that the deformations of the gear parts are initially neglected in the MBS simulation. Hence, the influence of the deformation on the system dynamics cannot be covered. Elastic multibody systems (EMBS) offer a good compromise between classic FEA and MBS methods. This work investigates the stress recovery in worm wheel gears with elastic multibody models.

The following computations are done with the *Gear Train Module* (GTM), which provides a tool-chain for EMBS simulations of gear trains using a floating frame of reference approach and modally reduced elastic gear models, see [2]. In [3], GTM was already shown to deliver valuable results for stress calculations in classical spur gear models. With recent extensions, the tool-chain now also conceptually enables the simulation of arbitrary gear geometries, including worm gears. Contact interactions between gears are considered by a bounding volume hierarchy (BVH) coarse collision check, see [4]. This guarantees the yield of compact sets of potential contact areas, which then are further investigated by a general nodal contact calculation, using a penalty approach for normal contact. The stress recovery divides into two main parts. In a preprocessing step, so-called stress modes, which define nodal or elemental stresses at each mode according to the body's model order reduction, are assembled. The final stress calculation is done in a post-processing step by superposition of the mentioned stress modes according to the elastic coordinates.

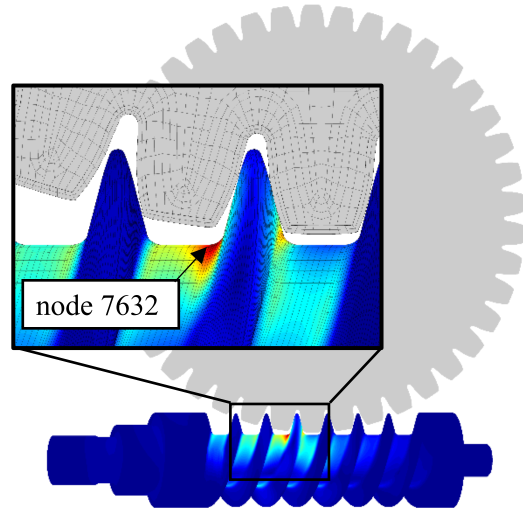

Fig. 3: Visualization of the von Mises stress at 1.49E-4 s

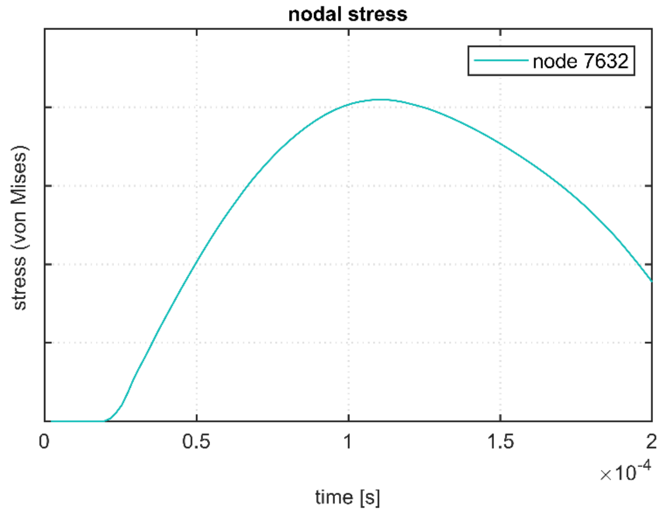

Fig. 4: Von Mises stress of the tooth root node 7632 over time

The model that was used in this work consists of a worm gear and a worm wheel from an EPSdp steering system. Different dynamic load cases are investigated with this model. Further, valid locations for the dynamic stress on worm gear geometries are discussed. The load case shown in Figs. 3 and 4 defines an impact situation, where the driven worm hits the resting worm wheel at a rotational speed of 130 rad/s. Both bodies are modally reduced down to 100 elastic degrees of freedom. The resulting stress distribution at 1.49E-4 s is shown in Fig. 3. It can be seen, that the resulting stresses in the worm's tooth root can be recovered, whereas stresses on tooth flanks cannot due to errors coming from local deformations. This corresponds to the findings from [3], where very good agreement in tooth root stress for modally reduced elastic gear bodies is stated, whereas correct contact stress demands more complex model order reduction techniques. The von Mises tooth root stress over time at node 7632 is shown in Fig. 4.

This work shows the calculation of stresses in worm gears by the use of elastic multibody models. The fast computation times of this method allows the consideration of highly dynamic load cases. Further investigations have to be done on contact friction models and the consideration of the polymer material of the worm wheel's rim.

References

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