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Modeling of Surface Zone Influences in Generating Gear Grinding

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Abstract

The complex contact and chip forming conditions complicate the characterization and analysis of cause and effect connections in generating gear grinding. Especially influences of the grinding process on the surface zone in generating gear grinding are unknown. Due to this existing gap of knowledge the formation and development of thermal damages in generating gear grinding is the objective of this report. In the report an empirical and analytical process model for generating gear grinding will be introduced. The chip geometries and contact conditions for this model can be calculated by a manufacturing simulation. Furthermore, methods will be introduced to determine the model parameter and the process related influences on the external zone.

Keywords: Generating Gear Grinding; Surface Zone; Cutting Forces; Simulation

1. Introduction and challenge

To improve the load carrying capacity and the noise behaviour case hardened gears usually are hard finished. One possible process for hard finishing of gears is generating gear grinding which has replaced other grinding processes in batch production of small and middle size gears [1-4]. Despite the wide industrial application only a few scientific analysis exist [5-7].

The science-based analysis of generating gear grinding needs a high amount of time and effort. One reason are the complex and continuously changing contact conditions between tool and gear flank. In comparison with other grinding processes in generating gear grinding always multiple points of the grinding tool are in contact. The number of contact points change continuously during the tool rotation, Fig. 1.

An even number of contact points on the right and on the left tool flank leads to an uniform distribution of forces. With an uneven number of contact points also the force distribution will be uneven. This leads to an inconsistent distribution of the cutting forces. In the example in Fig. 1 (bottom right) on the line of contact of the left tool flanks the forces are split in two contact points. On the right tool flank the cutting force is increased, because only one point has contact. This fact can lead to a higher stock removal at this contact point and to a high excitation [5].

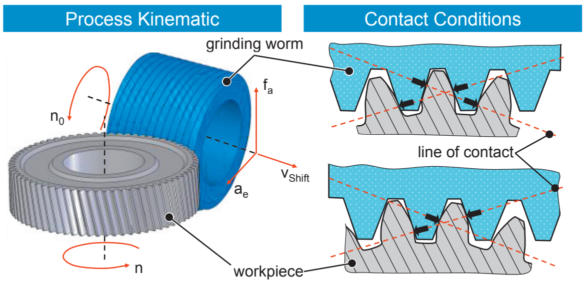

Fig. 1. Kinematics and contact conditions in generating gear grinding

These complex contact and chip forming conditions complicate the characterization and analysis of cause and effect connections in generating gear grinding. Furthermore, the application of the existing knowledge of other grinding processes on generating gear grinding is not possible. Especially, the influence of the grinding process on the surface zone in generating gear grinding is unknown.

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2. Research objective

The thermo-mechanical influence on the surface zone is a significant quality criteria for gear functionality [8-11]. Also for generating gear grinding it is necessary to determine thermal and mechanical loads and their influencing factors to avoid negative thermal surface zone inducements.

The global research objective is the description and prediction of process related surface zone impacts in generating gear grinding. Therefore, an empiric-analytic modeling approach has been developed for the prediction of thermally induced microstructure changes in generating gear grinding. In this report the modeling approach and the methods for the determination of the single model parameters are introduced.

3. Process model for generating gear grinding

The empirical model for the determination of surface zone influences is based on the following scientific assumption, which has already been validated for other grinding processes [12, 13]: Based on the knowledge of temporal and local specified thermal and mechanical energy inputs surface zone influences can be predicted in generating gear grinding.

In generating gear grinding the local specific energy $e_{GG,y}$ at a user-defined tooth profile point y must be smaller than the critical local specific energy $e_{GG,y}*$ to prohibit damages of the surface zone, like grinding burn, equation 1 [14].

$$e_{GG,y} < e_{GG,y}* \tag{1}$$

The local specific energy $e_{GG,y}$ can be determined by multiplication of cutting power $P_{c,y}$ and contact time $t_{K,y}$ related to the removed chip volume $V_{cu,y}$, equation 2.

$$e_{GG,y} = \frac{P_{c,y} \cdot t_{K,y}}{V_{cu,y}} < e_{GG,y}* \tag{2}$$

The cutting power includes both the mechanical and thermal energy dues. A qualified approach to determine the power $P_{c,y}$ is the product of resulting local cutting force $F_{c,y}$ and cutting speed $v_{c,y}$, equation 3.

$$e_{GG,y} = \frac{F_{c,y} \cdot v_{c,y} \cdot t_{K,y}}{V_{cu,y}} < e_{GG,y}* \tag{3}$$

To determine the local energy input for generating gear grinding processes the resulting local cutting force $F_{c,y}$, the cutting speed $v_{c,y}$, the chip volume $V_{cu,y}$, and the contact time $t_{K,y}$ must be calculated for every tooth profile point y. The approach for determination of the contact time and the cutting forces will be introduced below. Calculation equations for the local cutting speed in generating gear grinding can be found in literature [15].

4. Determination of chip geometries and contact conditions

In grinding processes the cutting force is usually commensurate to the chip geometry [1, 16]. The chip geometry can be described by chip volume, cutting length, cutting depth, and contact width. Due to process kinematics and contact conditions determination of chip geometries is not facilely possible in generating gear grinding. Therefore, a manufacturing simulation has been developed.

4.1. Manufacturing Simulation

The manufacturing simulation for generating gear grinding processes is based on penetration calculation. The unique feature of this simulation is that three dimensional chip geometries can be calculated not only for the machining of one tooth flank but also for the whole contact area between grinding tool and workpiece. To achieve a three dimensional penetration volume between tool and workpiece (chip volume) the single surfaces are approximated by triangles.

The manufacturing simulation was developed at the WZL and is called GearGRIND3D. In Fig. 2 the input and output values of the manufacturing simulation GearGRIND3D are shown.

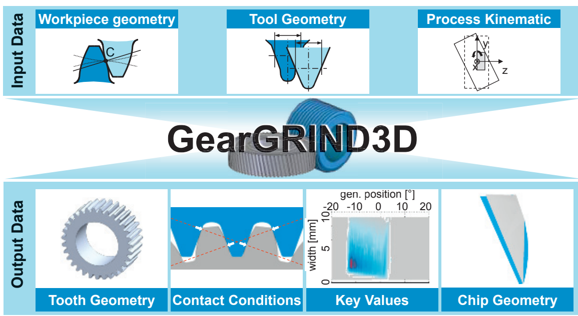

Fig. 2. Potentials of the manufacturing simulation GearGRIND3D

As input values the geometry of workpiece and tool are described. Tool and workpiece geometries are based on equations for standardized gear geometry calculation [17]. Furthermore, the process kinematics has to be defined. The kinematics is similar to the kinematics known from gear hobbing. That means a generating rolling movement is superposed with an axial feed.