

Influence of Grinding Burn on the Load Carrying Capacity of Parts Under Rolling Stress

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TECHNICAL PAPER

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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 demand for continuous improvement concerning economic efficiency of products and processes leads to an increasing cost pressure in manufacturing and design of power transmissions. Therefore the power density of gears has to be increased which leads to a demand for higher gear quality. In more and more cases this can only be achieved using hard finishing processes. From a manufacturing point of view, process costs have to be decreased as well which means that also a higher productivity is needed.

The demand for higher gear qualities leads to an increased use of gear grinding. The necessary increase of productivity takes the process closer to the risk of thermal damages such as grinding burn on the gear flank. The influence of thermal damage on the set in behaviour is nevertheless hard to judge so that damaged gears are often scrapped. This leads to increasing failure costs.

Especially the lack of knowledge of the effect of grinding burn on the load carrying capacity of gears leads to the point that the same degree of damaged is judged differently by different companies. Therefore it is necessary to do trials with thermally damaged parts in order to know how much a certain degree of thermal damage influences the load carrying capacity.

The investigations described in this report are aiming to determine the load carrying capacity of parts under rolling stress. Therefore thermally damaged rollers are employed on a roller test rig, since with this analogy process the part geometry is easier to describe and easier to damage reproducibly using this analogy process.

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Introduction

The demand for a continuous improvement of the economic efficiency of products and processes leads to an increasing cost stress in design and manufacturing of power transmissions. Therefore the power density of each gear inside a transmission has to be increased leading to a demand for higher gear qualities. For more and more gears these quality demands can only be met applying hard finishing processes.

Therefore the use of gear grinding processes has increased over the past years. Especially in gear grinding the efforts taken for a rise in productivity lead to an increasing risk of inducing thermal damages to the external zone of the gear flanks [1], [2], [3], [4]. The consequences of such thermal damages on the performance of a gear are today hardly predictable. Therefore even slightly damaged gears are scrapped in many cases resulting in high costs.

Due to the lack of knowledge concerning the influence of thermal damages on the performance of a gear each company has different rules on the acceptable limit of a thermal damage. Therefore baseline knowledge is needed in order to have a basis deciding how to treat gears with grinding burn.

Today there is a good knowledge about the influence of grinding burn on the tooth root load carrying capacity of gears with grinding burn [4], [5]. The determination of the influence on the flank load carrying capacity though is a lot more difficult. The problem is, that, e. g. in gear profile grinding, thermal damages only occur locally. Therefore it cannot be ensured that the damaged area is also the highly loaded one. The interpretation of test results and especially their generalization is problematic [6], [7].

Therefore this report aims to determine the load carrying capacity of parts under rolling stress compared to the degree of thermal damage. The performance of rollers reproducibly thermally dam-

aged using a laser shall be determined on a roller test rig. This kind of trial set up ensures the highly loaded area on the part to be also the damaged area. The loading and load distribution on the rollers is comparable to the situation of a gear tooth flank.

Previous investigations: round robin test on nital etching

Previous to the investigations described in this report WZL carried out a round robin test on nital etching together with the member companies of the WZL Gear Research Circle. This test aimed to investigate the reliability of the nital etching procedure concerning the detection of grinding burn.

Different samples from two case hardened materials were sent to the participating companies. On each sample laser damaged tracks with a different degree of damage were applied. The task of the companies was to undergo the samples their standard nital etching procedure, to evaluate the degree of grinding burn and to decide if a gear with such degree of damage would still be used or scrapped.

The results have shown, that grinding burn could be detected using the nital etching procedure by all fifteen participating companies reproducibly. Still significant differences were found concerning the evaluation of the etching result. Especially concerning the slightly damaged areas the opinions about the possible use of the samples differed significantly. This shows that there is a high uncertainty about the influence of different degrees of thermal damage on the performance of a gear.

Objective

In using gear grinding processes thermal damages such as grinding burn occur from time to time. The important question after the detection of grinding burn on a gear is, if these damages have a significant influence on its performance.

The objective of this paper is to determine the load carrying capacity of thermally damaged parts under

rolling stress. Since the carrying out of such examinations using real gears is problematic, rollers are chosen as an analogy. This way it can be assured that the highly loaded area is also the damaged area. The thermal damage is induced into the rollers using a laser. This ensures a reproducible induction of different degrees of thermal damage.

The examined degree of thermal damage reaches from non-damaged parts as a reference up to a rehardening zone as the worst case. Also two degrees of a tempered zone have been examined.

Workpieces and execution of the trials

Roller test rig and geometry

The roller geometry is derived from the contact conditions between two gear flanks. The roller radius is taken from the curve radius of the gear flank involute profile in the contact. In this case the pitch circle was chosen as the basis for the determination of the roller radius. The outer diameter for both rollers is $D_1 = D_2 = 42$ mm. The test roller, which is to be thermally damaged, has a cylindrical shape. The contra roller is bossed in order to prevent wear in the area of the roller edges. In order to prevent edge pitting on the contra roller, a diameter in axial direction of

$D_3 = 166$ mm is applied for crowning. The further data can be taken from **Figure 1**.

Figure 2 shows the test rig and the technical data. The motor drives a transmission. The drive gear of the transmission is coupled with test roller and the driven gear is connected to the contra roller. Gohritz found for this gear set that a pitting would be most likely to occur in the area of a negative slippage of $s = -24$ % [8]. Therefore a slippage between the two rollers of $s = -24$ % is realized through a gearing between the two mating rollers. The revolution speed on the drive side is $n_1 = 2850 \text{ min}^{-1}$.

The oil is supplied by an injection system with a temperature of $\vartheta_{\text{oil}} = 55$ °C and a tolerance of $\Delta\vartheta_{\text{oil}} = \pm 3$ °C. A typical oil for industrial gear box applications with typical additives is used. The contra force in order to realize the Hertzian stress is realized by a hydraulic pressure system.

It is known to date that a roller test still does not fully represent an exact analogy to a real gear flank. Therefore typically higher Hertzian stresses can be applied to rollers compared to gear flanks due to geometrical effects. Still the relation between different roller e. g. for material testing still can be transferred from roller tests to real gears. Therefore a reference within the roller tests is needed [9], [10].

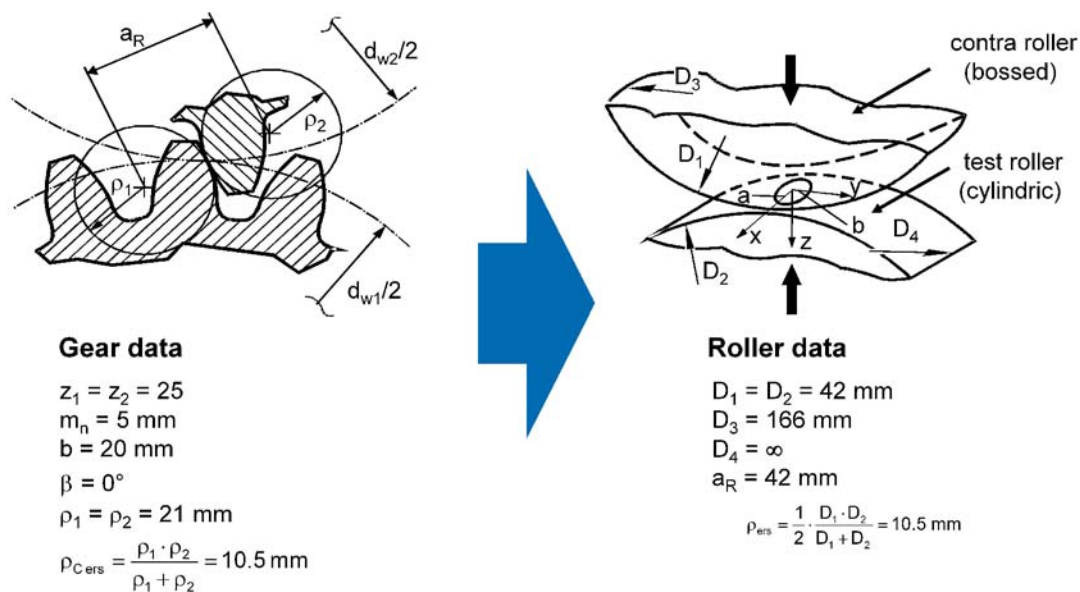


Figure 1. Geometry of gear flank and test roller