The processing accuracy of the gear

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Abstract. The paper presents analysis of processing quality of gears. A special attention was drawn to detecting and removing burns, the existence of which greatly reduced operating properties of gears. The study emphases the influence of schemes, processing modes and abrasive tools features on the physico-mechanical layer of teeth processed and phase changes, micro-cracks appearances, depth and degree of hardening, meaning and character of residual stresses distribution.

1 Introduction

The formation of the surface layer during deep grinding of gears from alloyed steels occur under the influence of an uneven thermodynamic influence on the work-piece and, as a consequence, the appearance of inhomogeneous elasto-plastic deformations along the section of cavity profile between the adjacent teeth and the structure-phase transformations from heating and cooling of metal. This leads to distortion of the teeth profile, to the appearance of a step error and a decrease in the kinematic accuracy of the gear and to the appearance of grinding defects on the treated surfaces. Experience shows that the accuracy of machining of gears depends not only on the rigidity and kinematic accuracy of the machine, but also on the accepted grinding modes, tool characteristics and the conditions of its correctness.

The following describes an example of the profile deep grinding of identical gears on the same P600G machine with a grinding wheel with one characteristic. With the option of processing in a softer profiling mode, when the total allowance was divided into 5 passes, the accuracy of the gear wheel was achieved no less than with the optimal version in 2 passes.

As an example illustrating the accuracy of this processing process, measurements are given of spur gears manufactured by ARP GmbH Alpirsbah (Germania) with the following specifications: module - 5 mm, angle of engagement - 20 °, number of teeth - 23, width of sprocket -80 mm. Accuracy of gears according to DIN 3062 - 6th qualitet.

The gears were machined by the method of profile deep grinding on a 53A30P machine model with a highly porous disk with the characteristic 25A16PM212K. The preliminary profiling of the teeth was carried out by the method of deep grinding in 2 passes, and after carburizing with quenching, fine grinding was also performed in 2 passes. The meshing parameters were measured on a special-purpose gear-measuring center model P 100 CNC from company Klingelnberg. Measurement protocols containing graphical and digital information on the accuracy of profiles and tooth lines, as well the step errors and radial runout of the sprocket are shown in Figure 1 in accordance with GOST 1643-81.

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The received high accuracy of gear wheel processing is provided due to the kinematics of profile grinding process (absence of the long and difficult kinematic chains, control from highly developed system of CNC) and high dimensional stability of the abrasive tool. The requirements of the drawing and the results of measuring the processing accuracy parameters after grinding with a high porosity circle are given in Table 1.

Table 1. Precision parameters of gears

Precision parameters	Notation	Tolerance by the drawing,μm	The real precision, μm
Total profile error	F_a	12	6.4 ÷ 7.9
Profile shape deviation	F_{fa}	10	6.4÷6.8
The deviation of gear angle	F_{ka}	±7	-1.5÷2.6
Form error of the tooth straightness	F_P	9	0.4÷0.6
Angle deviation of the tooth straightness	F_{fp}	10	1.2÷5.8

Thermal action during grinding is often accompanied by structural changes in the surface layer of the treated material in the form of burns. Depending on the capacity of the heat source, the time of its action, and also the heat resistance of the processed steel, structural changes can develop into different depths and have a different nature. After the most intense thermal action, the surface layer represents secondary hardening austenite-martensite, under which is located a zone of the secondarily tempered metal with the structure of troostomartensite and troostite. With a decrease of heating of the surface layer, a secondary release structure is formed in it, proceeding through all the stages of tempering into the basic structure of martensite.

The likelihood of the burns appearance during tooth grinding depends not only on the processing conditions of processing, but also on the grade of the steel being processed. For heat-resistant steels of the type AISI 415, 16Cr3NiWMo this probability is lower than for non-heat-resistant steels such as 14NiCr14 and others [1].

During etching, the areas with a modified microstructure after tooth-grinding are usually extended along the tooth or revealed as a dashed grid, depending on the processing method. The greatest number of burns strokes and their maximum intensity, as a rule, is observed on the heads of ground teeth. Closer to the teeth legs, their number and intensity decrease or they are generally absent. Structural changes cause concomitant changes in the hardness and stress of the surface layer of the treated teeth. The micro-hardness in the burn zones is reduced, and residual tensile stresses are formed in the surface layer. Cogwheels with burns have bending endurance 1.4 to 1.6 times less than ground wheels without burnings. Accordingly, the durability of contact fatigue in gears with burns is 3.5 times lower [1, 2, 3, 4, 5, 6 and 7].

The appearance and development of grinding nature defects, before all, of burns and micro-cracks, caused by structural-phase changes in the surface layer, depends on the temperature and the time of its action. In the gear grinding schemes used, the heating intensity and the degree of its localization greatly differ and are related to the kinematic features of contacting grinding wheel with the profiled surface of the teeth. Under optimal conditions of gear grinding by various rolling patterns or profile processing by highly porous abrasive wheels, as experimental studies have shown, production tests and experience of industrial application, burns and micro-cracks on the machined surfaces of the teeth are not observed.

A general recommendation to prevent grinding defects in all gear grinding schemes is the decrease of the heat source intensity and the heating time of the treated zone. The use of new highly porous circles already by itself reduces the heating temperature by 300 to 400 ° C compared to grinding wheels with a normal structure. In combination with the optimization of the processing mode due to the speed increase of the relative movement