Grinding burns in the technological surface of the gear teeth of the cylindrical gears

Przypalenia szlifierskie w technologicznejwarstwie wierzchniej zębów walcowych kół zębatych

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The article presents the results of research on the grinding of the technological grinding of the tooth surface of toothed wheel cylinders. The toothed teeth with straight teeth, modules m = 2÷6 mm, bore width b = 26÷94 mm, number of teeth with = 12÷48 made of 40H and 12H2N4A steel with a hardness of 60 HRC. For grinding, T1Q grinding wheel has the following parameters: D = 350 mm, H = 25 mm, δ = 1400, grains 99A, grain size 60, hardness H, structure 5, binder V. The results of tests show the dependence of grinding scales on the parameters used machining and thickness of the sliced layer and this means the heat effects in the cutting zone.

KEYWORDS: burns, grinding, gears, TTL

During the technological process, various types of disturbances occur in the OUPN system (machine - handle - workpiece - tool), which affect the quality of the toothed gears, especially the quality of the technological surface layer (TWW) [1-3, 5]. Minimizing or eliminating the interference of the process is therefore important.

The paper discusses the effects of gear teeth production by assessing the TWW structure [5, 6] and cases, in which the grinding burns are formed (white spots).

Methodology of research

Examination of the burns occurrence in the TWW toothed gears was performed on the Niles type ZSTZ 315 C1 grinder, the characteristics of which allowed to grind the gear teeth with the following parameters: width of the grinding wheel s = 20÷170 mm, number of double gear wheels n_s = 102÷315 min^{-1}, peripheral feedrate p_o = 80÷800 mm/min. Grain accuracy tests were carried out in accordance with PN-85/M-55551 - they confirmed that the machine meets the requirements and can be used for tests [5]. The grinder was equipped with grinding wheels on 3 sides, ie a front dresser and 2 side dressings, which allowed the grinding and leveling of the grinding wheel after each pass around the tooth gear.

Grinding wheel T1Q type with the following parameters was used:

- outer diameter D = 350 mm,
- width H = 25 mm,
- corner angle δ = 140°,
- abrasion grain 99A of size 60,
- hardness H,
- structure 5,
- binders V.

Grinding wheel hardness was tested by Grindo-Sonic method and wheel grinding balance was performed on Torino's K300BR type. Eccentric grinding value of 1.0 μm at a speed of 1000 min^{-1}. The wheel was smoothed and sharpened at an angle of 20°, and the depth sharpening was 0.01 mm at a speed of 0.06 mm/min.

Cylindrical gears with straight teeth with modulus m = 2÷6 mm, rim width b = 26÷94 mm and teeth number z = 12÷48, made of 40H and 12H2N4A steel with a hardness of 60 HRC [6].

The grinding depth of teeth was 0.03÷0.12 mm, with the allowance for one side of the tooth in the range of 0.12÷0.35 mm.

For grinding, 1:40 ER fluid was introduced into the cutting zone at 15 dm^3/min - permissible level of contamination was 40 μm per liter of fluid [5].

The state of TWW gears was examined by microscope, x-ray analysis, and hardness measurements on a PMT-3 instrument. The depth of the structural changes were determined at 3 tooth zgładach undergoing digestion [5]. In addition, surface fatigue strength testing of gear teeth was performed. The number of cycles was 36×10^4/h with a load of 3.87 kN.

Structural changes resulting from burns

In TWW gear teeth, there are numerous burns of varying severity. In the case of grinding to a small depth (<0.03 mm) and lower transverse feedrates (<1.5 mm in a dual pitch), thermal process is characterized by low intensity of heat release in the cutting zone. This leads, in various places of ground surface of the gear tooth, to a thin layer of a secondary hardening of 1÷3 μm thickness [5, 6]. Under this layer, there is a martensite formed by tempering, which slightly increases the strength when a temperature is reached in the cutting zone, which prevents the structure from breaking into cementite and ferrite.

With elevated grinding parameters [5], local deep scorching occurs on the surface of the teeth, which is characterized by the fact that the secondary hardened layer lies on the surface of strongly tempered metal and progressively passes through all tempering stages (from the troostic-sorbitic to the final hardening structure).

The etched tooth surfaces after grinding contain: a deep-etching portion in the form of lines or strips located along the generatrices (troostite), a small area of secondary hardening and light gray parts (martensitic).

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In most cases, the surface of the gears after grinding can present burning of scorching with a troostic or troostic-sorbitic structure due to the tempering. In various places over the tempered layer, there is very thin (1÷3 μm), undigested re-hardened layer of the material (fig. 1-4).

The steel structure in fig. 1 displays ferrite and pearlite mesh cementite at grain boundaries, while fig. 2 - light alloy ferrite with a separate pearlite against the ferrite alloy.

After grinding (fig. 3), the material structure contains changes with fine-grain structure along the grain boundaries of pearlite and cementite.

Fig. 1. Microstructure of gear tooth of 40H steel (× 500)

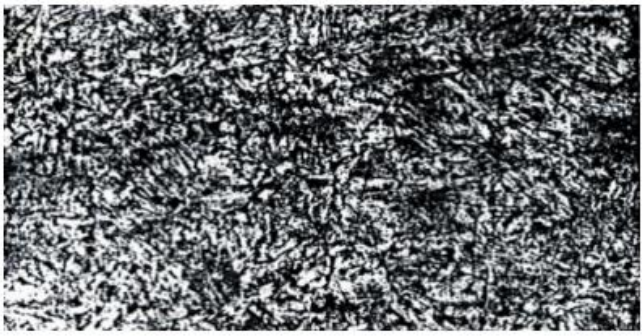

Fig. 2. Microstructure of gear tooth of 12H2N4A steel (× 500)

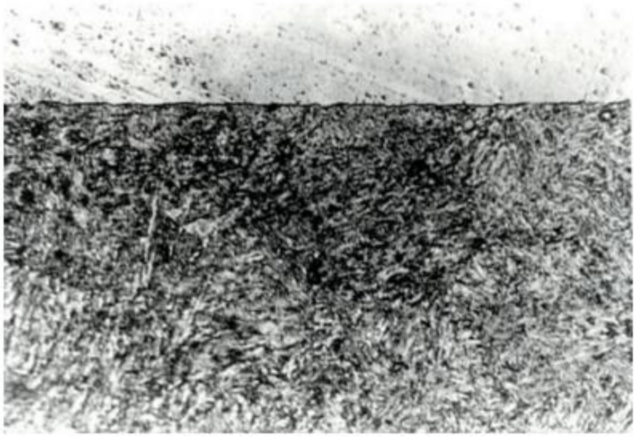

Fig. 3. Microstructure after grinding of 40H steel gear (× 500)

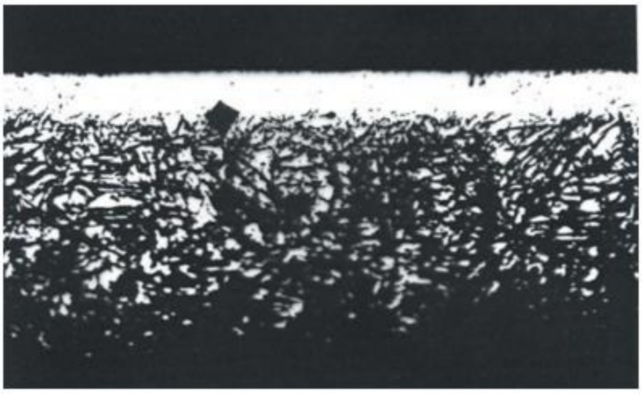

Fig. 4. Microstructure after grinding of 12H2N4A steel gear (× 500)

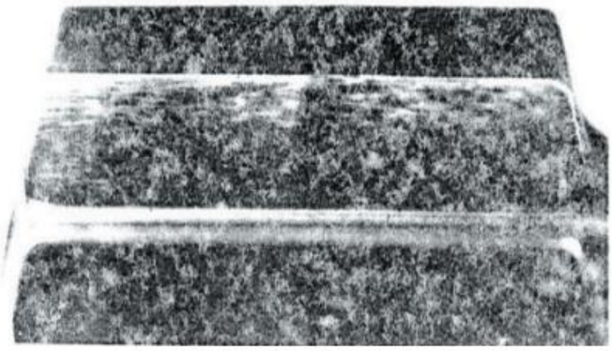

Fig. 5. Microstructure after grinding of 12H2N4A steel gear (× 100)

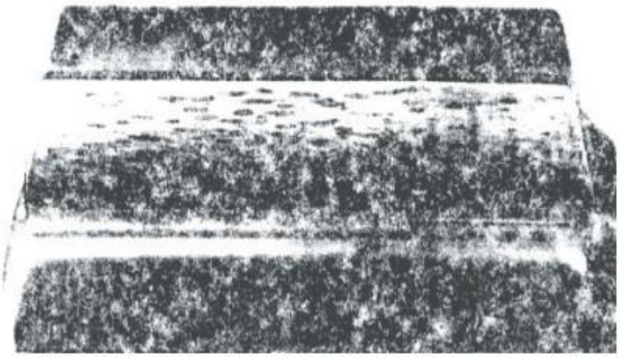

Fig. 6. Microstructure after grinding of 12H2N4A steel gear (× 300)

The gears shown in fig. 5 and fig. 6 have been subjected to heat treatment (carburizing, hardening, milling, tempering) and then grinding. TWW was etched with nital to detect high intensity burns. Tempered martensite and residual austenite were visible on the TWW containing residual martensite and austenite. Measurement of meso-hardness was done by Knoop method. The surface hardness was 6.81 kN/mm^2, while the meso-hardness of the output structure was 8.07 kN/mm^2. Fig. 7 shows the value of meso-hardness and depth of its layer in TWW for grinding burns occurring.

It should be noted that deep grinding burn (95÷100 μm) results in a decrease in hardness from 60 HRC to 50 HRC [5, 6]. In the tests, the grinding burns were less intense and less deep (fig. 7). Therefore, the hardness of the examined steel was much lower and amounted to about 2.1 kN/mm^2.

Fig. 8 shows the meso-hardness values for depth of their layers in TWW gear tooth. Studies have shown that in the case of data in fig. 8, grinding burns do not occur.

However, it should be borne in mind that the magnitude of the *K* factor (the criterion for determining the depth and intensity of structural changes in the workpiece) [6] depends on the depth of grinding for a single passage and changes as the radius of curvature of the ground tooth is increased. The increase in this coefficient and the depth of grinding is due to the increase in cross-section of the cutting layer and thus the grinding performance [6]. Determining the admissible value of the coefficient *K* allows the analysis of the influence of various parameters leading to the increase of heat in the cutting zone, which in turn allows to select such parameters and cutting conditions that minimize the amount of heat produced in the cutting zone [6].

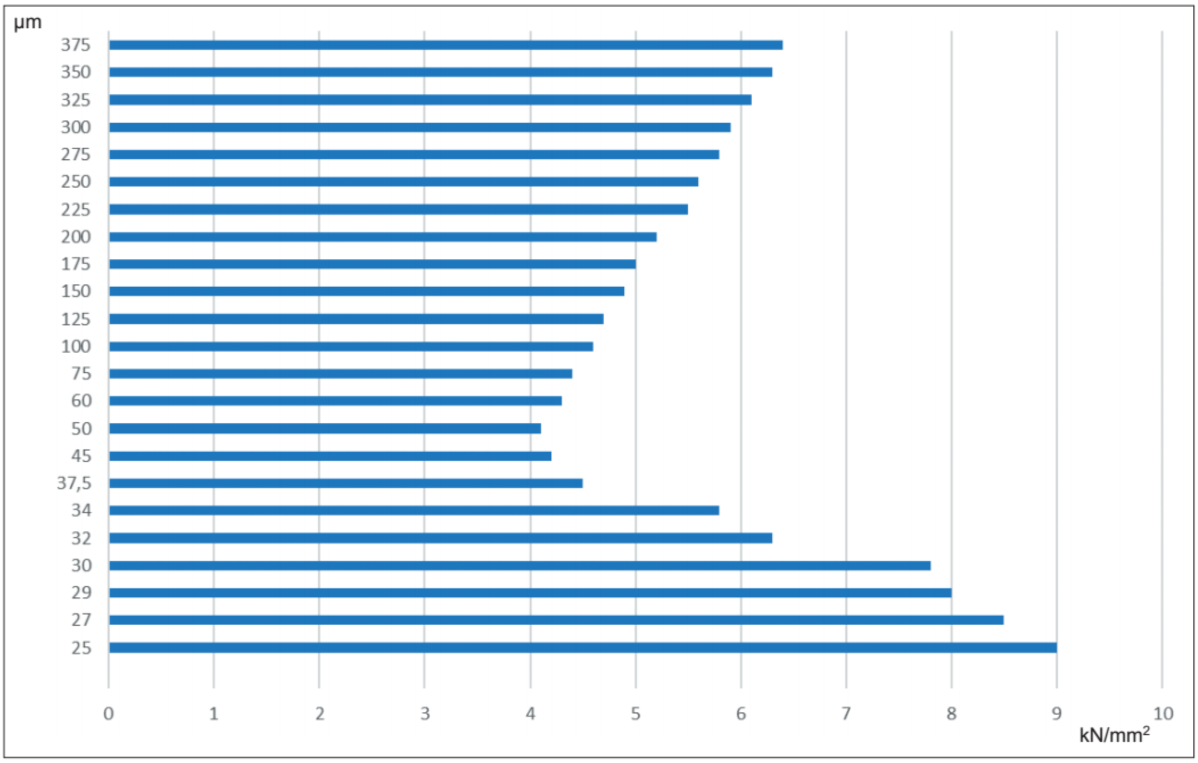

Fig. 7. Distribution of meso-hardness (determined by Knoop's method) in TWW gear teeth after grinding

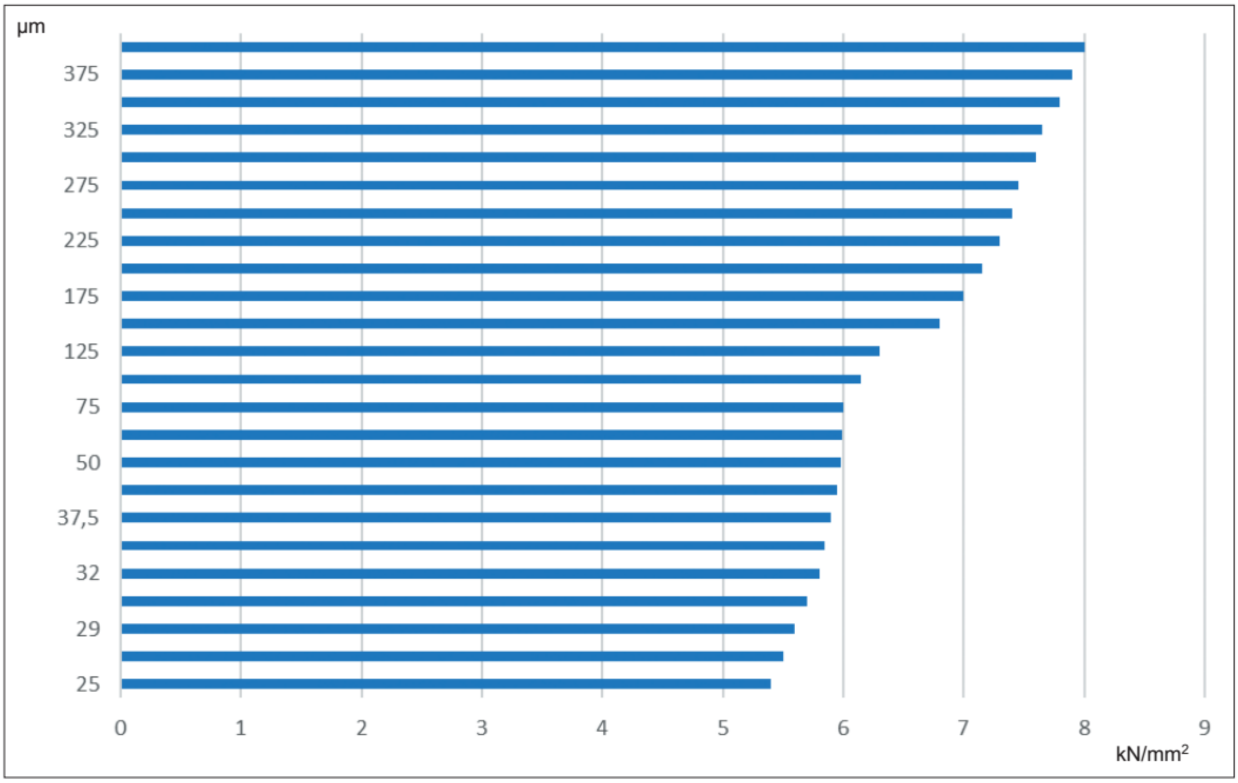

Fig. 8. Values of meso-hardness (determined by Knoop's method) and its depth in TWW gear teeth after grinding

Conclusions

Due to the appropriate *K* factor, the grinding burns can be minimized or excluded (fig. 8). To do this, it is necessary to:

- correctly set grinding conditions, for which factor *K* does not exceed permissible value [6];
- for the manufacture of gears, use steel EI415 and EI417 that are resistant to heat;
- reduce the size of the range from the front of the tooth wheel, thus reducing motion along the tooth profile;

check the sharpening radius of the working edge of the grinding wheel.

Grinding burns are unfavorable phenomenon accompanying grinding the gear teeth. The teeth of these gears become worn very rapidly and their surfaces - destroyed. In practice, this can lead to severe accidents or even disasters. Therefore, the process of grinding the gear teeth must be carried out in such a way to prevent the formation of such phenomena. Hence, the correctness of the *K* factor selection is important. In this way, the disadvantageous conditions that interfere with the grinding process can be eliminated.

The study showed that burns lead to a number of significant changes in TWW by changing the microstructure and meso-hardness, which significantly impairs the mechanical properties of the layer. As a result, the gear teeth with such defects cannot be exploited.

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