

Enhancing cutting performance of cemented carbide rotary burrs through coupled electromagnetic treatments of the burrs

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Abstract. Rotary burrs made of WC-8Co cemented carbide are widely used in automated filing systems, yet rapid cutting-edge wear significantly limits their performance. For this purpose, coupled electromagnetic treatments were applied to the WC-8Co cemented carbide region of rotary burrs to enhance their cutting performance. Four key performance parameters were evaluated: average cutting-edge wear, cutting-head diameter wear, average machining depth, and material removal amount. The cutting performance and the resulting surface roughness of workpieces machined with treated and untreated burrs were compared. As a result, under optimal conditions (0.6 T magnetic field and 1.2 V electric field), coupled electromagnetic treatment reduced average cutting-edge wear and cutting-head diameter wear by 15.4% and 21.4%, respectively, increased average machining depth and material removal amount by 21.3% and 25.2%, respectively, and decreased the surface roughness of the machined workpieces by 36.2%. The study through experimental and numerical analysis confirmed that these enhancements in cutting performance are largely attributed to the increased thermal conductivity and hardness of the treated burrs, which result from reductions in magnetic domain walls and increases in crystal defects induced by the coupled electromagnetic treatment. Such changes collectively suppressed adhesion wear, oxidation wear, and abrasive wear, thereby enhancing the tool's cutting performance.

Keywords: Coupled electromagnetic treatment / cemented carbide / rotary burrs / cutting / wear

1 Introduction

Machining tools are critical components in modern manufacturing, as their performance directly determines machining efficiency, accuracy, and cost [1,2]. For different machining requirements, the appropriate selection of tools and their materials is essential [3–6]. Rotary burrs are a new type of file, typically used in conjunction with high-speed electric grinders or pneumatic tools. They are widely applied in the fields of mechanical manufacturing and parts processing. They play a crucial role in the fine machining of metal materials, as well as in removing flash, burrs, and weld seams from castings, forgings, and welded parts [7]. They are important tools for improving production efficiency and achieving filing automation. Compared to the low-efficiency reciprocating cutting method of traditional files the rotary burrs use a high-speed rotational cutting method. This not only significantly enhances cutting efficiency but also greatly expands their range of applications. However, due to their high operating speeds,

the complex shapes of processed workpieces, and the unstable forces during processing, rotary burrs experience rapid wear of the cutting edges and a short operational lifespan which reduces their economic benefits.

As demand for reducing costs, improving machining efficiency, and achieving energy savings and emission reductions continues to grow in the modern machining industry, numerous advanced technologies have been extensively researched and applied [8]. These technologies aim to enhance the machining performance of tools, including: employing coating techniques to increase tool hardness and wear resistance [9]; implementing heat treatment to optimize the microstructure of tool materials and subsequently improve performance [10]; and utilizing the cooling and lubrication functions of cutting fluids to further enhance tool performance [11]. However, despite their effectiveness, these methods often involve complex procedures, high energy consumption, and large waste emissions, making them less compatible with environmentally sustainable production. In recent years, physical field treatment technologies have attracted widespread attention due to their cleaner, more efficient, and cost-effective advantages. Extensive research has demonstrated the

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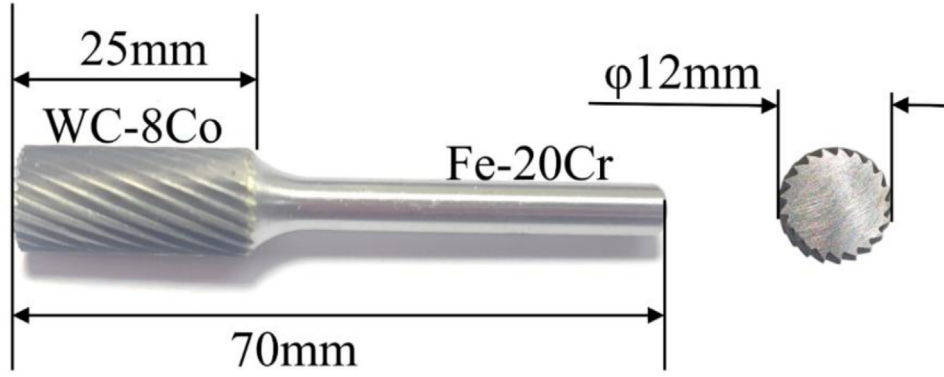


Fig. 1. Type A welded rotary burrs.

application of various physical field treatment techniques to enhance tool machining efficiency and economic performance, including electric fields [12,13], magnetic fields [14], and coupled electromagnetic fields [15]. These physical field treatment technologies are powered by clean and sustainable electricity, achieving material modification through energy transfer without the use of chemical additives or the generation of waste liquid. This enables genuine zero carbon emissions throughout the processing stage, fully aligning with the sustainable development principles of modern manufacturing.

The electric field can regulate dislocation motion, thereby modifying the mechanical properties of materials [16]. Meanwhile, ferromagnetic materials undergo magnetostriction under magnetic fields, resulting in microstructural changes that in turn influence macroscopic properties [17,18]. Coupled electromagnetic treatment (CEMT) technology combines the advantages of electric field and magnetic field treatments, enabling the simultaneous application of these two physical fields to the sample. This approach facilitates the coupling and synergistic optimization of the mechanisms by which electric and magnetic fields alter material properties, significantly enhancing the material's performance and microstructure, far surpassing the effects of using electric or magnetic field treatments independently [19]. Zhong et al. [20] found that pulsed magnetic field treatment effectively reduced the residual stress in cemented carbide tools by 30%, while CEMT further reduced stress by 65%, highlighting the superior performance of CEMT in stress relief. Liao et al. [21] further investigated the effects of CEMT and single magnetic field treatment on the performance of cemented carbide tools. Their results demonstrated that CEMT exhibited significantly better outcomes in extending tool lifespan compared to single magnetic field treatment. Liu et al. [22] applied CEMT to WC-6Co cemented carbide tools, altering their microstructure by increasing the dislocation density, which ultimately led to approximately 2% and 12% improvements in hardness and transverse fracture strength, respectively, while reducing electrical conductivity by 5%. Zhou et al. [23] conducted studies on the performance enhancement of cemented carbide tools via CEMT. Their results indicated that CEMT

significantly reduced cutting force and cutting temperature, and under optimal treatment parameters, tool lifespan was extended by an impressive 133%.

The aforementioned studies indicate that physical field treatment technologies have been widely applied in machining processes such as turning and milling, significantly enhancing machining performance, with coupled electromagnetic fields demonstrating the best results. However, research on the application of CEMT technology to rotary burrs is still in its early stages, and the specific mechanisms by which coupled electromagnetic fields affect the cutting process of rotary burrs remain to be explored in depth.

In this study, self-developed coupled electromagnetic field excitation equipment was employed to perform CEMT on WC-8Co cemented carbide rotary burrs under different process parameters. By comparing the wear and cutting efficiency of the rotary burrs after cutting experiments, the optimal process parameters were determined. Furthermore, the mechanisms by which CEMT affects the cutting behavior of rotary burrs were investigated by analyzing the micro-morphology and elemental distribution of the cutting edges in both UT and CEMT samples. The changes in thermal conductivity and hardness of WC-8Co before and after treatment were evaluated to further clarify the effect of CEMT. Finally, the microstructural evolution of WC-8Co under CEMT was systematically investigated to reveal the strengthening mechanism.

2 Material and methods

2.1 Tool and workpiece

As shown in Figure 1, the rotary burr used in this study is a type A welded rotary burr. It consists of a WC-8Co head welded to a Fe-20Cr shank. The dimensions are as follows: the burr head diameter is $\phi 12$ mm, the shank diameter is $\phi 6$ mm, the burr head length is 25 mm, and the shank length is 45 mm. It has 21 teeth, and the cutting edges are right-handed with a helix angle of 25° to the axis. The cemented carbide grain size of the WC-8Co burr head ranges from 1.0 to $1.2\mu\text{m}$. The physical properties of WC-8Co and Fe-20Cr are shown in Tables 1 and 2.

Table 1. Physical properties of WC-8Co.

Physical properties	Value
Hardness (HRA)	89
Bending strength (MPa)	1500
Compressive strength (MPa)	4470
Elastic modulus (GPa)	600–610
Impact toughness (J/cm ²)	2.5
Density (kg/m ³)	14600
Thermal conductivity (W/(m·K))	80

Table 2. Physical properties of Fe-20Cr.

Physical properties	Value
Hardness (HBS)	≤ 179
Compressive strength (MPa)	≥ 835
Elastic modulus (GPa)	207
Density (kg/m ³)	7830

Table 3. Physical properties of 45 steel.

Physical properties	Value
Hardness (HRC)	20–30
Density (kg/m ³)	7850
Elastic modulus (GPa)	210
Poisson's ratio	0.31
Compressive strength (MPa)	600
Thermal conductivity (W/(m·K))	48

The workpiece used in the cutting process is a cubic 45 steel block with dimensions of 160 mm × 40 mm × 20 mm, and its physical properties are shown in Table 3.

2.2 CEMENT

As shown in Figure 2, the WC-8Co rotary burrs were subjected to CEMENT. During the treatment, the burr was positioned at the center of the coil and firmly secured with copper electrodes, with its axis aligned parallel to that of the electrodes. Pulsed currents were applied to the rotary burr through the copper electrodes, while the pulsed magnetic field in space was generated by the excitation coil and acted on the sample, achieving coupling between the electric field and the magnetic field. In this experiment, untreated (UT) samples were used as references. For samples CEMENT-1 to CEMENT-5, a constant voltage of 1.2V was applied, while the magnetic field intensity was varied incrementally from 0.2T to 1.8T, with a step of 0.4T between adjacent samples. For samples CEMENT-6 to CEMENT-9, the magnetic field intensity remained constant at 0.8T, while the voltage at both ends of the rotary burr varied in a gradient manner from 0.6V to 2.4V, with a

voltage gradient of 0.6V between each rotary burr. Detailed process parameters are shown in Table 4. It should be noted that the magnetic field excited by the excitation coil is unevenly distributed in space, with the maximum magnetic field intensity at the center of the coil. The magnetic field intensity represented in the study refers to the magnetic field intensity at the center of the coil, and the entire treatment process was conducted at standard atmospheric pressure and room temperature.

2.3 Machining tests

In this study, cutting tests were conducted using a six-axis cutting robot, as shown in Figure 3a. The six-axis cutting robot consists of a six-axis robot (LM1400-3C-6, Erbid, China) and a high-speed motor (EFS-C-800, Laoan Intelligent, China). The high-speed motor operates at a rotational speed of 24,000 rpm with a maximum power output of 0.8 kW. As illustrated in Figure 3b, the machining surface consisted of a 160 mm × 20 mm area on the workpiece, with the burr rotation direction aligned parallel to the helical orientation of the cutting edges. The rotary burrs were used to cut along the surface of the workpiece at a rotational speed of 24,000 rpm, with a feed rate of 0.015 mm/r and a cutting depth of 0.1 mm. After the rotary burrs moved from one end of the workpiece to the other, they disengaged from the workpiece, returned to the initial position, and resumed cutting. This process was repeated 30 times, and then the robot and motor were stopped for 15 min for cooling. Each rotary burr undergoes a total of 90 reciprocating cutting operations, and the cutting parameters are kept consistent throughout.

2.4 Cutting performance evaluation

Common parameters used to evaluate tool performance include tool wear and material removal amount [24,25]. In this study, the wear amount of the rotary burrs and the material removal capability were used to evaluate the cutting performance. As rotary burrs are a novel type of cutting tool with no defined flank face, the conventional parameter of flank wear is not applicable for evaluating their wear condition. Therefore, this study proposed two parameters, average cutting-edge wear (ACEW) and cutting-head diameter wear (CHDW), to evaluate the wear condition of the rotary burrs. Additionally, the average machining depth (AMD) and material removal amount (MRA) were used to evaluate the material removal capability of the rotary burrs.

As shown in Figure 4a, during the cutting process, the sharp edges of the rotary burr gradually become blunted, leading to a measurable wear width on the cutting edges. A greater width indicates more severe wear. Therefore, in this study, the ACEW is used to characterize the average wear width of the cutting edges. The wear width of each cutting edge was measured using a 2D tool measuring device (YK-D1900B, Yunce, China), and the average value was calculated to obtain the ACEW, as defined by equation (1). In addition, since rotary burrs are cylindrical cemented carbide tools, wear on the cutting edges results in a reduction in burr head diameter. The more significant

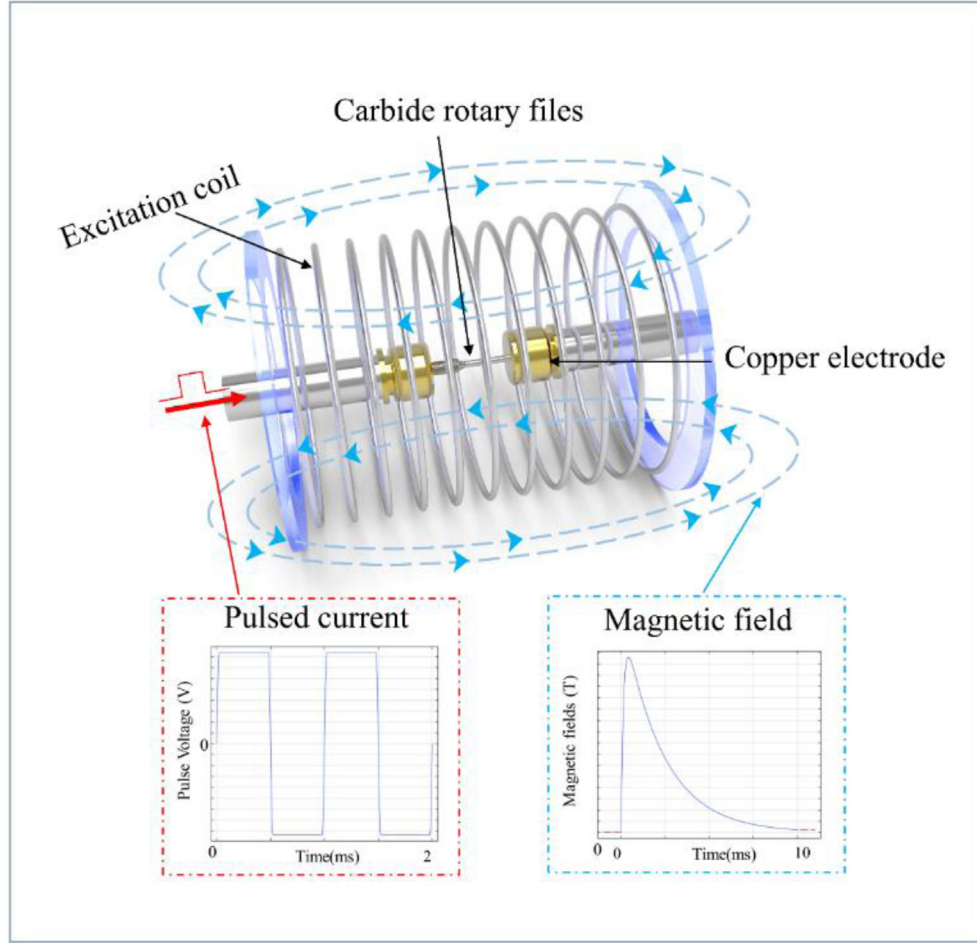


Fig. 2. Schematic diagram of the CEMT process.

Table 4. CEMT process parameters.

Physical properties	Value
Hardness (HRC)	20–30
Density (kg/m^3)	7850
Elastic modulus (GPa)	210
Poisson's ratio	0.31
Compressive strength (MPa)	600
Thermal conductivity ($\text{W}/(\text{m} \cdot \text{K})$)	48

the diameter reduction, the more severe the wear. Thus, the parameter CHDW is introduced to quantify the change in head diameter. The burr head diameter was measured before and after cutting using a micrometer (MDC-25SX, MISUMI, China), and the CHDW was calculated using equation (2).

As shown in Figure 4b, material is progressively removed from the workpiece during the cutting process, resulting in reductions in both width and weight. Under identical cutting conditions, greater reductions indicate higher material removal capability of the rotary burr. Therefore, the parameters AMD and MRA are used to

represent the reduction in workpiece width and weight, respectively. The width before and after cutting was measured using a vernier caliper (CJW888, Aireze, China), and AMD was calculated using equation (3). Simultaneously, an electronic balance (BH-30, Yousheng, China) was used to measure the change in workpiece weight, and MRA was obtained via equation (4).

$$ACEW = (\sum_{i=1}^n w_i) / n \quad (1)$$

$$CHDW = d_1 - d_2 \quad (2)$$

$$AMD = wd_1 - wd_2 \quad (3)$$

$$MRA = wt_1 - wt_2 \quad (4)$$

Where:

w_i is the maximum wear width of one of the cutting edges of the rotary burr.

n is the number of teeth of the rotary burr, which is 21 in this study.

d_1 is the diameter of the rotary burr before cutting.

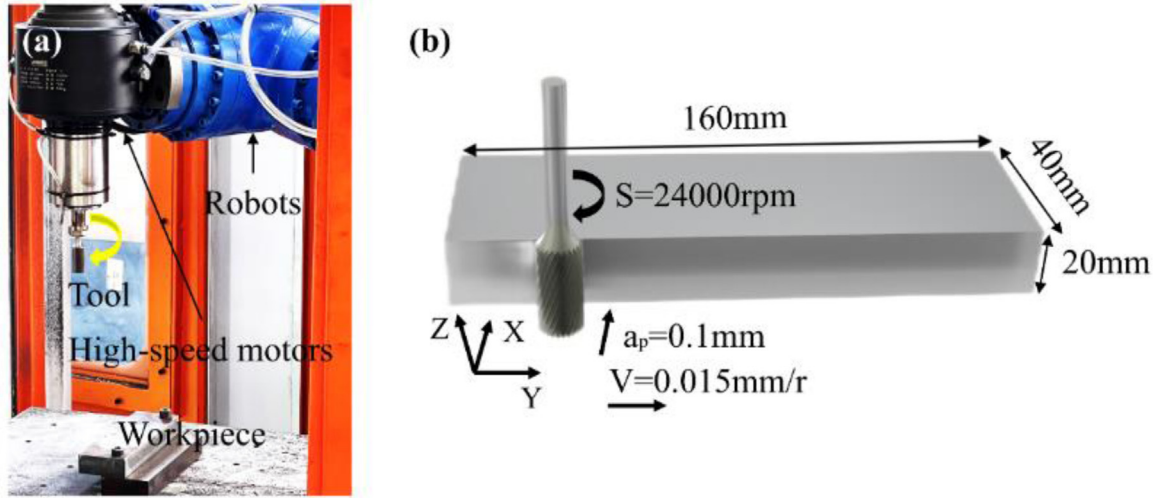


Fig. 3. Cutting experiment: (a) Cutting experiment platform; (b) Schematic diagram of cutting experiment.

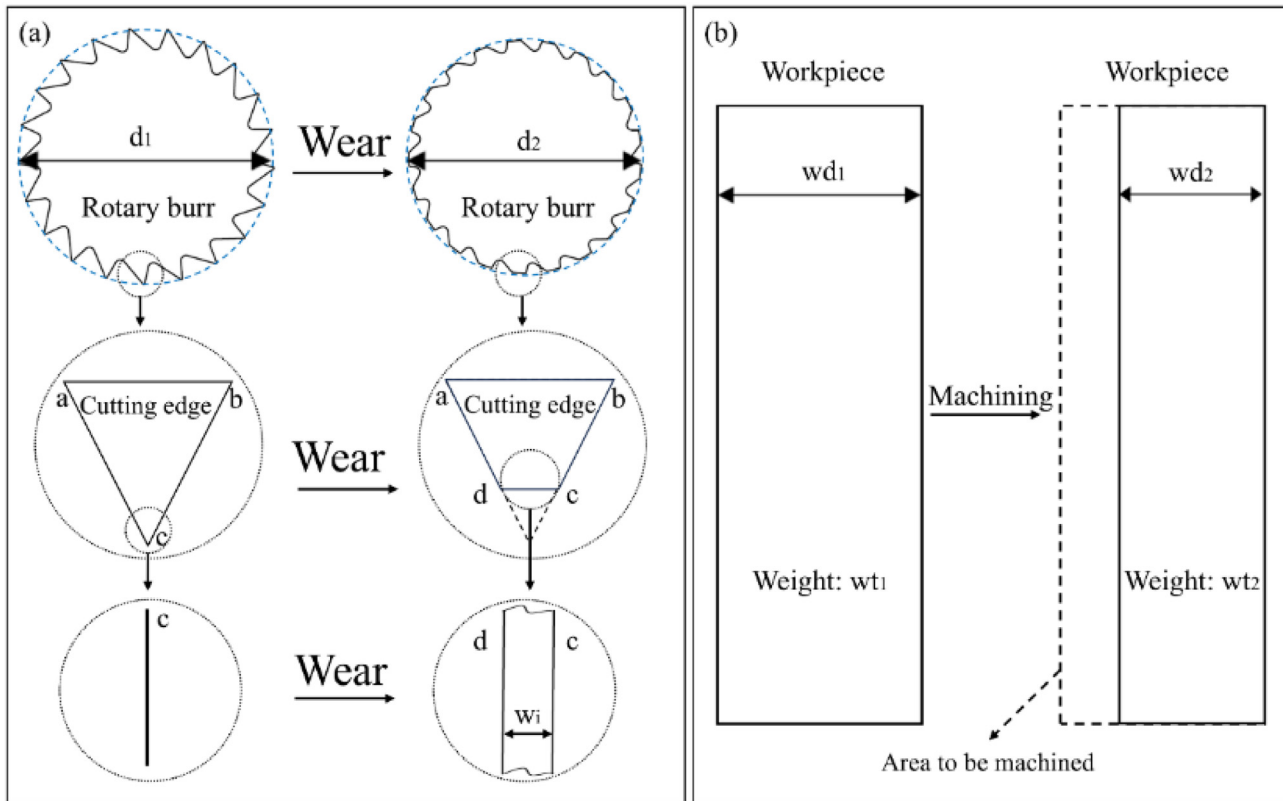


Fig. 4. Schematic diagrams of the machining process: (a) Schematic of rotary burr wear; (b) Schematic of workpiece material removal.

d_2 is the diameter of the rotary burr after cutting.

wd_1 is the average width of the workpiece before cutting.

wd_2 is the average width of the workpiece after cutting.

wt_1 is the weight of the workpiece before cutting.

wt_2 is the weight of the workpiece after cutting.

To investigate the influences of the CEMTs on the cutting performance of the rotary burr, statistical analysis was conducted on the ACEW, CHDW, AMD, and MRA of

the rotary burr. To ensure statistical reliability and minimize chance variability, three samples were prepared for each type of burr (UT and CEMT-1 to CEMT-9), and repeated tests were conducted. The test results were statistically analyzed using the mean and standard deviation of the three samples in each group.

After the cutting experiments, the surface roughness of the workpiece was measured multiple times using a white light interferometer (Contour GT-K, Bruker, USA).

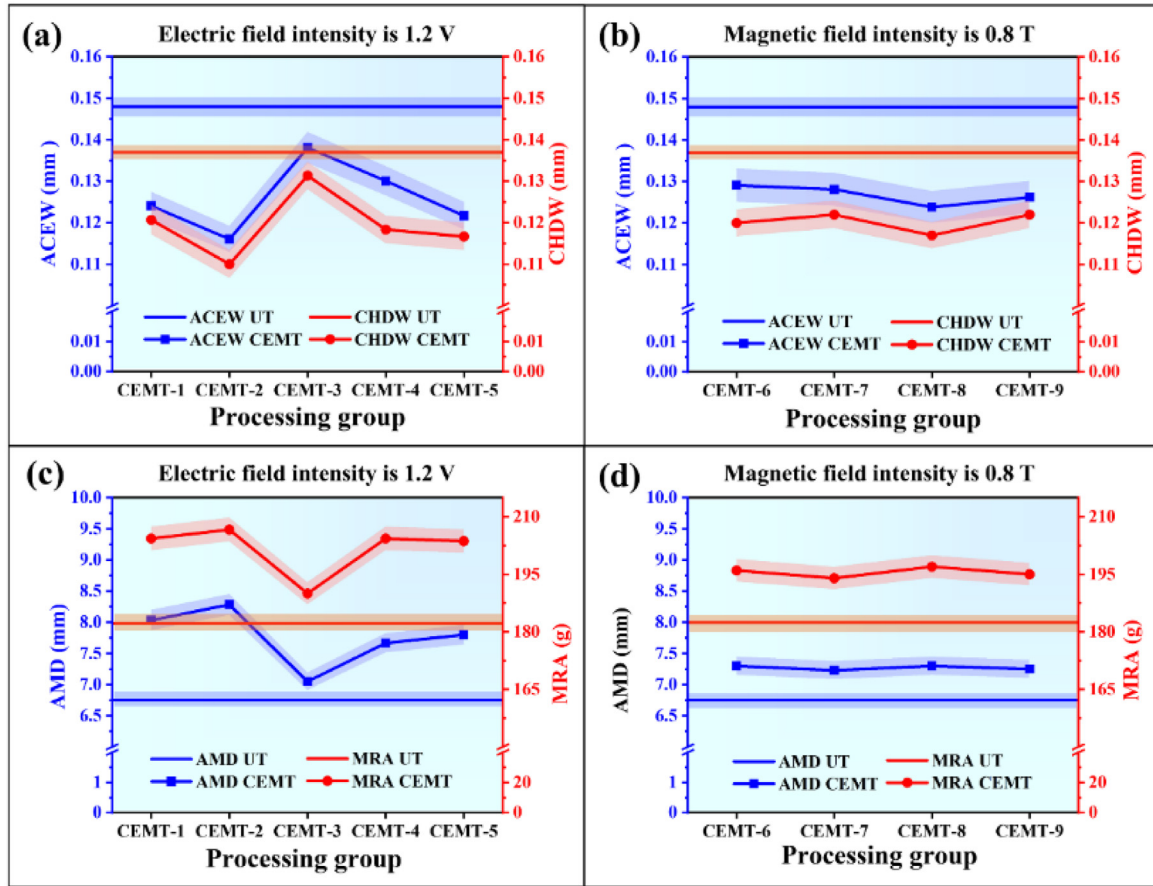


Fig. 5. Cutting experiment results: (a) Effects of different magnetic field parameters on ACEW and CHDW; (b) Effects of different electric field parameters on ACEW and CHDW; (c) Effects of different magnetic field parameters on AMD and MRA; (d) Effects of different electric field parameters on AMD and MRA.

The worn morphology of the rotary burr cutting edges were observed using a Field Emission Scanning Electron Microscope (SEM, Apreo 2 SEM, Thermo Fisher Scientific, USA) equipped with an Energy Dispersive Spectrometer (EDS, Aztec X-Max 80T, Oxford Instruments, UK) for elemental analysis.

2.5 Material performance testing

In this study, the thermal conductivity of WC-8Co before and after CEMT was measured at 300°C using a laser flash thermal conductivity analyzer (LFA46700B-0965-L, NETZSCH, Germany). Meanwhile, the Vickers hardness was measured using a digital microhardness tester (HXD-1000TMC, Beijing Shiji Kexin, China) under a load of 10 N and a dwell time of 10 s. For both the thermal conductivity and hardness tests, the samples were treated using the same process parameters as those of the CEMT-2 sample.

2.6 Microstructural observation

In this study, transmission electron microscopy (TEM) was employed to investigate the effect of CEMT on the microstructure of WC-8Co. The samples were examined and analyzed using a transmission electron microscope (FEI TALOS F200X G2, Thermo Fisher Scientific, USA)

operated at an accelerating voltage of 200 kV. Elemental composition of different phases in the samples was quantitatively analyzed using the energy-dispersive X-ray spectroscopy (EDS) function attached to the TEM. A comprehensive analysis of the microstructural changes induced by CEMT was conducted through TEM imaging, high-resolution TEM (HRTEM), and selected area electron diffraction (SAED) patterns.

The sample preparation process was as follows: The WC-8Co samples were thinned using an ion milling system (Gatan 695, Gatan, USA). The ion beam energy was sequentially set to 5 keV, 4 keV, and 3 keV, with ion gun angles of $\pm 8^\circ$, $\pm 4^\circ$, and $\pm 3^\circ$, respectively. Each thinning stage lasted for 5 min until the sample reached a thickness suitable for TEM observation. Finally, the prepared thin foil samples were placed in the TEM for observation and analysis.

3 Results and discussion

3.1 Tool cutting performance

As shown in Figures 5a and 5b, after CEMT, both ACEW and CHDW significantly decreased, indicating that the treatment can reduce the wear of the rotary burrs. Nevertheless, the reduction in wear of the rotary burr

varies under different treatment parameters. Among the rotary burrs subjected to CEMENT, the CEMENT-2 sample exhibits the smallest ACEW and CHDW, while the CEMENT-3 sample shows the largest ACEW and CHDW. Compared to UT, the ACEW and CHDW of the CEMENT-2 sample decreased by 15.4% and 21.4%, respectively. As shown in [Figures 5c](#) and [5d](#), AMD, and MRA of the rotary burr increased significantly under different treatment parameters, indicating that CEMENT can increase the material removal rate of the rotary burr, but the degree of improvement varied. Among the rotary burrs subjected to CEMENT, the CEMENT-3 sample exhibits the smallest AMD and MRA, while the CEMENT-2 sample shows the largest AMD and MRA, with increases of 21.3% and 25.2%, respectively, compared to UT.

Comparing the four evaluation parameters, it was found that the CEMENT-2 sample exhibited the least wear and the greatest material removal, indicating the best cutting performance enhancement. Therefore, the process parameters corresponding to the CEMENT-2 sample were identified as the optimal CEMENT parameters for improving the cutting performance of rotary burrs. It is also noteworthy that the CEMENT-3 sample showed significantly poorer tool wear and material removal compared to other CEMENT samples, being similar to the UT sample. A comparison between CEMENT-1 to CEMENT-5 samples and CEMENT-6 to CEMENT-9 samples revealed that the values of the four performance evaluation parameters for the rotary burrs fluctuated significantly with changes in the magnetic field intensity gradient ([Figs. 5a](#) and [5c](#)), while the parameter values showed little variation with changes in the electric field intensity gradient ([Figs. 5b](#) and [5d](#)). These results indicate that variations in magnetic field intensity have a greater impact on the cutting performance of rotary burrs, while changes in electric field intensity exert a relatively minor effect. Therefore, this study will subsequently focus on exploring the cutting characteristics and physical properties of UT and CEMENT-1 to CEMENT-5 samples.

3.2 Surface roughness analysis of the workpiece

The surface roughness of the workpiece is an important indicator for evaluating tool cutting performance [26]. The surface morphologies of the workpieces for UT and CEMENT-1 to CEMENT-5 samples are shown in [Figure 6](#). It is clear that the surface of the workpiece processed by the UT sample exhibits irregular pits of various depths and unevenness, while the surface of the workpiece processed by the rotary burr after CEMENT has fewer pits and is relatively smoother.

A statistical analysis of the surface roughness of the workpieces was conducted. The arithmetical mean height (S_a) was used as the evaluation parameter [27], as shown in [Figure 7](#). The S_a of the workpiece processed by the rotary burr after CEMENT is lower than that of the UT. Among them, the workpiece processed by the CEMENT-2 sample shows the lowest S_a , measured at $1.85\mu\text{m}$, representing a 36.2% decrease compared to the $2.9\mu\text{m}$ observed for the UT. This indicates that CEMENT can reduce the surface roughness of the workpiece after processing and improve the surface quality of the workpiece.

3.3 Wear behavior

In the process of machining the workpiece, the initially sharp cutting edge of the rotary burr will gradually wear down, and the width of the cutting edge will gradually increase, leading to a continuous weakening of its cutting performance. To further investigate the effect of CEMENT on the wear behavior of the rotary burr, the surface of the cutting edge after ultrasonic cleaning in ethanol was analyzed using SEM and EDS to explore the mechanism by which CEMENT reduces the wear of the rotary burr and increases the material removal rate.

[Figure 8a](#) shows the macroscopic morphology of the rotary burr after cutting tests, where UT and CEMENT-3 samples exhibit obvious blueing, CEMENT-5 sample slightly blueing, while the remaining rotary burrs do not. This is due to the different degrees of oxidation of the cemented carbide, where a significant blueing indicates a deeper degree of oxidation [28]. To further explore the differences in oxidation between UT and CEMENT samples, element analysis was conducted on the side surfaces of the cutting edges of UT and CEMENT-2 samples. The regions shown in [Figures 8b](#) and [8c](#) are the morphologies of the cemented carbide cutting edge side surfaces, and [Figures 8d](#) and [8e](#) are the EDS elemental surface scans of the two regions. The EDS elemental surface scans show that the oxygen content on the side surface of the CEMENT-2 sample cutting edge is 7.72%, significantly lower than UT's 13.0%, representing a reduction of 40.6%.

[Figures 9a](#) and [9c](#) show the morphology of the cutting edges of UT and CEMENT-2 samples. A comparison reveals inconsistent regions on the surface of the CEMENT-2 sample cutting edge, indicating different materials, and there are substances similar to swarf attached to the edge of the cutting edge; no such phenomenon is observed on the UT sample surface. EDS elemental scans were performed on different positions (p1, p2, p3, p4) on the UT and CEMENT-2 sample surfaces. The results show that the cutting-edge surface of the UT sample contains higher levels of Fe and O but no detectable W ([Fig. 9b](#)). In contrast, point p2 on the CEMENT-2 sample exhibits the highest W content, along with notable amounts of Fe, O, Co, and C ([Fig. 9d](#)). At point p3, Fe is predominant, accompanied by substantial W and O signals ([Fig. 9e](#)), while point p4 shows relatively high concentrations of Fe and O ([Fig. 9f](#)). These findings indicate that the UT sample's cutting edge is covered with an adhered layer formed by the oxidation of both workpiece and base materials. In comparison, the CEMENT-2 sample's cutting edge is partially covered with adhered material, with exposed base material and oxidized swarf present along the edge.

[Figure 10](#) compares the surface morphology of the cutting edges of UT and CEMENT-1 to CEMENT-5 samples after the cutting experiment. It was found that all cutting-edge surfaces were welded with irregularly shaped adhered layers. The cutting-edge surfaces of the UT and CEMENT-3 samples were fully covered by the adhered layer, whereas those of the other rotary burrs exhibited only partial adhesion. These areas were mainly concentrated on the right side of the cutting edge, whereas the left side was predominantly exposed base material without any adhered

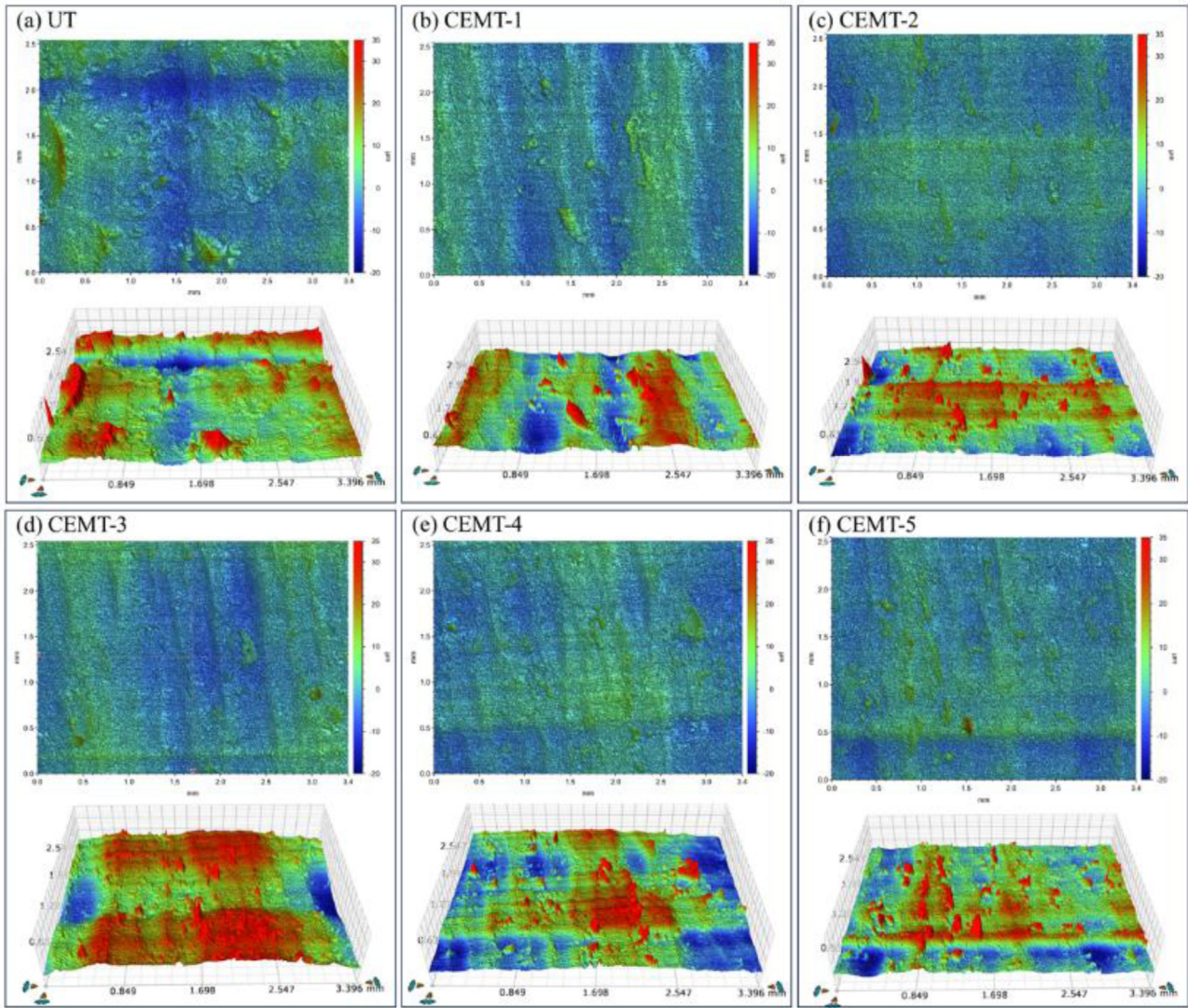


Fig. 6. Surface morphologies of workpieces after cutting with different rotary burrs: (a) UT; (b) CEMENT-1; (c) CEMENT-2; (d) CEMENT-3; (e) CEMENT-4; (f) CEMENT-5.

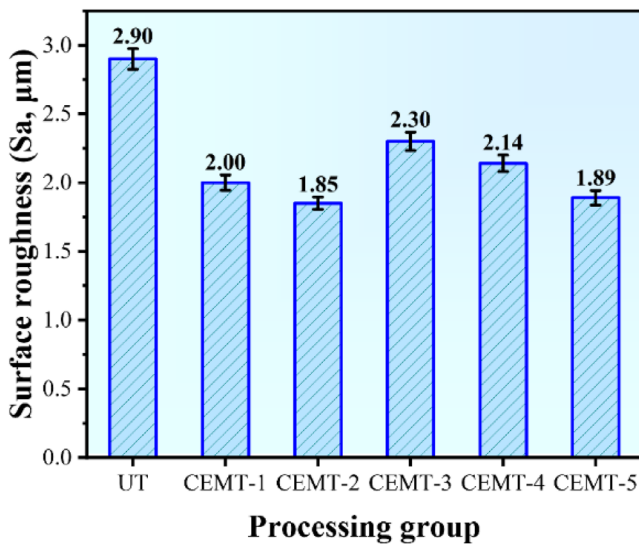


Fig. 7. The surface roughness of workpieces.

layer. (Figs. 10a1–10f1, Figs. 10a2–10f2). All rotary burrs showed obvious scratches on the adhered layer surface (Figs. 10a3–10f3). The adhered layer on the UT sample cutting edge surface exhibited multiple cracks, and a small part of the adhered layer had peeled off (Fig. 10a3). These phenomena indicate that during cutting, the rotary burr mainly experiences abrasive wear, diffusion wear, oxidation wear, and adhesion wear.

The high-temperature and high-pressure processing environment during cutting causes mutual diffusion between the workpiece material and the rotary burr material at the friction interface, resulting in diffusion wear of the rotary burr. The high temperature generated during cutting causes melting of the workpiece surface material in the friction zone. Under the effect of diffusion, the melted workpiece surface material mixes with the diffused rotary burr material and firmly bonds to form an adhered layer on the cutting-edge surface. During friction, the workpiece leaves scratches on the adhered layer surface. This is because the adhered layer is firmly bonded to the cutting-edge surface and mainly acts as

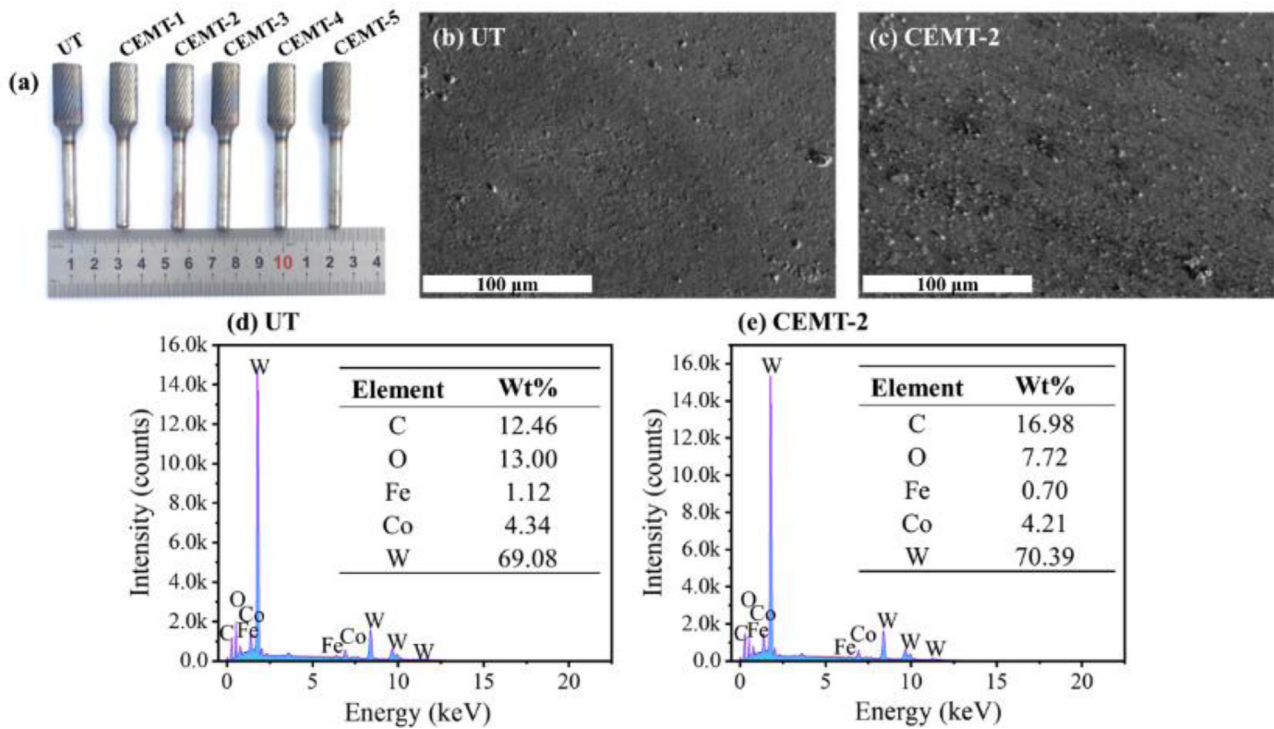


Fig. 8. Morphological characterization and EDS elemental analysis of rotary burrs after cutting experiment: (a) Macroscopic morphology; (b, c) Microscopic morphology of cutting-edge side of UT and CEMENT-2 samples; (d, e) EDS elemental analysis of cutting-edge side of UT and CEMENT-2 samples.

a barrier, replacing direct frictional contact between the rotary burr base and the workpiece. Therefore, when the workpiece comes into contact with the cutting edge and friction occurs, it actually happens between the workpiece and the adhered layer, effectively protecting the rotary burr base and significantly reducing abrasive wear. Additionally, the coverage of the adhered layer isolates the rotary burr base from contact with air, hindering the oxidation process of the rotary burr cutting edge and reducing oxidation wear. The formation of the adhered layer significantly reduces the direct contact between the rotary burr base and the workpiece, thereby slowing down the wear rate of the cutting edge to some extent. However, the hardness and strength of the adhered layer are relatively low. Excessive coverage and thickness of the adhered layer may hinder effective contact between the rotary burr substrate, which possesses superior mechanical properties, and the workpiece, thereby reducing cutting performance. Furthermore, thicker adhered layers are prone to cracking under cyclic impact forces, eventually leading to peeling. Since the adhered layer is tightly bonded to the base, the peeled adhered layer will carry away some base material, promoting adhesive wear of the tool.

Combined with Section 3.2, the workpiece surface roughness of UT and CEMENT-3 samples is relatively high, while the workpiece surface roughness of the other tools is relatively low. This effect is attributed to the complete coverage of the cutting edge surfaces by the adhered layer in the UT and CEMENT-3 samples. At this time, the main frictional objects are the adhered layer and the workpiece, resulting in poor cutting performance and inferior workpiece surface quality. For the other tools, although

there is an adhered layer on the cutting-edge surface, the tool base is also exposed. At this time, the main frictional objects are the tool base, the adhered layer, and the workpiece. The mechanical properties of the tool base are excellent, leading to good cutting performance and superior workpiece surface quality.

Chips are the direct product of the cutting process, and their shape and formation process are influenced by cutting conditions [29]. As shown in Figure 11, in the cutting test in Section 2.2.2, the abrasive chips generated by the 90th machining were captured. Observation revealed that all chips generated by the rotary burrs were flaky. Among these, the chip sizes of UT and CEMENT-3 samples were significantly smaller than that of chips produced by other rotary burrs (Figs. 11a and 11d). The smaller the chip size, the lower the material removal rate of the rotary burr. This phenomenon is consistent with the lower AMD and MRA values of UT and CEMENT-3 samples in Figure 5c. This can be attributed to the fact that the adhered layers in UT and CEMENT-3 samples covered a large area and were thick, which hindered effective contact between the workpiece and the burr substrate with better mechanical properties, thus reducing the material removal capability of the rotary burrs.

3.4 Effect of hardness and thermal conductivity on tool wear

CEMT affects the hardness of cemented carbide [30], and the hardness of the substrate is an important factor affecting the tool's wear resistance. To investigate the effect of CEMENT on material hardness, the WC-8Co sample

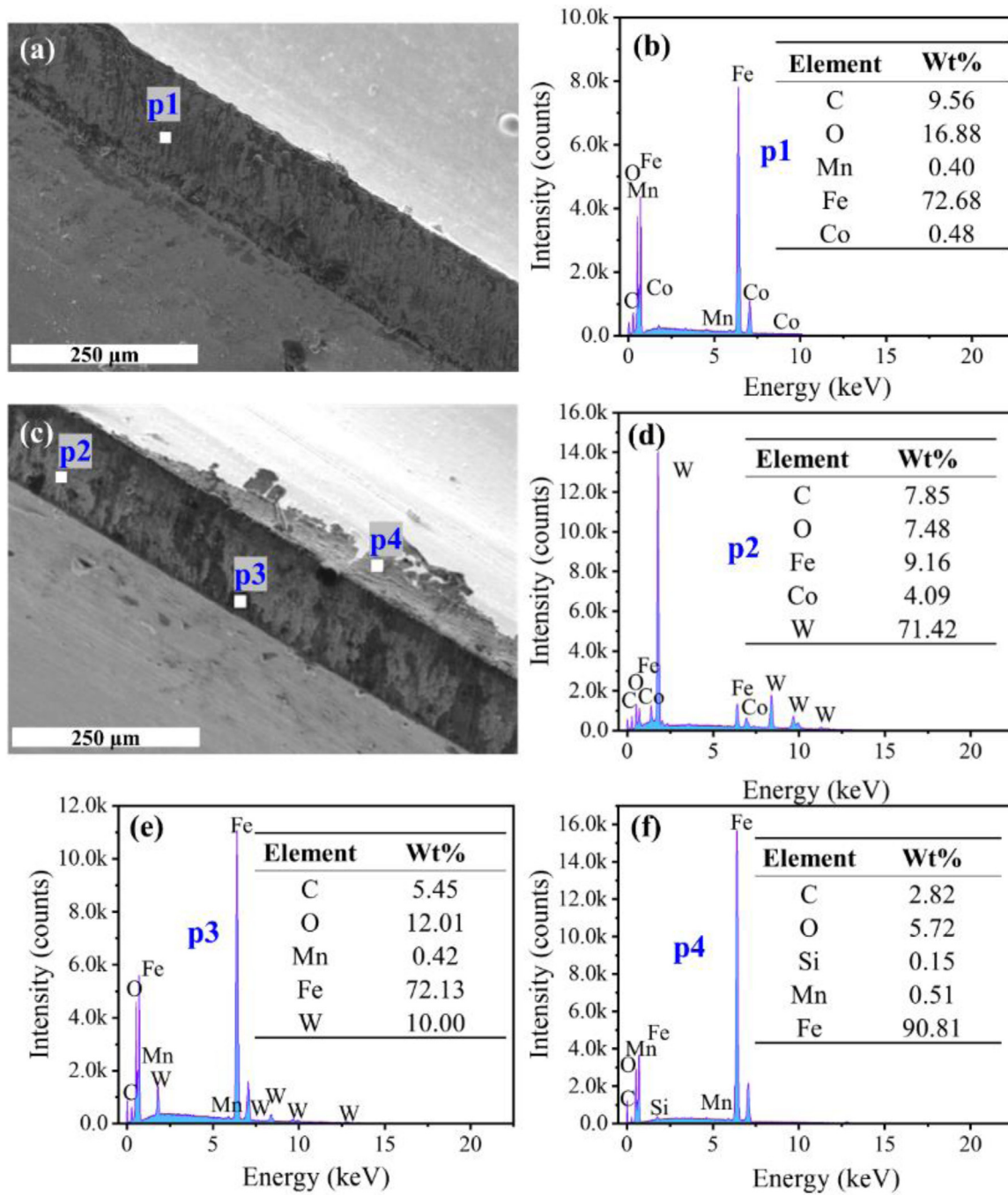


Fig. 9. SEM micrographs and EDS elemental analysis of UT and CEMT-2 samples cutting edge surfaces: (a) UT; (b) p1; (c); CEMT-2 (d) p2; (e) p3; (f) p4.

was subjected to CEMT using the previously identified optimal process parameters. The differences in hardness before and after treatment were systematically measured, as shown in Figure 12. The results indicate that CEMT elevated the material hardness from 1702.9 HV to 1811.2 HV, a relative enhancement of 6.4%. This increase in hardness contributes to improved wear resistance and, consequently, enhanced cutting performance [17].

The machining temperature has a significant impact on the cutting performance and wear resistance of the tools; excessively high machining temperatures can adversely

affect both the cutting performance and wear resistance of the tools [31]. The formation of the adhered layer is affected by the processing temperature. As the processing temperature increases, the atomic activity at the contact interface between the tool and the workpiece material increases, weakening the interaction forces between the atoms. This promotes mutual elemental diffusion between the workpiece and tool materials, enhancing interfacial adhesion and facilitating the bonding of workpiece material to the tool surface, ultimately leading to the formation of an adhered layer [32]. The thermal conductivity of the tools is

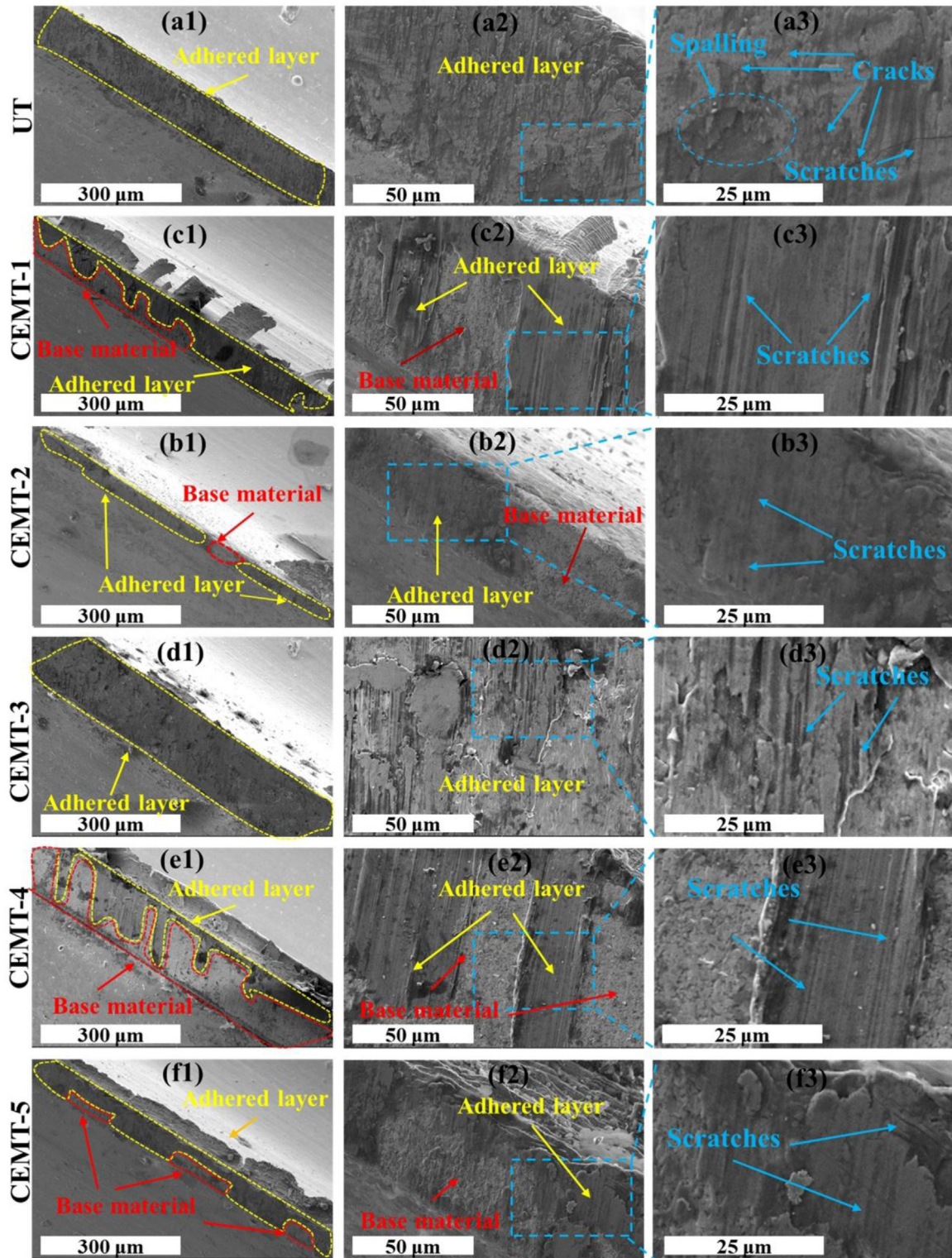


Fig. 10. SEM micrographs of rotary burrs cutting edge surfaces after cutting experiment: (a1-a3) UT; (b1-b3) CEMENT-1; (c1-c3) CEMENT-2; (d1-d3) CEMENT-3; (e1-e3) CEMENT-4; (f1-f3) CEMENT-5.

one of the factors influencing the machining temperature. An increase in thermal conductivity can lower the machining temperature [33], reduce the formation of the adhesion layer, and decrease adhesive wear of the tools [34].

To investigate the reasons for the inconsistent formation of the adhesion layer between UT and the CEMENT samples, the thermal conductivity of WC-8Co before and after the CEMENT was measured, with the CEMENT

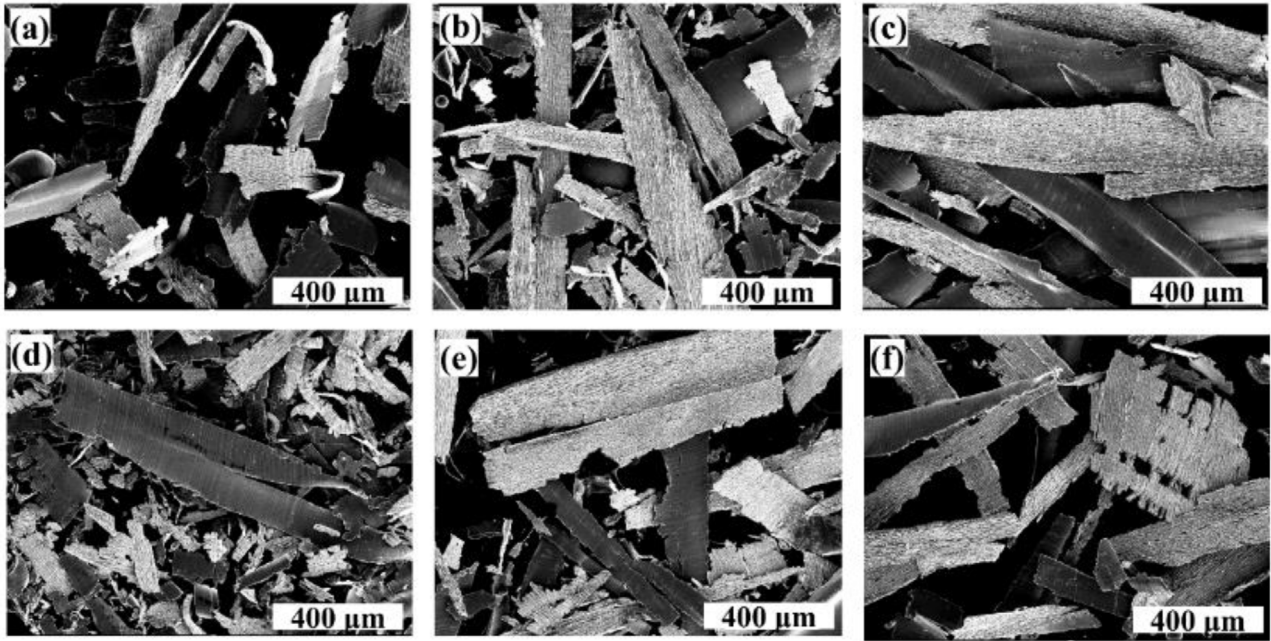


Fig. 11. SEM images of chips produced by cutting with different rotary burrs: (a) UT; (b) CEMENT-1; (c) CEMENT-2; (d) CEMENT-3; (e) CEMENT-4; (f) CEMENT-5.

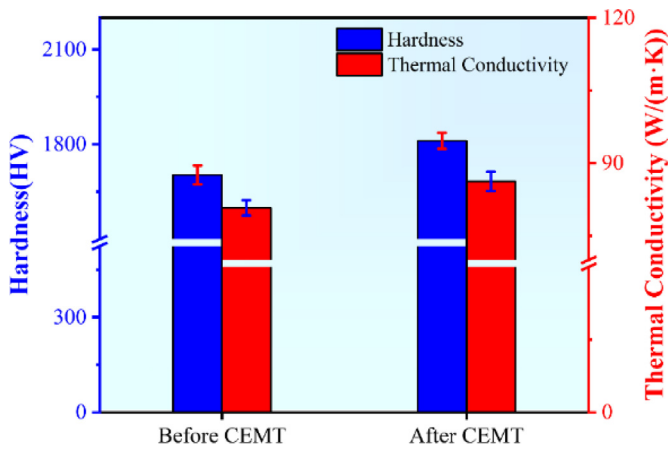


Fig. 12. Comparison of hardness and thermal conductivity of WC-8Co before and after CEMENT.

parameters being set to the optimal ones mentioned previously. Figure 12 presents the thermal conductivity measurement results. After the CEMENT, the thermal conductivity of WC-8Co increased from 80.73 (W/(m·K)) to 86.18 (W/(m·K)), representing a 6.75% improvement. The increase in thermal conductivity promotes the transfer of heat in the rotary burr during cutting, reduces heat accumulation at the friction interface, lowers the processing temperature, inhibits the mutual diffusion of elements between the workpiece material and the rotary burr material, thereby suppressing the formation of the adhered layer. Additionally, since the left side of the cutting edge in Figure 10 is the side entering the workpiece, this area accumulates less heat during cutting, making it less likely for the workpiece to soften and adhere to the rotary burr. In contrast, the right side of the cutting edge is the side exiting

the workpiece, where more heat accumulates during cutting, causing softening of the workpiece in this part and adhesion to the cutting edge, thereby forming the adhered layer.

3.5 Microstructural evolution

As shown in Figure 13a, two distinct microstructural morphologies are observed in the WC-8Co, corresponding to the WC phase and the Co phase. The granular structures are outlined in red, while the regions with various morphologies between the granules are marked in blue. As shown in Figure 13b, the granular structures contain 84.88% W and 13.55% C, indicating they are WC phase. In Figure 13c, the other type of region contains as much as 97.88% Co, indicating it is the Co phase.

Figure 14 shows the TEM morphological features of the WC and Co phases in UT and CEMENT-2 samples. The low-magnification images (Figs. 14a1 and 14b1) simultaneously capture both WC and Co phase regions. A noticeable increase in crystal defects (appearing as dark lines) is observed in the CEMENT-2 sample, indicating a higher defect density compared to UT. In the high-magnification images of the WC phase (Figs. 14a2 and 14b2), more dark stripes are clearly visible in the CEMENT-2 sample, which are typical dislocation morphologies, suggesting that CEMENT promotes dislocation multiplication. In the high-magnification images of the Co phase (Figs. 14a3 and 14b3), the UT sample exhibits only a few stacking faults with a single orientation, whereas the CEMENT-2 sample shows more densely distributed stacking fault bands with varying orientations. These observations indicate that CEMENT effectively increases the density of crystal defects such as dislocations and stacking faults in WC-8Co.

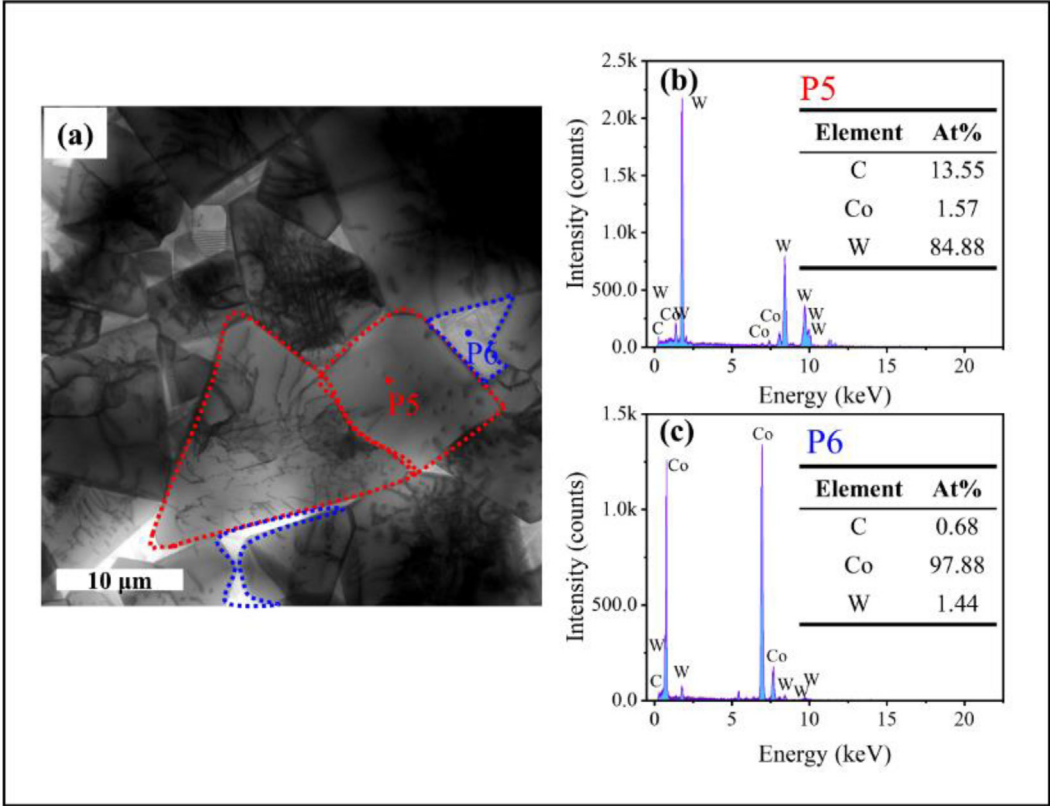


Fig. 13. Bright-field TEM image of UT sample and EDS analysis of different phases: (a) TEM image; (b) EDS results of WC phase; (c) EDS results of Co phase.

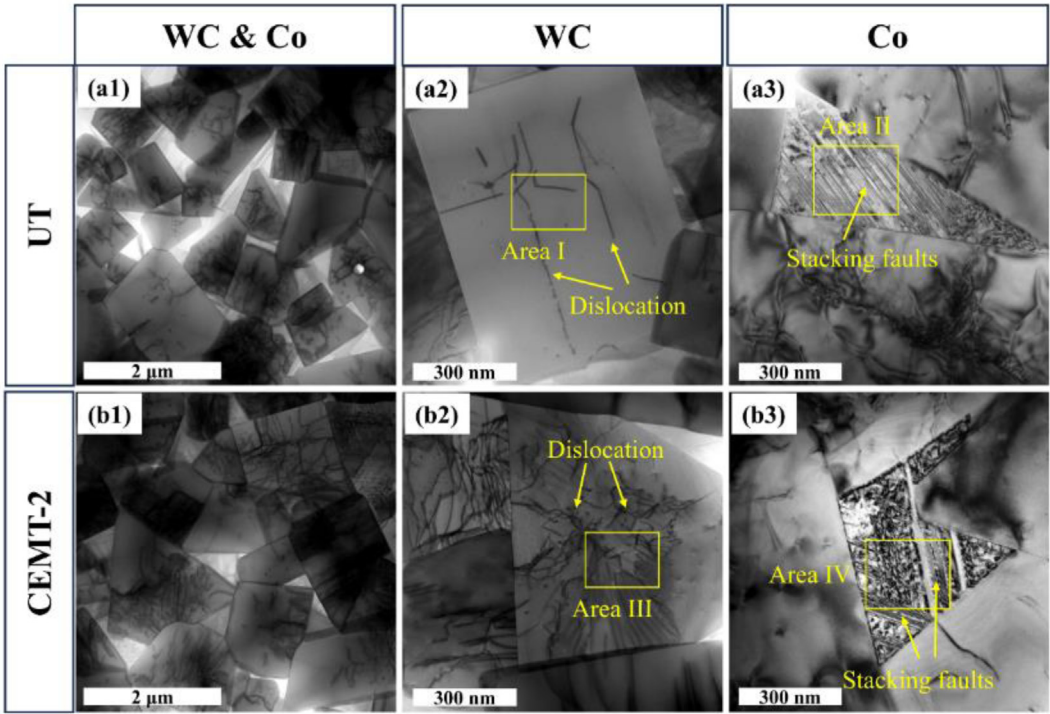


Fig. 14. Bright-field TEM images of WC and Co phases in UT and CEMENT-2 samples: (a1-a3) UT; (b1-b3) CEMENT-2.

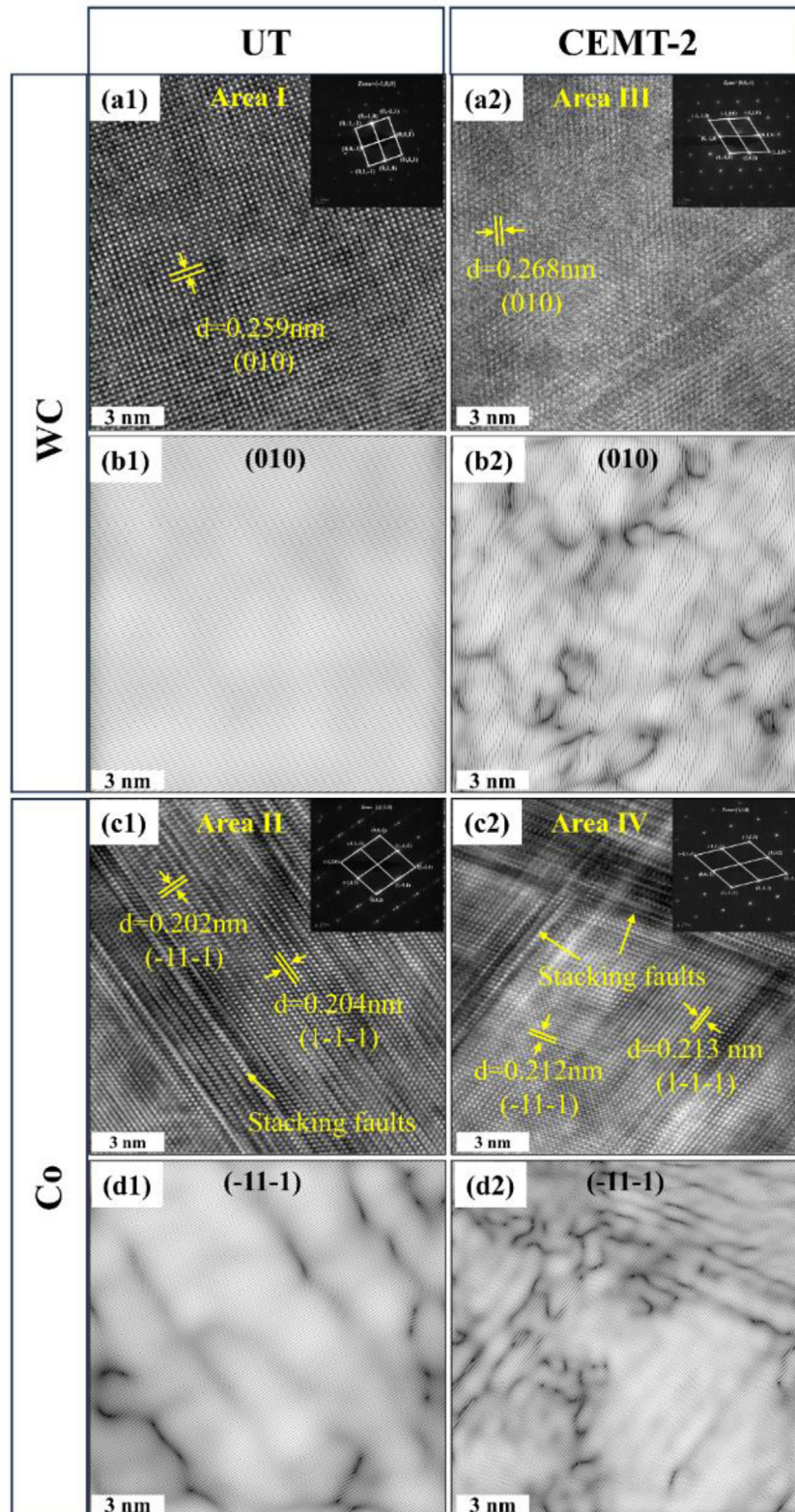


Fig. 15. HRTEM images of WC and Co phases in UT and CEMENT-2 samples and their corresponding IFFT images: (a1-d1) UT; (a2-d2) CEMENT-2.

Dislocations, stacking faults, and other crystal defects can lead to lattice distortion. To better observe the lattice distortion caused by increased crystal defects, high-resolution TEM (HRTEM) imaging was performed on

the red-boxed regions in Figure 14, and the images were processed using inverse fast Fourier transform (IFFT), as shown in Figure 15. In the UT sample, the lattice fringes of the WC phase are relatively clear, while those in the

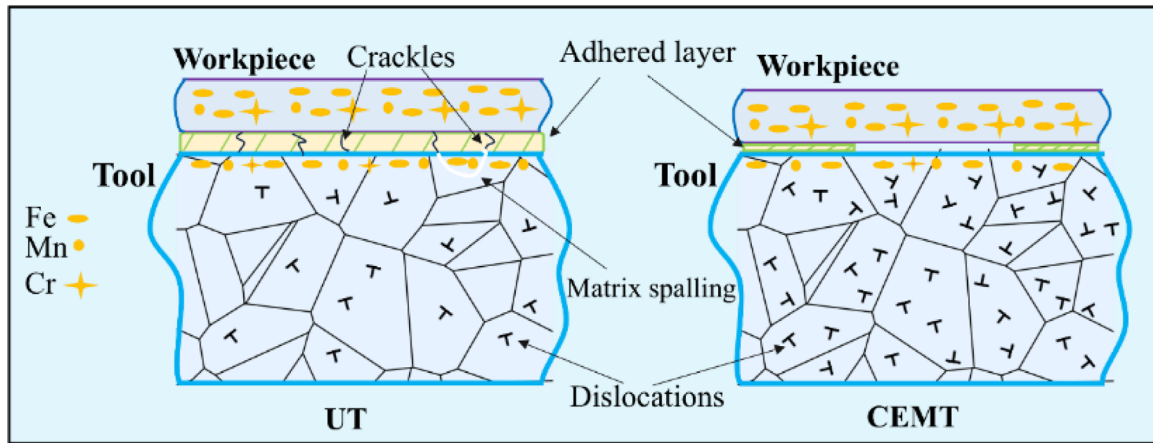


Fig. 16. Schematic illustration of the effect of CEMENT on the cutting behavior of rotary burrs.

CEMT-2 sample appear significantly blurred (Figs. 15a1 and 15a2), indicating more pronounced lattice distortion in the WC phase after CEMENT. Further IFFT analysis of the HRTEM images (Figs. 15b1 and 15b2) reveals that the moiré fringes in the WC phase of the UT sample are well-ordered, suggesting high lattice integrity, whereas the moiré fringes in the CEMENT-2 sample are disordered, indicating evident lattice distortion. Similarly, in the Co phase, the UT sample shows few stacking faults with a single orientation, while the CEMENT-2 sample exhibits densely distributed stacking faults with multiple orientations. In regions dense with stacking faults, the lattice fringes become noticeably blurred (Figs. 15c1 and 15c2), and the corresponding IFFT results (Figs. 15d1 and 15d2) further confirm that the moiré fringes in the Co phase of the CEMENT-2 sample are more disordered, verifying intensified lattice distortion. Moreover, the interplanar spacings of both the WC and Co phases increased after CEMENT, further confirming the enhancement of lattice distortion induced by the treatment.

The dislocation multiplication induced by CEMENT leads to the accumulation of internal stress fields in the crystal, resulting in lattice distortion. This distortion hinders the movement of other dislocations, enhances the interactions between dislocations, and improves the material's resistance to plastic deformation, manifesting as increased hardness [35,36]. As linear crystal defects, dislocations disrupt the periodicity of the lattice and act as scattering centers for phonons, thereby reducing phonon transport. With increasing dislocation density, the average free path of phonons shortens, leading to a decrease in thermal conductivity. Moreover, the non-uniform stress fields caused by lattice distortion further intensify phonon-defect scattering, inhibiting heat diffusion [37–39]. Therefore, the dislocation multiplication and lattice distortion induced by CEMENT are not responsible for the increase in the thermal conductivity of WC-8Co.

Interfaces, crystal defects, and crystal structure are key factors affecting the thermal conductivity of materials [40]. In magnetic materials, domain walls are magnetic interfaces that separate regions with different magnetization directions, which can scatter phonons and reduce thermal conductivity [41]. Thus, reducing domain walls

helps enhance thermal conductivity. Previous studies have shown that an external magnetic field can align the magnetization directions of domains, promote domain wall movement, and drive the merging of adjacent domains, ultimately reducing or eliminating domain walls [42,43]. The Co phase in WC-8Co is a magnetic phase, and the magnetic field applied during CEMENT can reduce the number of domain walls in the Co phase, thereby decreasing phonon scattering and enhancing the thermal conductivity of WC-8Co.

3.6 Comprehensive analysis

The influence of CEMENT on the cutting behavior of rotary burrs is shown in Figure 16. The UT sample has a lower thermal conductivity, causing heat accumulation at the friction interface, promoting the diffusion of elements between the rotary burr and the workpiece material, resulting in a widely distributed and thicker adhered layer. The thicker adhered layer undergoes continuous mechanical impact from cyclic loads during processing, which may lead to cracking and subsequent detachment. During detachment, part of the rotary burr's base material is carried away, exposing the base material again to form another adhered layer at this location. The cyclic formation and removal of this adhered layer progressively erode the substrate, resulting in severe adhesive wear that compromises the cutting efficiency of the rotary burr and reduces the surface quality of the workpiece.

After CEMENT, the thermal conductivity of the rotary burr increases, enabling heat at the friction interface to be conducted more quickly into the interior of the tool. This reduces the processing temperature and suppresses the diffusion of elements between the rotary burr and the workpiece material. As a result, the distribution area and thickness of the adhered layer decrease, and parts of the rotary burr base material are exposed, the adhesive wear of the rotary burr is reduced. Meanwhile, the dislocation multiplication and lattice distortion induced by the coupled electromagnetic field increase the hardness of WC-8Co, thus enhancing the burr's wear resistance. The exposed base material with superior mechanical properties directly contacts and participates in the cutting process

with the workpiece, which contributes to improved cutting performance of the rotary burr, a finding consistent with previous study [44].

4 Conclusion

The study reported in this paper presents, for the first time, an application of coupled electromagnetic treatment technology to improve the service life and cutting performance of WC-8Co rotary burrs, while also investigating the mechanisms by which coupled electromagnetic treatment influences the cutting behavior of these tools. Abundant experimental results lead to the following conclusions:

- The coupled electromagnetic treatment of the rotary burrs can help to reduce the average cutting-edge wear and cutting-head diameter wear of the rotary burrs while enhancing the average machining depth and material removal amount. For WC-8Co rotary burrs, the optimal process parameters are a magnetic field intensity of 0.6 T and an applied voltage of 1.2 V at both ends of the rotary burrs.
- Under these optimal treatment conditions, the cutting performance of the rotary burrs improved substantially. The average cutting-edge wear and cutting-head diameter wear decreased by 15.4% and 21.4% respectively, and average machining depth and material removal amount increased by 21.3% and 25.2% respectively, compared to the cutting using untreated rotary burrs.
- The wear of the rotary burrs mainly includes abrasive wear, oxidation wear, and adhesive wear. Compared to the untreated rotary burrs, except for the CEMT-3 sample, the coverage area of the adhered layer on the cutting-edge surface of the rotary burrs is reduced, thereby adhesive wear being reduced. After a coupled electromagnetic treatment, the thermal conductivity of WC-8Co increases, making it easier for heat at the friction interface to transfer to other areas, reducing cutting temperature. This is the direct cause to the decrease of the coverage area of the adhered layer, and consequently, oxidation wear of the rotary burrs is also reduced.
- After the coupled electromagnetic treatment, the surface quality of the workpiece improves, and the surface roughness decreases, with a reduction of up to 36.2% achieved. The improvement in surface quality is attributed to the reduced coverage area of the adhered layer, allowing the mechanically superior substrate of the rotary burrs to directly contact the workpiece surface, enhancing the material removal ability of the rotary burrs, and making the workpiece surface smoother.
- After coupled electromagnetic treatment, the hardness and thermal conductivity of WC-8Co increased by 6.4% and 6.75%, respectively. The increase in hardness is mainly attributed to the rise in crystal defects and the enhancement of lattice distortion induced by coupled electromagnetic treatment. Simultaneously, the applied magnetic field reduced the number of magnetic domain walls in the Co phase, thereby decreasing phonon scattering and improving the material's thermal conductivity.

- A decrease in the coverage area of the adhered layer exposes more of the substrate, which may potentially increase abrasive wear and oxidation wear due to greater contact with the workpiece and the surrounding air. However, after a coupled electromagnetic treatment, the reduced cutting temperature and the increased hardness of the rotary burrs effectively suppress both oxidation wear, adhesive wear and abrasive wear. Consequently, the tool's overall wear behavior ultimately manifests as a decrease in total tool wear.

Glossary

ACEW	Average Cutting-Edge Wear (mm)
AMD	Average Machining Depth (mm)
CEMT	Coupled electromagnetic treatment
CHDW	Cutting Head Diameter Wear (mm)
EDS	Energy Dispersive Spectrometer
HRTEM	High Resolution Transmission Electron Microscope
IFFT	Inverse Fast Fourier Transform
MRA	Material Removal Amount (g)
SEM	Scanning Electron Microscope
TEM	Transmission Electron Microscope
UT	Untreated
w_i	Maximum wear width of one of the cutting edges of the burr (mm)
n	Number of teeth of the rotary burr
d_1	Diameter of the rotary burr before cutting (mm)
d_2	Diameter of the rotary burr after cutting (mm)
wd_1	Average width of the workpiece before cutting (mm)
wd_2	Average width of the workpiece after cutting (mm)
wt_1	Weight of the workpiece before cutting (g)
wt_2	Weight of the workpiece after cutting (g)

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Conflicts of interest

The authors declare that they have no conflict of interest.

Data availability statement

Not applicable.

Author contribution statement

Shiyuan Zhang: Writing–original draft, Investigation, Formal analysis, Data curation. **Ming Jiang:** Writing–original draft, Software, Investigation, Data curation. **Bo Zeng:** Software,

Writing–review & editing. Wei Chen: Methodology, Software. **Kunlan Huang**: Funding acquisition, Supervision, Writing–review & editing. **Jie Wang**: Writing–review & editing, Validation.

References

- G.L. Zhao, B. Zhao, W.F. Ding, L.J. Xin, Z.W. Nian, J.H. Peng, N. He, J.H. Xu, Nontraditional energy-assisted mechanical machining of difficult-to-cut materials and components in aerospace community: a comparative analysis, *Int. J. Extreme Manuf.* **6** (2024) 82
- M. Chinnasamy, R. Rathanasamy, S.K. Pal, S.K. Palaniapan, Effectiveness of cryogenic treatment on cutting tool inserts: a review, *Int. J. Refract. Met. Hard Mater.* **108** (2022) 105946
- B. Wu, H. Xiao, M. Zhang, B. Zhao, W. Ding, Tribological behavior of tool-workpiece interface during milling of ultra-high strength steel under different cooling conditions, *Front. Mech. Eng.* **20** (2025) 28
- L.Y. Li, Y.B. Zhang, X. Cui, Z. Said, S. Sharma, M.Z. Liu, T. Gao, Z.M. Zhou, X.M. Wang, C.H. Li, Mechanical behavior and modeling of grinding force: a comparative analysis, *J. Manuf. Processes.* **102** (2023) 921–954
- S. Pawanr, K. Gupta, Dry machining techniques for sustainability in metal cutting: a review, *Processes* **12** (2024) 28
- Y.L. He, Y.X. Fan, D.P. Wang, R. Zitoune, J. Luo, J.D. Qi, The cutting performance of coated and uncoated segmented flute routers with tool wear progression in milling multidirectional CFRP composites, *Wear* **578** (2025) 206199
- W. Cai, Y.X. He, C.X. Li, Research on grinding staggered teeth on ball-end rotary burr, *Int. J. Adv. Manuf. Technol.* **32** (2006) 911–917
- L. Wang, W. Cai, Y. He, T. Peng, J. Xie, L. Hu, L. Li, Equipment-process-strategy integration for sustainable machining: a review, *Front. Mech. Eng.* **18** (2023) 36
- K. Bobzin, High-performance coatings for cutting tools, *CIRP J. Manuf. Sci. Technol.* **18** (2017) 1–9
- J. Agyapong, A. Czekanski, S. Boakye-Yiadom, Effect of heat treatment on microstructural evolution and properties of cemented carbides (WC-17Co) reinforced with 3% volume hexagonal-boron nitride (h-BN) and processed by selective laser sintering (SLS), *Mater. Charact.* **174** (2021) 110968
- M. Yang, H. Ma, Z. Li, J. Hao, M. Liu, X. Cui, Y. Zhang, Z. Zhou, Y. Long, C. Li, Force model in electrostatic atomization minimum quantity lubrication milling GH4169 and performance evaluation, *Front. Mech. Eng.* **19** (2024) 55–72
- L.X. Zhao, G.J. Chen, J. Liu, J.S. Huang, Experimental study on electric pulse assisted cutting of tungsten alloy, *Int. J. Adv. Manuf. Technol.* **136** (2025) 5271–5279
- A. Gangopadhyay, G. Barber, H. Zhao, Tool wear reduction through an externally applied electric current, *Wear* **260** (2006) 549–553
- S. Yang, M. Zhang, B. Lu, M. Wu, Y. Yang, G. Yang, Investigation of pulsed magnetic field treatment to enhance the properties of printed circuit board micro drill, *Wear* **564–565** (2025) 205699
- B. Zeng, Z.Q. Xie, Q. Li, J. Wang, K.L. Huang, H. Yu, Residual stress relaxation of 2A02 blade forging under electromagnetic coupling energy, *Rare Metal Mat. Eng.* **52** (2023) 4055–4064
- M.Q. Li, Y.D. Shen, K. Luo, Q. An, P. Gao, P.H. Xiao, Y. Zou, Harnessing dislocation motion using an electric field, *Nat. Mater.* **22** (2023) 958–963
- Y. Yang, Y. Yang, Q. Li, Y. Qin, G. Yang, B. Zhou, C. Deng, M. Wu, An eco-friendly pulsed magnetic field treatment on cemented carbide (WC-12Co) for enhanced milling performance, *J. Cleaner Prod.* **340** (2022) 130748
- M. Yuan, J. Wang, L. Wang, F. Zhong, K.L. Huang, Y.K. Tian, Electromagnetic coupling field strengthening of WC-TiC-Co cermet tools, *Ceram. Int.* **47** (2021) 3747–3759
- Q. Li, X.T. Wang, Y. Qin, K.L. Huang, J. Wang, Improvement of the fatigue life of an electron-beam welded Ti2AlNb joint subjected to an electromagnetic coupling treatment, *Mat. Sci. Eng. A-struct.* **909** (2024) 146848
- F. Zhong, J. Wang, Q.W. Zhang, J.G. Huang, W. Wang, J. Xu, K.L. Huang, Y. Qin, Residual stress reductions of carbide cutting tools through applying pulsed magnetic field and coupled electromagnetic field – mechanism analysis and comparison study, *Int. J. Adv. Manuf. Technol.* **121** (2022) 4757–4775
- L. Wei, Y. Yang, G. Yang, M.X. Wu, C. Wei, X.L. Wu, Effect of electromagnetic compound treatment on microstructure and performance of cemented carbide, *J. Wuhan. Univ. Technol.* **34** (2019) 1119–1126
- J. Liu, C. Wei, G. Yang, L.B. Wang, L. Wang, X.L. Wu, K. Jiang, Y. Yang, A novel combined electromagnetic treatment on cemented carbides for improved milling and mechanical performances, *Metall. Mater. Trans. A.* **49a** (2018) 4798–4808
- W.M. Zhou, J.C. Lin, F. Feng, Y. Ma, H.T. Zha, W. Ji, E.L. Jiang, Z.P. Cai, P.F. Feng, Performance improvement of carbide cutting tool for Ti6Al4V alloys using electromagnetic treatment, *Int. J. Adv. Manuf. Technol.* **113** (2021) 1547–1560
- T. Benkedjouh, K. Medjaher, N. Zerhouni, S. Rechak, Health assessment and life prediction of cutting tools based on support vector regression, *J. Intell. Manuf.* **26** (2013) 213–223
- B. Wang, Z.Q. Liu, Y.K. Cai, X.C. Luo, H.F. Ma, Q.H. Song, Z.H. Xiong, Advancements in material removal mechanism and surface integrity of high speed metal cutting: a review, *Int. J. Mach. Tools Manuf.* **166** (2021) 103744
- S.J. Zhang, S. To, S.J. Wang, Z.W. Zhu, A review of surface roughness generation in ultra-precision machining, *Int. J. Mach. Tools Manuf.* **91** (2015) 76–95
- A. Berrais, A. Boudebane, M. Labaiz, A. Montagne, S. Lemboub, M.Z. Touhami, A. Ourdjini, Analysis of wear of a nitrided AISI H13 hot work tool steel in an aluminium hot extrusion process, *Wear* **514** (2023) 204587
- I. Efimovich, I. Zolotukhin, Oxidation temperatures of WC-Co cemented tungsten carbides, *Obrab Metallov.* **26** (2024) 199–211
- S. Wojciechowski, M. Matuszak, B. Powalka, M. Madajewski, R.W. Maruda, G.M. Królczyk, Prediction of cutting forces during micro end milling considering chip thickness accumulation, *Int. J. Mach. Tools Manuf.* **147** (2019) 103466
- Y. Wang, Z.G. Xing, Y.F. Huang, W.L. Guo, J.J. Kang, H.D. Wang, Z.N. Zhang, Effect of pulse magnetic field treatment on the hardness of 20Cr2Ni4A steel, *J. Magn. Magn. Mater.* **538** (2021) 168248

31. Ç.V. Yıldırım, M. Sarıkaya, T. Kivak, S. Sirin, The effect of addition of hBN nanoparticles to nanofluid-MQL on tool wear patterns, tool life, roughness and temperature in turning of Ni-based Inconel 625, *Tribol. Int.* **134** (2019) 443–456
32. J.G. Chen, M.L. Zheng, P.F. Li, W. Zhang, Y.S. Sun, Formation of sticking-welding on rake face of carbide tool and its theoretical model of element diffusion, *Chin. J. Nonferrous Met.* **29** (2019) 790–802
33. K.E. Sun, B. Zeng, Y. Qin, C.J. Deng, Y. Yang, K.L. Huang, J. Wang, An electromagnetic coupling treatment for improving the cutting performance of cemented carbide-coated tools, *J. Asian Ceram. Soc.* **11** (2023) 504–516
34. Q.W. Zhang, K.L. Huang, J. Wang, L. Wang, M. Yuan, Y.K. Tian, L. Ouyang, Effect of pulse electromagnetic coupling treatment on thermal conductivity of WC-8Co cemented carbide, *Ceram. Int.* **47** (2021) 22683–22692
35. L.N. Yu, K. Nishimoto, H. Hirata, K. Saida, Hardness prediction of the heat-affected zone in multilayer welded SUS316 stainless steel based on dislocation density change behavior, *Metall. Mater. Trans. A.* **55** (2024) 1788–1803
36. H. Wang, P.Y. Yang, W.J. Zhao, S.H. Ma, J.H. Hou, Q.F. He, C.L. Wu, H.A. Chen, Q. Wang, Q. Cheng, B.S. Guo, J.C. Qiao, W.J. Lu, S.J. Zhao, X.D. Xu, C.T. Liu, Y. Liu, C.W. Pao, Y. Yang, Lattice distortion enabling enhanced strength and plasticity in high entropy intermetallic alloy, *Nat. Commun.* **15** (2024) 6782
37. Y.X. Wu, Z.W. Chen, P.F. Nan, F. Xiong, S.Q. Lin, X.Y. Zhang, Y. Chen, L.D. Chen, B.H. Ge, Y.Z. Pei, Lattice strain advances thermoelectrics, *Joule*. **3** (2019) 1276–1288
38. L. Lindsay, R. Hanus, C.A. Polanco, Dislocation-limited thermal conductivity in LiF: revisiting perturbative models, *JOM*. **74** (2022) 547–555
39. Y.D. Sun, Y.G. Zhou, M. Hu, G.J. Snyder, B. Xu, W. Liu, Probing the phonon mean free paths in dislocation core by molecular dynamics simulation, *J. Appl. Phys.* **129** (2021) 055103
40. N. Burger, A. Laachachi, M. Ferriol, M. Lutz, V. Toniazio, D. Ruch, Review of thermal conductivity in composites: Mechanisms, parameters and theory, *Prog. Polym. Sci.* **61** (2016) 1–28
41. A. Sieradzki, A. Jezowski, R. Poprawski, The influence of ferroelastic domain formation on thermal conductivity in Li₂TiGeO₅ ceramics, *J. Therm. Anal. Calorim.* **115** (2013) 467–470
42. L. Zhang, Z. Chen, H. Wen, M. Wu, Y. Yang, K. Jiang, J. Liu, Modification effects of the pulsed magnetic field on the coated cemented carbides tool for enhanced mechanical and cutting performances, *Int. J. Refract. Met. Hard Mater.* **111** (2023) 106093
43. J.L. Ni, F. Hu, S.J. Feng, X.C. Kan, X.S. Liu, Magnetic properties of FeSiAl soft magnetic composites under transverse magnetic field, *J. Supercond. Novel Magn.* **34** (2021) 883–887
44. V.F.C. Sousa, J. Castanheira, F.J.G. Silva, J.S. Fecheira, G. Pinto, A. Baptista, Wear behavior of uncoated and coated tools in milling operations of AMPCO (Cu-Be) alloy, *Appl. Sci. –Basel*. **11** (2021) 7762–7783

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