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Influence of the Residual Stresses Induced by Hard Finishing Processes on the Running Behavior of Gears

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Motivation and objective

Noise behavior and load carrying capacity are important demands on power transmissions. The challenges in development, design and manufacturing of power transmissions are to meet these requirements economically and efficiently. The selection of a capable hard finishing process for a specific gear depends on the design of the transmission. Therefore it is important to know which requirements can be met by which hard finishing process.

To achieve high durability, high surface quality, low gear deviations, high gear quality and high residual compressive stresses are required. So far the influence of gear deviations and finish quality on the load-carrying capacity of gears have been analyzed. However, the influence of manufacturing induced residual stresses is yet unknown. Furthermore there is a lack of knowledge regarding how high the residual stresses caused by manufacturing have to be to influence the load carrying capacity of gears in a positive way.

The aim of the research project described in this paper is to analyze the influence of residual stresses induced by different hard finishing processes on the durability of gears. The testing pinions are hard finished by gear honing and generating grinding. Both processes are set up to comparable finish quality. Hereby the influence of the residual stresses on the durability can be analyzed independent from the geometrical conditions. In this paper the changes in residual stress and surface roughness during the test are described.

Approach

Figure 1 shows the approach of the project. At first residual stress measurements are carried out at industrially manufactured gears in a round-robin test. The intent is to determine the spread of the residual stresses on gears manufactured by the same hard finishing method. At the same time differences between the level of residual stresses resulting from different hard finishing processes can be determined. The hard finishing methods used are generating gear grinding and gear honing.

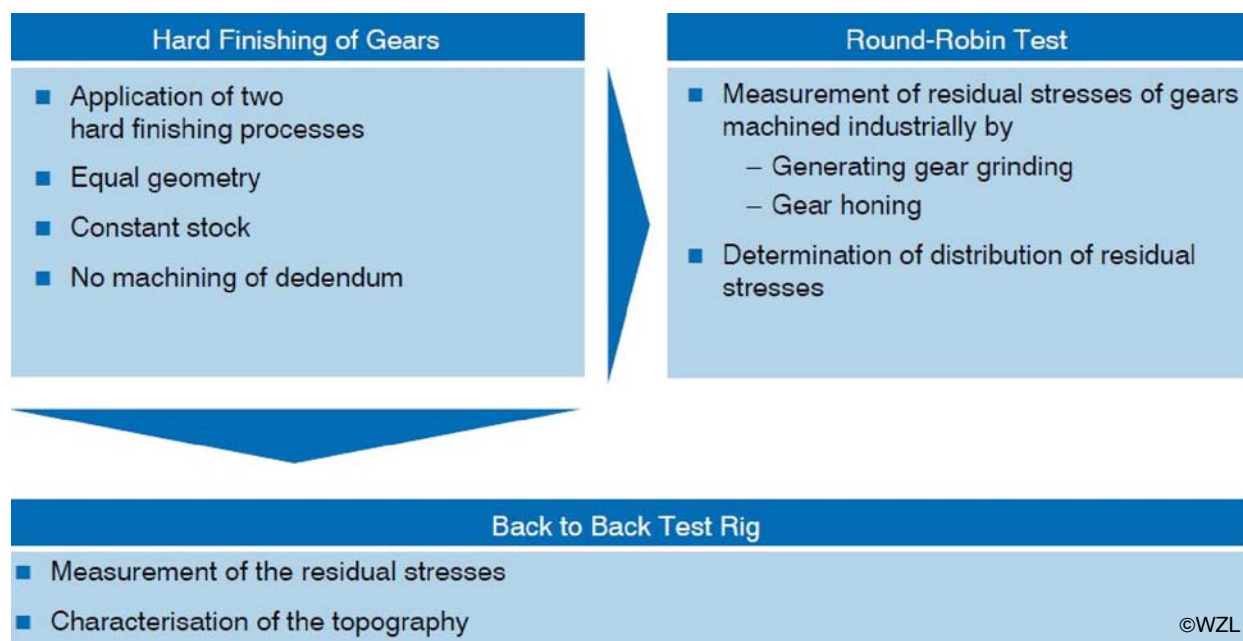


Figure 1. Approach

To analyze the changes in residual stress and surface structure of differently hard finished gears during the load cycles, testing pinions are manufactured by using generating gear grinding and gear honing, parallel to the industrial round-robin test. The testing pinions are mounted in a back-to-back gear test rig. At the beginning and after a defined number of load cycles the surface is analyzed by means of residual stress, roughness and hardness measurements. The testing gears used are exclusively manufactured by profile grinding.

Round-robin test to determine residual stresses due to hard finishing

Due to different workpiece materials, tool specifications and process parameters, different residual stresses are measured for workpieces manufactured by the same hard finishing process. Therefore the following questions result: How high are the residual stresses and the scatter of industrial produced gears? Does a specific hard finishing process lead to a certain residual stress level?

Furthermore it has to be answered whether the residual stress generated in a testing pinion is comparable to residual stress generated in gears manufactured in industry and whether the residual stresses of the testing pinion are representative for the industrial manufactured gears.

To answer these questions residual stresses are measured using X-ray diffraction at the testing

pinions and at the industrial manufactured gears. These automotive gears are hard finished by gear honing or generating gear grinding. The tools consist of corundum (aluminium oxide) and are ceramic bound. All in all, 25 gears are analyzed. The residual stresses are measured on the tooth flank at the position of the pitch circle at a depth of $a_B = 4.5 \mu\text{m}$.

The results are presented in Figure 2. In this figure the residual stresses are shown in the profile direction (above) and flank direction (bottom). The residual stresses induced by generating gear grinding are shown on the left side. Those induced by gear honing are presented on the right side. The helical striped show the residual stresses of the testing pinion manufactured under laboratory conditions.

In all for both directions, profile and flank, only residual compressive stresses are determined. Furthermore the residual compressive stresses in the profile direction are higher than in the flank direction. The difference between the maximum and minimum residual compressive stress measured for ground gears is $\Delta\sigma_P = 237 \text{ MPa}$ in profile direction and $\Delta\sigma_F = 254 \text{ MPa}$ in flank direction. For honed gears the difference is $\Delta\sigma_P = 274 \text{ MPa}$ in profile direction and $\Delta\sigma_F = 163 \text{ MPa}$ in flank direction. Noticeable is that the scatter for honed gears in the flank direction is smaller.

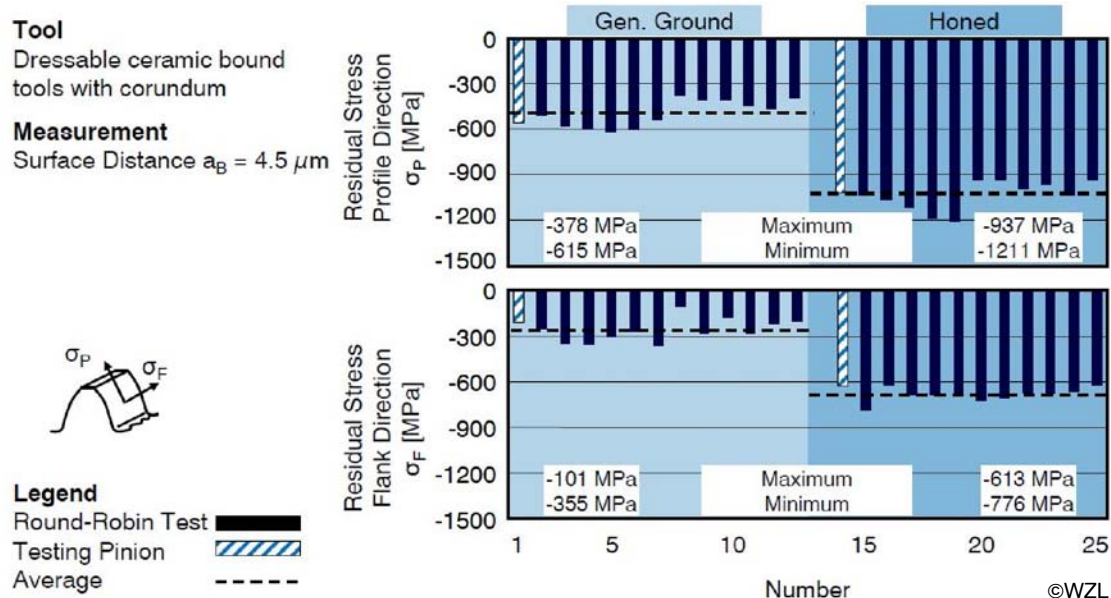


Figure 2. Measurement of residual stresses in round-robin test