INVESTIGATION OF SOFT MAGNETIC MATERIALS GRINDING

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Abstract: Grinding of soft magnetic materials in conventional conditions is difficult due to the fact that so called adherences from machined material appear on the working surface of grinding wheel. The conditions of grinding operations get better when special elements removing the adherences are used to clean the grinding wheel. The paper presents the influence of the machining parameters and the application of cleaning elements on the quality (roughness and hardening) of the surface being machined.

Key words: grinding, soft magnetic materials, roughness, surface hardening

1. INTRODUCTION

Common application of electronic elements has brought the necessity of significant increase of the number of manufactured parts. Miniaturization of electronic parts and their often complex structure have made their manufacture troublesome. The small size of parts, mostly with high accuracy and the use of special materials create serious problems. There is a group of those parts which is made of nickel and iron alloys. Those materials are called soft magnetic materials and they are known as permalloy. Quality requirements imposed on parts made of those alloys are very high to assure constant electrical properties. Losses in electronic devices deteriorate the quality class of the product. Improvement of productivity by an increase of the machining parameters, the use of other grinding wheel characteristics, etc. will result in a change of the surface layer characteristics [5]. This will influence an increase of the degree of hardening of the surface layer and, additionally, the change of the tool working conditions – the process of adherences build-up in the grinding wheel pores intensifies. Investigations have shown that productivity increase by raising the process parameters does not bring positive results [1, 2, 3, 4]. Various investigations conducted for years, aiming at improvement of the quality of elements made of nickel-iron alloys have not rendered expected effects. In the nineteen-sixties, elimination of adherences on large-pore grinding wheels by supplying cooling fluid through the wheel pores was promoted. The effects of that method, though principally positive, were dependent on the degree of the machining fluid purification.
2. INVESTIGATION PROGRAM

After an analysis of the literature on grinding elements of soft magnetic materials, considering also the very difficult position of the enterprise, a three-stage action program has been established. The enterprise was mainly interested in the surface roughness of the elements and minimal hardening of the surface layer. The first stage focused on the examination of surface roughness of ground elements and the degree of the surface hardness increase after grinding. The second stage included search of other machining parameters (grinding wheel speed, longitudinal feed speed and other granularity of the grinding wheel). The third stage included an attempt to find more advantageous conditions of forming parts than those applied so far. The investigation was conducted on about 5 mm thick plates made of waste materials – useless for the enterprise. Rectangular plates dimensioned 16 x 32 mm were fixed in a special chuck on a flat-surface grinder. The longer side was arranged in accordance with the feed in order to determine the process of adherences build-up. The experiments were performed on flat-surface grinders made by various producers in a number of industrial enterprises.

Examinations of the first stage were performed on an SPE 40 grinder for three wheel types: aluminium oxide one, diamond one and borazon one; the wheels had grain size corresponding to 60, hardness J, resin binder and open structure 9 - 11, wheel diameter 250 mm, wheel width 20 mm.

In the second stage, examinations were performed on various flat-surface grinders working with the wheel circumference. The selection of the machines depended on the conditions adopted in the program of experiments.

The examinations of the third stage were performed on various flat-surface grinders working with the wheel circumference, too. This has allowed for the verification of the results of the second stage examinations.

The machining fluid used in the examinations was water solution of oil, Emulgol E - 42 and Polgrind 1A. Roughness was measured by means of a C. Zeiss profile measurements gauge type ME and also by Hommel – Tester T 8000. Hardening measurement was performed by means of an MPT -3 microhardness tester with the load of 0,5 N. Adherences on the grinding wheel were inspected by means of a magnifying glass with a magnification of 5x. The method of the grinding wheel cleaning applied in the investigation was that stated in work [1]. The only difference was in two additional crossed nozzles arranged by the angle of 20° to the wheel generatrices.

2. INVESTIGATION RESULTS

2.1. Results of the first stage investigation

Figure 1 shows the influence of the removed layer thickness on the surface roughness. The curves represent the average values of roughness from 7 measurements. Roughness
measurements were performed at a distance of 5 mm from the sample end in order to find whether there are changes indicating adherences on the grinding wheel. Number 1 designates the curve obtained for various thickness of the layer removed by means of an aluminium oxide wheel. According to the company standards, only the Ra value for the removed layer thickness $a < 0.006$ mm is acceptable. Number 2 designates the roughness curve for the diamond grinding wheel. Admissible roughness appears for $a < 0.01$ mm. Number 3 designates the surface roughness curve obtained for borazon grinding wheel. In the range of the removed layer thicknesses under investigation, all the roughness values obtained are lower than the admissible one. A significant drawback is the fact of large value peaks occurring in the profilograms indicating adherences on the grinding wheel.

![Graph showing the influence of the removed layer thickness on the roughness and hardening of ground surfaces with various wheel types.]

**Fig. 1.** The influence of the removed layer thickness on the roughness of surfaces ground with the following kinds of wheels: 1 – aluminium oxide; 2 – diamond; 3 – borazon

In Figure 2 one can see the changes of the sample surface hardening after grinding with the previously specified wheels, as well as with a 99C silicon carbide one with the parameters as in the case of aluminium oxide wheel. The curves show that the highest hardening has been obtained for grinding with a diamond wheel, the lowest for grinding with silicon carbide wheel. Unfortunately, all the hardening values obtained are, in the opinion of the enterprise, too high. The shapes of the curves allow us to state that the sample surface hardening increases with the increase of the removed layer thickness.

![Graph showing the influence of the removed layer thickness on hardening of ground surfaces with various wheel types.]

**Fig. 2.** The influence of the removed layer thickness on hardening of surfaces ground with the following kinds of wheels: 1 – aluminium oxide; 2 – diamond; 3 – borazon; 4 – silicon carbide
2.2. Results of the second stage of investigation

The objective of the second stage was to determine the parameters of grinding in respect of reduction of the plate surface layer hardening after grinding. The examinations of the second stage concerned the influence of the grinding wheel rotational speed (Fig. 3), longitudinal feed of the plates (Fig. 4) and the wheel granularity (Fig. 5).

Figure 3 shows the influence of the grinding wheel rotational speed on the roughness and hardening of the surface layer. The examination was performed with a diamond grinding wheel; the removed layer thickness was \( a = 0.01 \) mm, the initial speed, \( v_{gw} = 20 \) m/s. Due to the existing conditions related to the machine design, the maximum grinding wheel speed has been limited to \( 40 \) m/s. The shape of the curve clearly shows that the roughness value \( Ra \) and the hardening of the surface get lower with the increase of the speed.

![Fig. 3. The influence of grinding wheel circumferential speed on the surface roughness and surface layer hardening after grinding with a diamond grinding wheel](image)

In Figure 4 one can see the influence of the plate longitudinal feed speed on the surface roughness and surface layer hardening. The investigation has been conducted as in the case of the assessment of the grinding wheel rotational speed influence with the initial feed of \( 6 \) m/min. Reduction of the feed down to \( 3 \) m/min has resulted in reduction of the surface roughness value \( Ra \) and its hardening. No adherences on the wheel have been observed.

![Fig. 4. The influence of feed speed on the surface roughness and surface layer hardness after grinding with diamond grinding wheel](image)
Figure 5 shows the influence of the grinding wheel granularity on the surface roughness and on the hardening of the surface layer. The examination has been performed with borazon wheels with granularities of B53, B75, B91 and B151 with the thickness of the removed layer $a = 0.01$ mm and initial circumferential wheel speed of 20 m/s, longitudinal feed of 6 m/min. The shape of the curves allows us to state that, while the grain size decreases, the surface roughness reduces significantly. When a B53 wheel is applied $Ra = 0.14 \mu m$ and hardening $\Delta H = 1.14$. However, single pits can be noticed in the profilogram and there are few adherences on the grinding wheel surface. In cases of larger granularities, more adherences are found on the wheels. The results of adherences on the grinding wheels presented here are in conformance with the data stated in literature.

![Graph](image)

**Fig. 5. The influence of borazon grinding wheel granularity on the surface roughness and on the surface layer hardening**

### 2.2. Results of the third stage

On the basis of the data from the preceding investigation stages, examination with a B35 10 open borazon grinding wheel has been undertaken, with the wheel circumferential speed of 40 m/s. The surface roughness obtained was $0.08 \mu m < Ra < 0.11$; hardening obtained was $1.08 - 1.11$. However, few traces of adherences were found. Subsequent examination concerned involved of the wheel circumferential speed, $v_{gw} = 75$ m/s (special borazon grinding wheel) with the wheel grain size of B35; other parameters as in the basic investigation. The results obtained were $Ra < 0.1 \mu m$, hardening $\Delta H < 1.1$; traces of adherences have not been observed.

Due to the fact that the enterprise preferred diamond grinding wheel examination of the wheel cleaning with a soft brass wire brush has been undertaken. This way of cleaning the wheel working surface was found to be effective, however it involves slightly more crush dressing of the grinding wheels.
3. SUMMARY

The investigation results presented here allow for the formulation of the following conclusions:

1. The surface roughness and hardening of the surface layer in the process of grinding soft magnetic materials depend on the kind of the abrasive material and the grain size as well as on the grinding process parameters.

2. Increase of the grinding wheel circumferential speed and reduction of the feed speed had an advantageous influence on the values under investigation. Basing on this, further investigation with a higher speed, e.g. 100 m/s, should be performed. Increase of the circumferential speed and feed reduction reduces the load of the grain edge.

3. Disadvantageous effects obtained when grinding with a diamond wheel are related to the shape of the grain edge.

4. The problem of cleaning the wheel of adherences requires additional investigation. The system based on publication [1], together with the brass brush, is not always fully positive – cases of grain losses together with the adherence elements take place.

Basing on the experiment results presented, attention should be drawn to the necessity of further works concerning the structure of the grinding wheel, as well as the parameters of the grinding process. Assessment of the influence of forces and machining temperature on the process of hardening is also necessary. The influence of the condition of the surface layer on the deterioration of the electromagnetic properties should also be assessed.

4. REFERENCES


