Influence of electromagnetic compound treatment on microstructure and properties of cemented carbide

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Abstract. In order to study the effect of external field treatment on mechanical properties, cutting performance, microstructure of cemented carbide, the cemented carbide samples were treated by different magnetic field frequency (f=0.3 Hz, 0.4 Hz, 0.5 Hz) processing methods using self-made electromagnetic compound treatment device. On the basis of the study of this method, the electromagnetic compound treatment method was proposed to couple pulsed magnetic field and pulsed current. The results show that after the treatment of magnetic field frequency, the hardness of the sample slightly higher than that untreated sample, the increase value of percent between 0.5% and 1.3%, the value of hardness was 1594.72 HV, 1587.76 HV, 1582.45 HV, the longer the magnetization time, the higher the hardness; the cutting performance was increased, which means the tool life was increased, the increase value of percent from 4.5% to 7.0%. After electromagnetic compound treatment, the increase value of percent was 1.7% and 2.3%, the value of hardness was 1601.6 HV, 1609.82 HV; the tool life was increased 7.5% and 8.4%. After external field treatment, the angular state of wolfram carbide (WC) particle was transformed into smooth state and was more evenly distributed.

1. Introduction

The cutting tool can withstand higher temperature and mechanical shock during machining, the residual stresses was generated during heat processing and grinding process will accelerate tool wear and influence the surface machining quality of the workpiece [1~3]. The improvement of tool has been an important research topic in the whole machinery manufacturing industry.

In recent years, the research on the improvement of material properties has been carried out by single action of pulsed magnetic field at home and abroad, and the results have been obtained. For example, the practice of American Innovex company shows that pulsed magnetic field treatment can improve the service life of the tool by improving the residual stress distribution in the tool [4].

In recent years, pulsed current treatment as a new technology to improve the microstructure and properties of materials has the advantages of clean, high efficiency and low cost, which has attracted the attention of the material workers [5~7]. The pulsed current treatment has been reported in the field of materials electro plasticity, amorphous, crack healing and fatigue performance improvement [8~12].

In this paper, the effect of electromagnetic compound treatment on the microstructure and performance of cemented carbide was analyzed and studied, and with the effect of magnetic field treatment alone under the same parameters has carried on the comparative analysis, provided support for further systematic study the change law of cemented carbide microstructure and performance under the external field.
2. Experiment

The experimental objects are cemented carbide cylinder sample and cemented carbide tool, and the workpiece material is 45# quenched and tempered steel.

The sample was put into a self-made electromagnetic compound treatment device. The electromagnetic compound treatment system mainly consists of three parts: pulsed magnetic field system, pulsed current system and control system, the schematic diagram was shown in figure 1 [13].

The pulsed magnetic field system consists of power supply, controller and magnetizing device. In electrical processing system generated electrical pulse by thyristor controlled alternating current transformer. When the electromagnetic compound processing is applied, the excitation power supplies the exciting current to the coil, and the magnetic induction intensity is generated in the closed magnetic circuit formed by the magnetic pole and the sample, while the pulse current is provided by the pulse power supply.

In this experiment, the magnetic field treatment (MFT) has three technics (MFT-A, MFT-B and MFT-C), and parameters were shown in table 1, the electromagnetic compound treatment (ECT) has two technics (ECT-A and ECT-B), parameters were shown in table 2.

![Figure 1. The diagram of electromagnetic compound treatment device.](image)

| Table 1. Magnetic field treatment parameters. |
|---------------------------------------------|
| Technics | Time (S) | Frequency (Hz) |
|----------|----------|----------------|
| MFT-A    | 60       | 0.3            |
| MFT-B    | 45       | 0.4            |
| MFT-C    | 36       | 0.5            |

| Table 2. Electromagnetic compound treatment parameters. |
|------------------------------------------------------|
| Technics | Current density (A/mm²) | Frequency (Hz) | Time (s) |
|----------|-------------------------|----------------|----------|
| ECT-A    | 10                      | 0.3            | 60       |
| ECT-B    | 20                      | 0.3            | 60       |

Then the experiment of turning excircle was done on the NC lathe by the unprocessed tool and the tool processed by magnetic field and electromagnetic compound treatment. During the experiment, the wear extent of flank surface was measured by image measuring instrument and the cutting force was measured by the dynamometer. The microstructure of the sample was observed by scanning electron microscope.
3. Results and discussion

3.1. Effect of external field treatment on microstructure of cemented carbide

Both magnetic field treatment and electromagnetic compound treatment can change the microstructure of the cemented carbide. Figure 2 showed the back scattered electron (BSE) photo of YG8 cemented carbide with untreated, magnetic field treatment and electromagnetic compound treatment.

![Figure 2. The BSE images of YG8: (a) untreated, (b) magnetic field treatment, (c) electromagnetic compound processing.](image)

It can be seen from figure 2 that: in the untreated, the WC (wolfram carbide) particle of cemented carbide is sharp and angular, as shown in figure 2 (a). The existence of angular result in the stress distribution is extremely uneven, which leads to stress concentration and is unfavorable to toughness of alloy. After magnetic field treatment and electromagnetic compound processing, the angular state of WC particle was transformed into smooth state, which reduces the stress concentration of contact points and improves the toughness of WC [14], as shown in figure 2 (b) and figure 2 (c). At the same time, it can be seen from figure 2 (b) and figure 2 (c) that the WC particle of cemented carbide was more evenly distributed.

3.2. Effect of magnetic field frequency on the mechanical properties of cemented carbide

When the magnetic field strength was fixed, the values of hardness by different magnetic field frequency (f=0.3 Hz, 0.4 Hz, 0.5 Hz) were obtained. The values were shown in figure 3.

![Figure 3. The values of different magnetic field frequency on hardness.](image)
It can be seen from the figure 3 that the hardness of the sample treated with magnetic field frequency slightly higher than that untreated sample. The increase range of percent between 0.5% and 1.3%, the value of hardness was 1594.72 HV, 1587.76 HV, 1582.45 HV, the longer the magnetization time, the higher the hardness. Preliminary analysis may be with the increase of magnetic field frequency, the lower the magnetization time, the lower the dislocation in the sample, the deformation ability of the sample was weakened, and the hardness decreased.

When magnetic field strength was fixed, the tool wear was obtained by changing different magnetic field frequency, the wear curve was done nonlinear fitting by Origin software, the cutting distance of flank surface average wear value of 0.3 mm were obtained, the values were shown in table 3.

| Techniques | Cutting distance (m) |
|------------|---------------------|
| UT         | 112.76              |
| MFT-A      | 120.62              |
| MFT-B      | 119.29              |
| MFT-C      | 117.78              |

It can be seen from table 3, the cutting performance of the tool after the magnetic field frequency was increased compared with the untreated tool, which means the tool life was increased from 4.5% to 7.0%. The influence of different magnetic field frequency on the mechanical properties of cemented carbide was analyzed combined with the front, it may be that the hardness of the material was increased after magnetic field treatment.

Figure 4 showed the influence of different magnetic field frequency on the main cutting force and wear extent.

![Figure 4](image)

**Figure 4.** The effect of magnetic field frequency: (a) main cutting force, (b) wear extent.

It can be seen from figure 4 (a) and figure 4 (b), the main cutting force and the wear extent curve are consistent. Therefore, the change of wear extent can be predicted by measuring the change of cutting force so as to study the change of tool cutting performance.

At the same time, after the treatment of magnetic field frequency, the change of treatment effect was not obvious. The preliminary analysis may be due to unsuitable selection of magnetic field treatment parameters, which result in no significant improvement in cutting performance, proper parameters and mechanism analysis were needed further research.

3.3. **Effect of electromagnetic compound treatment on the performance of cemented carbide**

In the case of not changing the magnetic field parameters, the electromagnetic compound treatment on the sample is carried out by means of coupling pulsed magnetic field and pulsed current, the hardness was obtained. The values were shown in figure 5.
Figure 5. The hardness values of electromagnetic compound treatment.

It can be seen from the figure 5 that the hardness of the sample treated with electromagnetic compound treatment increase than that untreated sample and magnetic field frequency treatment. The increase value of percent was 1.7% and 2.3%. The hardness value was 1601.6 HV, 1609.82 HV. Preliminary analysis because of the effect of pulsed current treatment in the electromagnetic compound treatment.

After the electromagnetic compound treatment, the wear curve was done nonlinear fitting by Origin software, the cutting distance of flank surface average wear value of 0.3mm were obtained, the values were shown in table 4.

Table 4. Tool cutting distance data of electromagnetic compound treatment.

| Technics | Cutting distance (m) |
|----------|----------------------|
| UT       | 112.76               |
| ECT-A    | 121.16               |
| ECT-B    | 122.18               |

It can be seen from table 4, the increase percent of cutting distance for cutting tool after electromagnetic compound treatment was 7.5% and 8.4%. It may be that the hardness of the material was increased after magnetic field treatment.

Figure 6 showed the influence of electromagnetic compound treatment on the main cutting force and wear extent.

Figure 6. The effect of electromagnetic compound processing: (a) main cutting force, (b) wear extent.

It can be seen from the figure 6 (a) and figure 6 (b), the main cutting force of the electromagnetic compound treatment tool smaller than that of the untreated tool, and the wear extent also less than that of the untreated tool. The main cutting force and the wear curve are consistent.
4. Conclusions

(1) This paper proposed a novel approach to improvement the properties of materials, that was: electromagnetic compound treatment. It was an important research direction and topic in the field of material processing.

(2) After the treatment of magnetic field frequency, the hardness of the sample slightly higher than that untreated sample, the value of hardness was 1594.72 HV, 1587.76 HV, 1582.45 HV; the longer the magnetization time, the higher the hardness; the cutting performance was increased, which means the tool life was increased, the increase value of percent from 4.5% to 7.0%. After electromagnetic compound treatment, the increase value of percent was 1.7% and 2.3%, the value of hardness was 1601.6 HV, 1609.82 HV; the tool life was increased 7.5% and 8.4%.

(3) After external field treatment, the angular state of wolfram carbide (WC) particle was transformed into smooth state and was more evenly distributed.

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