Computationally efficient model of gears

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Abstract

The necessity for having computationally efficient model of gears covering all aspects of gear teeth shape imperfections, gear wheel deformations and shaft misalignments is obvious especially when vibrations are estimated at higher frequencies. It is also useful for prediction of transmission error of a gearbox. The goal of this paper is to present the computationally efficient model of two mating gears. Usually it is used spring-damper pair instead of gear teeth contact, which is very fast but holds only little information about the contact itself. Finite element method based model covers most of the events during gear meshing, but the calculation is time consuming. The way of using pre-calculated contact stiffness leads to the fast model but the preparation of the contact stiffness is complex and nontrivial task. This paper shows the advanced computationally efficient model of gears based on the multi-body dynamics [1].

Geometrical conditions in the gearbox are in the Figure 1. From the point of modeling view the simple gearbox consisted of two mating gears could be separated into two parts, first one takes care about the properties of wheels, shafts, wheel-seats and shaft supports, marked in the Figure 1.

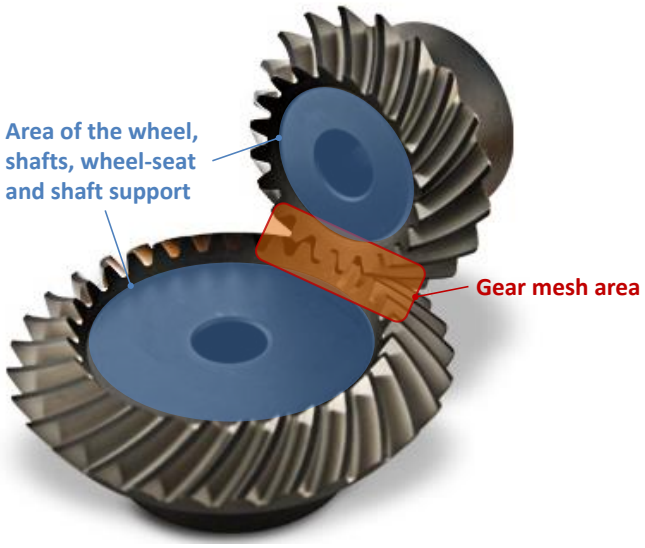

Figure 1: Gearbox overview.

The second part, denoted as a gear mesh area, marked in the Figure 1, for its modeling is usually used spring or stiffness matrix instead of teeth contact stiffness. The teeth engagement into the contact, the teeth flank shape (modifications, inaccuracies), the nonlinearity of teeth deformation and deformation of the wheel due to the loaded teeth are not taken into the account. This work has the aim to cover all influences playing the role in the gear mesh process.

At first, using ideal contact shape it is possible to find the teeth pairs, which could be in the contact. The contact points of one mating pair are located on the straight line. The start and end point of such line could be analytically solved. There is taken in the account shaft misalignments and wheel axis distance discrepancies.

Subsequently, the teeth pairs with contact lines are evaluated for contact forces in the next step. The forces are evaluated in the plane cuts of mating gears. The real flank profile is used here to evaluate penetration of undeformed mating teeth. The deformation is distributed into the both teeth tilting in the

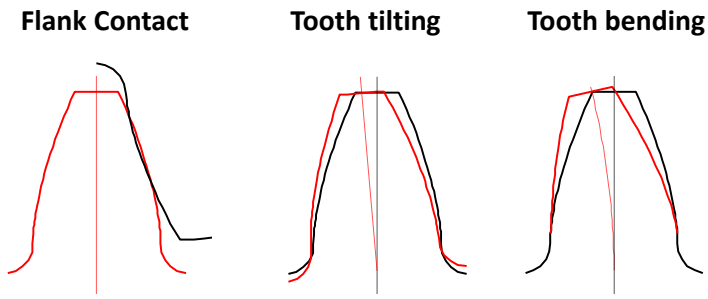

Figure 2: Lines of the contact.

wheel body, both teeth bending due to the flexibility of teeth themselves and tooth flanks deformation due to the contact itself, see Figure 2. The deformations are expressed as nonlinear analytical functions of contact position, gear parameters and contact force. Tooth tilting is derived in the [2] and tooth bending calculation is inspired by [3], the flanks contact evaluation is used in [4]. The approach covers all these compliances together with influences of tooth flanks real shape, wheel and shaft misalignments.
The nonlinear equation evaluating the contact force F_c with compliancy of teeth tilting $g_{tilting}$, compliancy of teeth bending $g_{bending}$ and contact compliancy $g_{contact}$ is shown in Equation (1), where δ is penetration of undeformed mating teeth. The compliancy $g_{contact}$ depends non-linearly on the contact force F_c. The penetration δ is calculated iteratively.

$$\delta = F_c \cdot g_{tilting} + F_c \cdot g_{bending} + F_c \cdot g_{contact}\left(F_c\right) \tag{1}$$

Using described approach it is obtained multi-body based model with concentrated information about gear meshing process but with faster simulation time than correspondent FEM model of mating gears. This model has aim to be used for noise and higher frequency vibration analysis for car gearboxes.

References

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