Influence of some parameters of magnetization and cutting modes on the tool life when machining construction materials

S M Khasanov and A A Yakubov
Mechanics of Materials Department, Tashkent State Technical University, 100093, University Street, Tashkent city, Uzbekistan

E-mail: asroryakubov.1974@mail.ru

Abstract. The article examines the study of the influence of the magnetic field on the wear resistance of tool materials. The issues of optimal modes of magnetization and cutting modes, as well as the influence of the rake angle are considered.

1. Introduction
Many different methods of increasing wear resistance of the cutting tool are known. They are nitriding, cyanation, processing by cold, cutting or processing of the tool in magnetic field, application of different lubricant cooling mediums, etc. Recently use of magnetic field in machining process was conducted in the different directions [11].

In [1], the possibilities of using a pulsed magnetic field to improve the complex of mechanical properties of copper and alloys D16, BrB2 and L63 are considered. It is shown that the effect of a pulsed magnetic field increases the characteristics of plasticity, fatigue strength and tribotechnical parameters.

A team of authors [2] carried out extensive work on the use of magnetic fluids as technological media in the machining of metals. They magnetized the tools directly during processing. The study was carried out in drilling and milling with magnetic fluids. The results showed an almost twofold increase in the tool life of drills and mills.

In work [3, 4], it is checked the effect of Herbert in quick cutting steels. Results of cross-validation testing of firmness of cutting tools are given in an initial status and after magnetization and also magnetic and abrasive processing is given. According to them processing of details in magnetic field ferromagnetic powders is the integrated method which is combined mechanical effect with use of magnetic field energy. As a result, Hardening of a surface layer was noticed.

The authors in [5] consider the use of magnetic microcapsules as LCTM (Lubricating and cooling technological means). They found that the use of LCTM microcapsules with a concentration of microcapsules (CM) from 1.0 to 4% promotes an effective increase in the durability of cutting tools not only in comparison with dry cutting, but also when using standard water-based and oil-based cutting tools.

Authors Skirdenko O.I. et al. [6] studied the state of the art of processing tool materials in magnetic and magnetic-pulse fields.

In their works, Ben A.P. and others [7] gave a device for magnetic-pulse processing of metal products with an automated selection of processing modes.
One of the methods for increasing the wear resistance of cutting tools is the magnetization of the cutting tool [8, 9, 10]. Many works have been devoted to the question of the influence of the magnetization of high-speed tools on the productivity of machining and on the wear resistance of cutters. Numerous experiments have established a significant effect of the magnetic field on the durability of the cutting tool. However, the optimal modes of magnetization have not yet been determined.

The analysis of literary data shows that the effect of using magnetic field in the course of cutting depends on such factors as time of magnetization and magnetic field strength. The strength of the magnetic field is directly proportional to the strength of the current in the circuit. Therefore, to determine the optimal value of the magnetization time - and the current strength - $J$, we determined the dependences $T = f(\tau)$ and $T = f(J)$ for non-magnetized and magnetized high-speed cutters when processing steel 25. Then we determined the coefficient of increasing the durability of the magnetized tool by the following formula:

$$K_T = \frac{T_{dmt}}{T_{dmn}}$$

where: $T_{dmt}$ - durability of a magnetized tool;

$T_{dmn}$ - durability of non-magnetized tool.

2. Experiments and results

The experiments were carried out at cutting modes $v = 120$ m / min; $S = 0.11$ mm / rev; and $\gamma = 15^0$, at which a stable effect of magnetization was observed. Figure 1 and Figure 2 show the influence of the magnetization time and current strength on the efficiency factor of the magnetic field, from which it can be seen that the optimal value of the magnetization time is $\tau = 3$ minutes, and the current strength is $J = 3.75$ amperes. Similar data were obtained when processing steels 40X and 45. Therefore, in all subsequent experiments, the magnetization of the cutting tool was carried out at $\tau = 3$ min, and $J = 3.75$ amperes.

It is clear that the strength of the magnetic field created by the coil at constant values of the magnetization modes depends on the size of the tool, which plays the role of the core. Therefore, a change in the length of the tool as a result of its regrinding leads to a change in the strength of the magnetic field created by the coil, and therefore to a change in the remanent magnetization.

![Figure 1. Influence of the magnetization time on the coefficient of life of the cutting tool when processing steel 25](image-url)
Figure 2. The influence of the current on the coefficient of life of the cutting tool when processing steel 25.

In order to check the influence of this factor on the wear resistance of high-speed tools, experiments were carried out to determine the residual magnetic induction with cutters having different lengths.

Figure 3. Influence of the length of the cutting tool on the coefficient of life of the cutting tool when machining steel 25.

The measurement of the residual magnetic induction was carried out by the ballistic method. For 3 cutters made of high-speed steel P18, having a length of 100; 150; 200 mm, preliminary resistance experiments were carried out when processing steel 25 at $S = 0.11$ mm/rev; $v = 152$ m/min. After that, these cutters were magnetized at the same modes of magnetization ($J = 3.75$; $\tau = 3$ min), and then the residual magnetic induction was measured. The results obtained showed that at $l_1 = 100$ mm $Br_1 = 0.33334$ tesla, at $l_2 = 150$ mm tesla, at $Br_2 = 0.36877$ mm tesla.

In order to determine the influence of the value of the residual magnetic induction on the wear resistance of the tool, resistance experiments were carried out for the above magnetized cutters. The data obtained showed (Fig. 3) that a change in the length of the cutters under the conditions of the experiments carried out does not significantly affect the effect of the use of magnetized tools.

One of the factors influencing the cutting temperature and plastic deformation of the cut layer is the rake angle $\gamma$. If the above assumptions are correct, then the effect of the magnetization of the cutting tool in a quantitative ratio should depend on the value of the rake angle $\gamma$. To check this, experiments
were carried out on steel 25 with a P18 high speed cutter at feed rates $S = 0.11; 0.15; 0.2 \text{ mm / rev.}$

In these experiments, the dependence $T = f (\gamma)$ was initially recorded for a non-magnetized cutter, and then the same cutter was magnetized and the corresponding dependence for a magnetized cutter was recorded.

Experiments have shown that in a wide range of values of the rake angle $\gamma$, (0 - 20°), the magnetization of the cutter in comparison with the non-magnetized one increases its durability. However, the effect of tool magnetization changes quantitatively with changing rake angle $\gamma$. The optimal rake angle $\gamma$ for magnetized tools for all investigated feeds is $\gamma = 15^0$. This can be explained by the optimal combination of plastic deformation of the cut layer and cutting temperature, contact surface area, heat removal conditions, and the value of the friction coefficient.

The next series of experiments was carried out at a constant value of the angle $\gamma = 15^0$ for various cutting speeds and feeds when machining steels 25 and 45. The results of the experiments are presented in Figures 4, 5, 6, 7. From the given data it can be seen that in the entire range of cutting speeds, in which the experiments were carried out, there is an increase in the resistance of the magnetized cutting tool.

![Figure 4](image1.png)  
**Figure 4.** Influence of cutting speed and cutting tool magnetization on the tool life when machining steel 25, $S = 0.11 \text{ mm / rev}$  
1. Non-magnetized tool  
2. Magnetized tool

![Figure 5](image2.png)  
**Figure 5.** The effect of the cutting speed and the magnetization of the cutting tool on the durability of the cutting tool when processing steel 25, $S = 0.15 \text{ mm / rev}$  
1. Non-magnetized tool  
2. Magnetized tool

However, there is a clear tendency towards a decrease in the effect of magnetization with increasing feed. This can be explained by the fact that thin chips heats up and deforms better and therefore their shrinkage is higher compared to thick chips due to an increase in the coefficient of friction. The results of friction experiments also showed that the greatest decrease in the coefficient of friction due to magnetization under experimental conditions occurs at low specific pressures and friction rates.

Hence, we can conclude that at lower values of feed, the decrease in the coefficient of friction due to magnetization of the tool material occurs by a large amount, and therefore, with a decrease in the feed value, the efficiency of magnetized tools increases.
Figure 6. The effect of cutting speed and magnetization of the cutter on the durability of the cutting tool when processing steel 25, $S = 0.2\ \text{mm} / \text{rev}$

1. Non-magnetized tool
2. Magnetized tool

Figure 7. Effect of cutting speed and cutter magnetization on the tool life when machining steel 45, $S = 0.11\ \text{mm} / \text{rev}$, $\gamma = 150\ \text{P6M5}$

1. Non-magnetized tool
2. Magnetized tool

2. Conclusions
Based on the performed theoretical studies and analysis of the obtained experimental data, the following conclusions can be drawn:

1. The optimal modes of magnetization of high-speed tools for their effective use are $J_{\text{opt}} = 3.75\ \text{ampere}$, $\tau_{\text{opt}} = 3\ \text{min}$;
2. Residual magnetic induction with a change in the length of the cutting tool changes slightly and does not significantly influence the effect of the use of magnetized tools.
3. Rake angle $\gamma = 15^\circ$ and cutting speed when machining structural carbon steels have a significant effect on the efficiency of magnetized tools and this effect decreases with increasing feed.

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