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Calculation of Load Distribution in Planetary Gears for an Effective Gear Design Process

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[The statements and opinions contained herein are those of the author and should not be construed as an official action or opinion of the American Gear Manufacturers Association.]

Abstract

The design of gears - especially planetary gears - can just be carried out by the consideration of influences of the whole drive train and the analysis of all relevant machine elements. In this case the gear is more than the sum of its machine elements. Relevant interactions need to be considered under real conditions. The standardized calculations are decisive for the safe dimensioning of the machine elements with the consideration of realistic load assumptions. But they need to be completed by extended analysis of load distribution, flank pressure, root stress, transmission error and contact temperature.

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Introduction

For the dimensioning of highly stressed toothings the analysis of load distribution and the definition of tooth flank modifications belongs to the principal tasks. Similar problems appear at the evaluation of toothing damages and failure modes of whole gears. Although there are a large number of standards for the calculation of spur gears, ISO 6336. It is necessary to have special and powerful calculation software which is reflecting the force-deformation-relation for every point of the contact area more precisely. The cause is the divergence from the conjugated toothings at gear wheels of spur and planetary gears. Often the flanks are modified in height and width direction. With these modifications the load-dependent deformations of the toothing and the surroundings as well as toothing errors, position errors of the housing boreholes and bearing clearance can be compensated. Also the gear noise as well as the load capacity is influenced in a positive way.

For the determination of the load distribution in planetary gear stages the deformation analysis is a more complex task as for spur gear stages. The deformation of the wheel body as well as the adjacent structures and the planet carrier can't be calculated efficiently in an analytical way. They need to be investigated with FE calculations or extended model approaches.

With a detailed load distribution analyses software /7/ all necessary calculations for the load analysis of planetary gears are united. The relevant deformations are determined with automatically generated FE meshes of the gear wheels and planet carrier and are used for the load distribution calculation afterwards. The software MDESIGN LVR^{planet} allows the load distribution calculation of planetary stages with spur, helical and double helical gear wheels. Therefore analytical functions for the contact area are in use. As result you can see the fast computing time despite of the high-resolution rough

discretization of the used model. The load, pressure, root stress distribution and width load factor can be interpreted, Figure 1.

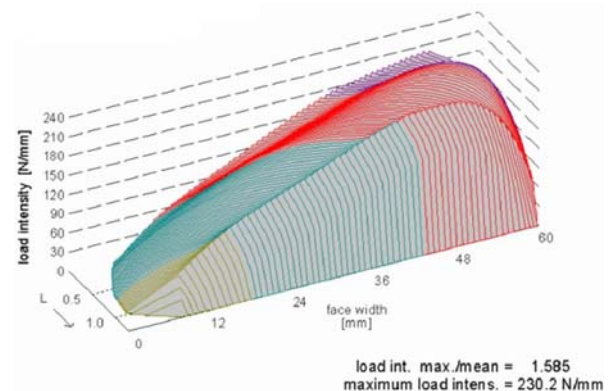


Figure 1. Bad load distribution on flank

Furthermore the program is giving suggestions how to modify the flanks for a well-balanced load distribution, see Figure 2.

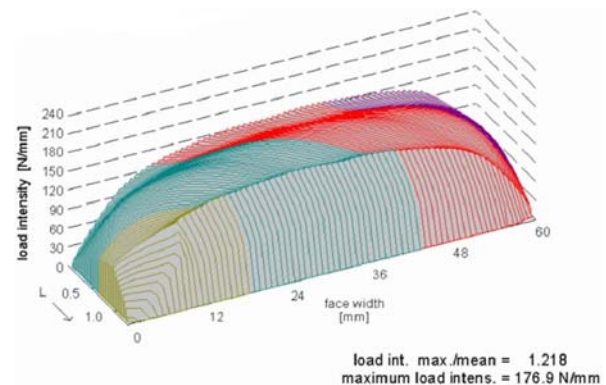


Figure 2. Good load distribution on flank

To solve all this calculation tasks in an efficient way it is necessary to install calculation software. To reduce the necessary inputs to a minimum it is indispensable to have a high degree of connections between the single calculation modules (gear design, calculation accord. Standards, load distribution analysis). In the background the task is efficiently solved with scientific established calculation kernels and uniform interfaces. So a

fast and secure concept, dimensioning and calculation of the machine element, the gear and the whole drive train are possible. There is the possibility to optimize toothing, shafts, bearings and bolts with use of real load assumption. Using this calculation software already at an early point of the product life cycle, PLC, you can get secure statements of your finish product without manufacturing prototypes. This calculation method can't totally replace the measuring campaign and test runs but unnecessary iterations can be switched off.

Applications of large gearboxes

The gearboxes described in this article are mostly used in heavy drive trains, special purpose machinery and in wind power plants, Figure 3. The characteristic of all these operating areas are turbulent and unsteady loads, uncertain boundary conditions and in some cases very high load peaks.

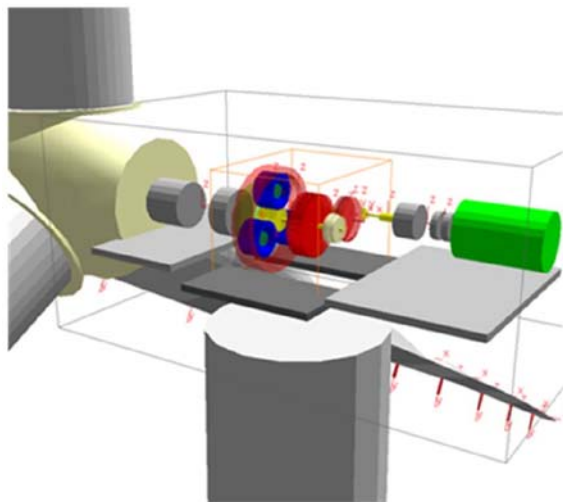


Figure 3. Application – wind power plant

For wind turbines the wind, the start- and stop procedure are the most important dynamic input parameter – and also the biggest unsureness for load conditions. By the mills there is the same fact in terms of flow of material, Figure 4.

A very special case study is the drive train of big mining trucks with high power output up to 700 kW and cyclic loads for transportation in surface mining's, Figure 5.

In all of these operation areas there are high requirements to design, optimization and calculation of drive trains and especially gearboxes.

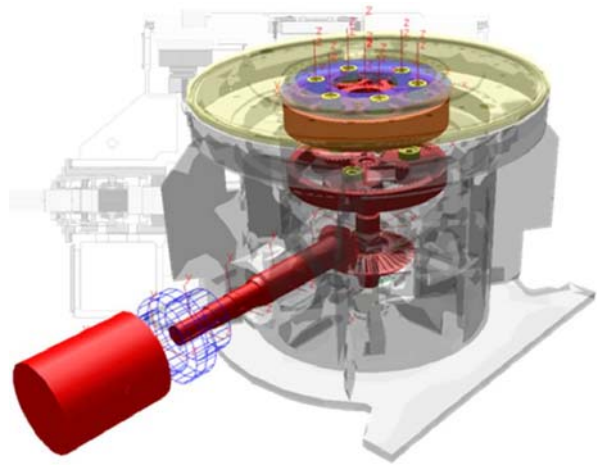


Figure 4. Application – cement mill



Figure 5. Application – mining truck

Another example of a large gearbox with high power output and cyclic loads is the foundry crane in Figure 6 for transportation of melted mass.

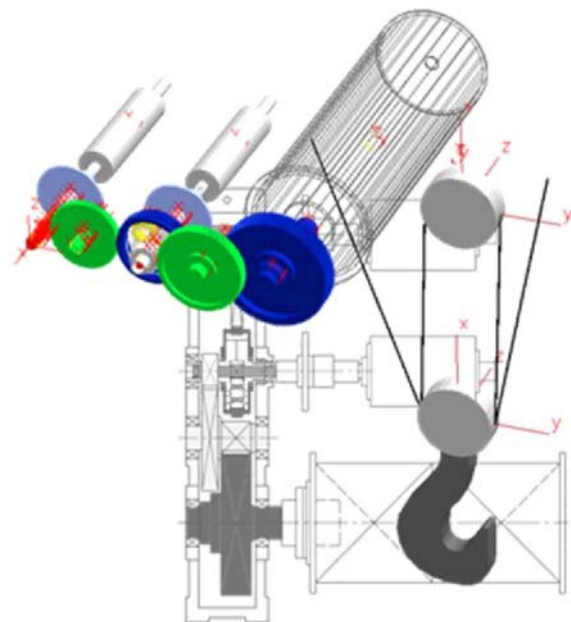


Figure 6. Application – foundry crane