Effect of micro textures on the cutting performance of circular saw blade

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Abstract
In this paper, linear micro textures that parallel to the sawtooth edge were fabricated on the surface of the high-speed steel W6Mo5Cr4V2 circular saw blade by laser engraving. Furthermore, cutting performance of micro textured circular saw blade (TCS) and traditional circular saw blade (CS), including sawing arc length, sawing force, sawing temperature, machined surface roughness, and wear mechanism, were investigated in sawing 304 stainless steel pipes under the cutting fluid condition. Results showed that the largest sawing arc length and sawing force were occurred on the circular saw blade sawing outward from the inner wall. In addition, TCS exhibited better cutting performance mainly due to the following two aspects, on the one hand, the effective sawtooth-chip contact length was reduced due to the micro textures fabricated on the sawtooth surface; on the other hand, cutting fluid can be better penetrated into the micro textures and formed stable lubrication film in sawtooth-chip contact interface.

Keywords Micro textures · Circular saw blade · Cutting performance · Cutting fluids

1 Introduction
In the manufacturing industry, as the starting point of workpiece machining, sawing was widely used in material cutting, tailing removal, and other important processes. The sawing tools exhibited higher machining efficiency on account of its multiple sawtooth in comparison with milling and turning tools. It can be classified into three kinds according to the application and structure of saw blade, which were hack saw blade [1], band saw blade [2, 3], and circular saw blade [4, 5]. The circular saw blade was widely used in the cutting of various kinds of metal and wood due to the higher machining accuracy and cutting efficiency in comparison with the band saw blade and hack saw blade. According to the material and parameters of the sawtooth, the circular saw blade can be divided into two categories, one was that the solid saw composed of high-speed steel or cemented carbide; the other was that the sawtooth with good hardness and wear resistance inserted or welded into the circular saw blade [6]. The cutting performance, wear characteristic, and dynamic stability of the circular saw blade were investigated by numerous scholars [7–11]. Bradbury et al. [7] employed M2 high-speed steel as circular saw blade material sawing difficult-to-cut material, and indicated that the sawing characteristic of the workpiece and tool material plays a significant role in the sawing process. Alam et al. [10] presented a method to improve the stability of the circular saw blade by controlling workpiece feed speed, and monitored the lateral deflection of the saw blade. It indicated that the lateral deflection of circular saw blade within a desired limit.

Recently, many scholars had proved that micro textures were an effective method to improve the friction condition of the friction pair surface, and micro textures were widely used in piston rings, tools, seals, wet clutches, and bearings surface [12–18]. Different types of micro textures engraved on the surfaces of the cutting tools have shown the effect in lowering sliding friction, reducing tool-chip contact length, promoting heat dissipation, and relieving adhesive wear [19–23]. Kawasegi et al. [23] fabricated three types of patterns (parallel, perpendicular, and cross patterns) on the rake face of the cutting tools. It was found that the textures perpendicular to the chip flow was beneficial to reduce cutting force. Deng et al.
produced three rake-face textured tools with different micro structures and found that the elliptical grooves promoted better dry cutting performance than the parallel or linear grooves. In addition, micro textures also used in drilling and milling processes [25–28]. Zhou et al. [27] successfully fabricated micro textures parallel to the cutting edge on the rake face of the milling tools and carry out milling tests with nanofluids; it obtained that the cutting force, surface roughness, and wear rate of the tools were significantly decreased. Ling et al. [28] fabricated rectangular micro textures on the surface of drill tools, and found that the micro textures effectively reduced the adhesion of the workpiece material and improved the tool’s life. However, very limited research works have been reported concerning micro textures fabricated on the sawtooth surface of the circular saw blade. Thus, the effect of micro textures on the cutting performance of circular saw blade needed to be further studied.

In this paper, four linear micro textures that parallel to the sawtooth edge were fabricated on the surface of the high-speed steel W6Mo5Cr4V2 circular saw blade by laser engraving. Then, the depth, width, and microstructure of the micro textures were obtained. Sawing 304 stainless steel pipes tests were carried out with the micro textured circular saw blade (TCS) under the cutting fluid condition. The sawing properties, including sawing arc length, sawing forces, sawing temperatures, machined surface roughness, and wear of the tools were investigated. This research can provide a good reference for reducing the wear of circular saw blade, improving the machining surface quality, and prolonging the tool’s life. If possible, micro textured circular saw blade will be widely applied industrially in the future.

2 Experimental details

2.1 Specimen preparation

In this paper, high-speed steel W6Mo5Cr4V2 was chosen as circular saw blade material from Yongkang Meili Juye Co., Ltd., China; the composition and mechanical properties of circular saw blade are shown in Table 1. As shown in Fig. 1, the diameter of circular saw blade was 200 mm, thickness was 2 mm, teeth were 150, teeth space was 4.2 mm, and the installation hole diameter was 32 mm. Before micro texturing, in order to remove surface dirt, the circular saw blade was put in the alcohol solution ultrasonic cleaning for 15 min, and then drying for 10 min. The micro textures were designed and fabricated on the rake face by Nd: YAG laser equipment (DP-H50, Jinan Xinchu Co., Ltd., China) and the processing parameters are listed in Table 2. The circular saw blade was fixed on the indexing plate, rotated the indexing by 2.4° after each machining until all the teeth were micro textured. The micro textures of the teeth surface were observed using white light interferometer (Wyko NT9300, Veeco Inc., USA) and scanning electron microscope (SEM; QUANTA FEG 250, FEI Inc., USA).

Figure 2 illustrates the schematic diagram and SEM surface morphologies of the micro textures. As shown in this figure, four micro textures were designed in the sawtooth surface, and the distance from the cutting edge was 200 μm; the spacing between the micro textures was 300 μm. The three-dimensional surface profile and cross section morphology of micro textures are shown in Fig. 3. It can be seen that the depth of the micro textures was about 10 μm, and width was about 45 μm.

2.2 Sawing tests

Figure 4 shows the photos of sawing tests that executed with turning machine CKD6150H. The circular saw blade was mounted on the spindle of the machine tool and with the following geometry: rake angle $\gamma = -15^\circ$, sawing width $d = 2$ mm. Two kinds of circular saw blade were prepared: the micro textured was fabricated on the rake face of the sawtooth (named TCS), and the conventional circular saw blade with the same composition was also employed (named CS) for the purpose of comparison. The 304 stainless steel pipes were employed as the workpiece material with the diameter of 30 mm and the wall thickness of 2 mm. The 304 stainless steel pipes were installed and fixed on the tool rest and fed along the Y-axis at a certain rate. The entire process of TCS and CS sawing tests was under the emulsified cutting fluids (solcut oil-V600, DOMINO Co., Ltd., China) and the sawing conditions are shown in Table 3. When cutting the 304 stainless steel pipes, cutting fluids were continuously supplied from one side of the sawtooth to the tool-chip contact area with a flow rate of 11.2 L/min. After cutting the pipes, it stopped the supply of cutting fluid immediately.

| Material | C  | W  | Mo | Cr | V  | Mn | Fe | Density | Hardness | Young’s modulus |
|----------|----|----|----|----|----|----|----|---------|----------|-----------------|
| W6Mo5Cr4V2 | 0.91 wt.% | 6.05 wt.% | 5.30 wt.% | 4.15 wt.% | 1.95 wt.% | 0.35 wt.% | Bal | 8.3 g/cm³ | 12.6 GPa | 204 GPa |

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The sawing forces were recorded by piezoelectric dynamometer Kistler 9275A. The sawing temperature was measured by an infrared thermal imager (Fotric 225/226) when the circular saw blade sawing 304 stainless steel pipes. The distance between the infrared thermal imager and the sawing position was about 1.5 m. And the emissivity of infrared thermal imager was determined according to the 304 stainless steel pipes (about 0.85). The surface and side worn morphologies of sawtooth were investigated by scanning electron microscope (SEM; QUANTA FEG 250, FEI Inc., USA), energy-dispersive X-ray spectrooscope (EDS, QUANTA FEG 250, FEI Inc., USA), and optical microscope (VK-X200, KEYENCE Co., Ltd., China). In addition, the measurement of the average machined surface roughness Ra was conducted at three different locations by a roughness tester (TR200, JITAIKEYI Inc., China).

### 3 Results and discussion

#### 3.1 Sawing arc length

The schematic diagram of sawing force is showed in Fig. 5(a). In this work, the sawing force was affected by the sawing force per tooth, sawing arc length and teeth space. The sawing force of circular saw blade was the sum of the cutting forces of each working sawtooth. And the number of working sawtooth was related to sawing arc length and tooth pitch. Therefore, under certain sawing conditions, the sawing force $F$ was greatly affected by the sawing arc length. According to the formula of trigonometric function and common chord length of two circles (Fig. 5(a)), the sawing force $F$ and sawing arc length $L$ were obtained from the following equations:

$$F = \frac{F_r \cdot L}{t}$$

### Table 2 Experimental parameters of the Nd:YAG laser

| Wavelength (nm) | Power (W) | Frequency (KHz) | Scanning speed (mm/s) | Number of scan | Pulse duration (ns) |
|-----------------|-----------|-----------------|-----------------------|----------------|---------------------|
| 1064            | 12        | 20              | 150                   | 1              | 10                  |

**Fig. 1** The photographs and SEM micrographs of a circular saw blade: (a) photographs of circular saw blade; (b) rake face of the sawtooth; (c) side morphology of the sawtooth
\[ L = \begin{cases} \frac{\pi R_1 \arcsin(x/2R_1)}{90} & (0 < \lambda < m, \text{or } 2R-m < \lambda < 2R) \\ \frac{\pi R_1 \{\arcsin(x/2R_1) - \arcsin(x_1/2R_1)\}}{90} & (m < \lambda < 2R-m) \end{cases} \]  

\[ x = 2\sqrt{(R_1 + R-\lambda/2) \cdot (R_1-\lambda/2) \cdot (R-\lambda/2) \cdot \lambda/2} / (R_1 + R-\lambda) \]  

\[ x_1 = 2\sqrt{(R_1 + R-\lambda/2) \cdot (R_1-\lambda/2) \cdot (R-\lambda/2) \cdot \lambda/2} / (R_1 + R-\lambda) \]  

where \( F \) was the resultant force of the circular saw blades, \( F_r \) was the sawing force per tooth (it can be decomposed into

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**Table 3** Some parameters of the sawing tests

| Parameter            | Values                      |
|----------------------|-----------------------------|
| Feed rate (f)        | 0.4, 0.6, 0.8, 1.0, 1.2 mm/r |
| Cutting speed (v)    | 50, 100, 150 m/min          |
| Workpiece            | 304 stainless steel pipe    |
| Cutting tool         | High-speed steel W6Mo5Cr4V2 |
| Sawing machine       | CKD6150H                    |
main sawing force $F_z$ and thrust force $F_y$ of each tooth), $L$ was sawing arc length, $t$ was the teeth space, $R_1$ was the diameter of circular saw blade, $R$ was external diameter of the workpiece, $r$ was inside diameter of the workpiece, $m$ was wall thickness, and $\lambda$ was the sawing depth.

In the sawing process, the teeth space $t$ and the sawing force of each tooth $P$ were constant, so the sawing force was proportional to the sawing arc length. The variation of sawing arc length is showed in Fig. 5(b). When the sawing depth increased from 0 to 2 mm, the sawing arc length was increased rapidly, from 0 to about 14 mm. Then, the sawing arc length began to decrease and remain stable about 4 mm with the increasing of sawing depth. Subsequently, the sawing arc length began to increase again, and the sawing arc length reached the maximum at the sawing depth of 28 mm, which was about 16 mm. Finally, the sawing arc length rapidly decreased to 0 mm.

3.2 Sawing force

The effect of the sawing speed and feed rate on the sawing force (main force $F_z$, and radial thrust force $F_y$) for TCS and CS was analyzed. Figure 6 illustrates the variation of sawing force at sawing speed 50 m/min and feed rate 0.8 mm/r. For CS, the variation of main force $F_z$ was increased sharply from 0 to about 270 N before 2 s. Then, $F_z$ decreased quickly and reached the minimum value about 95 N at 8 s. Afterwards, $F_z$ began to increase and reached the maximum value about 290 N at 14.5 s. Finally, $F_z$ decreased sharply from 290 to 0 N. The variation trend of radial thrust force $F_y$ was consistent with that of $F_z$, and the maximum and minimum values were about 190 N and 55 N, respectively. In comparison with CS, the main force $F_z$ and radial thrust force $F_y$ of the TCS were decreased by about 12% and 7%, respectively.
The variation of main sawing force $F_z$ with feed rate is showed in Fig. 7. For the sawing speed of 50 m/min, the main sawing force $F_z$ of CS was increased from 80 to 115 N with the increase of feed rate from 0.4 to 1.2 mm/r. For TCS, the main sawing force $F_z$ was decreased by about 8~12% compared with CS with the increase of feed rate. For the sawing speed of 100 m/min, the range of main sawing force $F_z$ value was wider than the sawing speed of 50 m/min from about 83 to 130 N. The main sawing force $F_z$ of TCS was reduced about 5~7% in comparison with CS with the increase.

Fig. 7  The variation of main sawing force $F_z$ with feed rate: (a) sawing speed 50 m/min; (b) sawing speed 100 m/min; (c) sawing speed 150 m/min

Fig. 8  The sawing temperature under the condition of sawing speed 100 m/min and feed rate 1.2 mm/r: (a) CS; (2) TCS
of feed rate. For the sawing speed of 150 m/min, the range of $F_z$ (from 86 to 161 N) was the largest with different feed rate, and the value of $F_z$ was close to each other of CS and TCS. Compared to CS, the main sawing force $F_z$ of TCS was reduced about 3~7%.

3.3 Sawing temperature

During the sawing process, a lot of energy would be involved for chip removal, which would generate considerable amounts of heat. In this work, the influence of sawing speed and feed
rate on the sawing temperature for CS and TCS was evaluated under lubrication condition. Figure 8 illustrates the sawing temperature in the tool-chip contact area of CS and TCS under the condition of sawing speed 100 m/min and feed rate 1.2 mm/r. It can be seen that the temperature of the cutting position and the circumferential of the circular saw blade were higher. For TCS, the sawing temperature was decreased by about 6.8% in comparison with the CS.

The contour map of the highest sawing temperature of CS and TCS with different sawing speed and feed rate during the sawing process is exhibited in Fig. 9. For the sawing speed of 50, 100, and 150 m/min, the sawing temperature of CS was increased from about 109 to 196 °C, 120 to 229 °C, and 137 to 320 °C, respectively, with the increase of feed rate from 0.4 to 1.2 mm/r. For the TCS, the sawing temperature was decreased about 6~14% under different sawing speed and feed rate in contrast with that of the CS. The emulsified cutting fluids can penetrate into the tool-chip contact area through the micro textures that resulted in better lubrication and cooling, and thereby reduced the cutting temperature.

3.4 Machined surface roughness

Five different areas of the machined workpiece surface were selected to measure the surface roughness, and then the average roughness value was calculated. The size of each area was 1.3 × 0.95 μm. The machined surface roughness Ra of the workpiece is measured and presented in Fig. 10. An increase of feed rate and sawing speed leads to the increase of surface roughness Ra. The machined surface roughness Ra of the workpiece was range from about 1.7 to 8.2 μm under different sawing conditions. When the sawing speed was 50 m/min, the machined surface roughness Ra was increased from about 1.78 to 3.41 μm with the increase of feed rate by CS. For TCS, the machined surface roughness was decreased about 1~5% in comparison with CS. When the sawing speed was

![Fig. 11](image-url)  
*Fig. 11* The morphology of machined surface by CS at feed rate 1.2 mm/r: (a), (b) sawing speed 50 m/min; (c), (d) sawing speed 100 m/min
100 m/min, the machined surface roughness was increased from about 1.35 to 3.31 μm with the increase of feed rate and reduced about 5~12% compared with CS. When the sawing speed was 150 m/min, the worn of CS and TCS was serious and the machined surface roughness changed greatly from about 3.31 to 8.19 μm. For TCS, the machined surface roughness was reduced about 4~5% compared with CS.

3.5 Morphology of machined surface

The machined surface roughness and burrs were important factors that affected the quality of steel pipe machining. The three-dimensional morphology, section profile height, and the burr height on the sides of machined surface by CS and TCS at feed rate 1.2 mm/r and different sawing speed are measured in Figs. 11, 12, 13, and 14, respectively. For CS, some abrasive marks, burrs, and adhesions were formed on the machined surface at the sawing speed 50 m/min (Fig. 11(a) and (b)). The maximum height of the burr was about 175 μm. The height of the adhesions and depth of plows were about 12 μm and 5 μm (Fig. 12(a) and (b)), respectively. When the sawing speed was 100 m/min, the height of burrs on the inner side machined surface of the steel pipe was higher (Fig. 11(c)). Figure 11(d) shows the machined surface roughness was increased significantly, and a large number of adhesions and cracks were appeared. And the maximum height of the burr was about 225 μm. The height of the adhesions and depth of plows were about 28 μm and 7 μm (Fig. 12(c) and (d)), respectively.

For TCS, the height of the adhesions, depth of plows, and the number and height of burrs on the inner side machined surface of the steel pipe were reduced compared with CS. When the sawing speed was 50 m/min, some lamellar adhesions and plows appeared on the machined surface. The burrs mainly existed in the inner machined surface of the steel pipe and the maximum height was about 117 μm (Fig. 13(a) and (b)). The height of the adhesions was about 10 μm (Fig. 14(a) and (b)), reduced about 16% in comparison with CS. The depth of plows was about 5 μm. For the sawing speed 100 m/min, the maximum height (about 150 μm) of the burrs and the surface roughness were higher in contrast to the low sawing speed (50 m/min); in addition, some cracks and plows were exposed on the machined surface (Fig. 13(c) and (d)). The height of the adhesions and depth of plows were about 7 μm and 6 μm (Fig. 14(c) and (d)), respectively. Compared
with CS, the quality of the machined surface by TCS was significantly improved.

### 3.6 Cutter worn characteristics

The worn of the tool surface was mainly caused by the physical and chemical reaction between the chip material and the circular saw blade material. Figure 15 exhibits the worn surface morphologies, tool-chip contact length, and corresponding EDS maps of the CS after sawing 15 times 304 stainless steel pipes with cutting fluid lubrication at different sawing speed (50–150 m/min) and feed rate (0.4–1.2 mm/r). The morphology results suggested many lamellar chips and wear debris adhering to the worn surface of the CS. The worn of the sawtooth sawing edge was serious, and the corners on the both sides had been worn out, and showed an arc shape as shown in Fig. 15(a) and (b). And the tool-chip contact length was about 1070 μm. In addition, the chip was seriously piled up at the corners of the sawtooth, and deformed severely. Figure 15(c) illustrates the shape of the chip adhesive on the sawtooth; it can be revealed that the force, extrusion, and deformation of the workpiece material removal in the sawing process. The corresponding EDS maps of the sawtooth worn surface are shown in Fig. 15(d–g). It can be seen that the whole sawtooth worn surface was covered with Ni element because the workpiece material was adhesive to the surface during the sawing process. The material of circular saw blade and workpiece did not contain Na element; however, the emulsified cutting fluid contained Na element. Figure 15(f) illustrates Na element was also observed to the sawing zone and played a lubrication and cooling effect during the sawing progress. In addition, oxidation occurred on the sawtooth worn surface (Fig. 15(g)). As mentioned above, although the emulsified cutting fluid can play a lubrication and cooling role, the severe adhesion and oxidation wear occurred on the sawtooth worn surface.

The worn surface morphologies, tool-chip contact length, and corresponding EDS maps of the TCS after sawing 15 times 304 stainless steel pipes with cutting fluid lubrication...
at different sawing speed and feed rate are shown in Fig. 16. A small amount of worn and adhesion of TCS sawtooth surface are showed in Fig. 16(a) in comparison with CS. Compared with CS, the tool-chip contact length of TCS was reduced about 15%. Micro textures still existed on the sawtooth surface and some adhesions appeared on the side of the micro textures away from the edge (Fig. 16(b)). The results showed that the cutting fluid can penetrate into the sawtooth-chip friction contact zone through the micro textures, thus reducing the sawing temperature and adhesion of the worn surface. Figure 16(c) illustrates the worn and adhesion of the sawtooth corners on the both side were reduced compared to CS. The corresponding EDS maps of the TCS blade worn surface are observed and showed in Fig. 16(d–g). The results showed that the adhesion of the workpiece material also covered whole sawtooth surface, and the serious adhesion occurred on the corners of the sawtooth edge. The distribution of the Na element was observed in Fig. 16(f) and further demonstrated that the cutting fluid successfully penetrated into the sawtooth-chip frictional contact zone during the sawing process. Furthermore, Fig. 16(g) illustrated that the oxidative worn occurred in the contact area of the sawtooth surface.

4 Discussion

The friction and lubricating behavior of the tool-chip interface would affect tool life and machined surface quality. In this work, the micro textures were fabricated on the tool-chip contact interface, and the performance of micro textured circular saw blade (TCS) in sawing 304 stainless steel pipes under different sawing speed and feed rate with fluid lubrication. The friction force \( (F_f) \) can be calculated from the following equation [29]:

\[
F_f = a_w I_f \tau_c
\]  

(5)

where \( a_w \) was the cut width, \( I_f \) was the tool-chip contact length, and \( \tau_c \) was the average shear strength at the tool-chip interface. Equation (5) indicated that the tool-chip contact length and average shear strength at the tool-chip interface played a great role in the friction of tool-chip interface, under certain cutting conditions.

As shown in Figs. 6 and 7, the sawing force (main sawing force \( F_z \) and thrust force \( F_y \)) of TCS was reduced compared to CS. It can be attributed to two mainly aspects: on the one
hand, the tool-chip contact length $l_f$ of the TCS was decreased in comparison with CS, which was mainly due to the fabrication of micro textures on the sawtooth surface [22, 24, 30]. And the effective tool-chip contact length $l_t$ of TCS can be calculated as:

$$l_t = l_f - nd_t$$  \hspace{1cm} (6)

where $d_t$ was the width of the micro texture and $n$ was the texture quantity in the effective contact zone. It can be seen that tool-chip contact area covered two micro textures of TCS, and the effective tool-chip contact length can be calculated according to Eq. (6) was about 813 $\mu$m. Compared to CS, the effective tool-chip contact length $l_t$ of the TCS reduced about 24%. On the other hand, in the sawing process of circular saw blade (CS), due to the high pressure and temperature of the sawtooth-chip interface, only little cutting fluid penetrated into the friction and contact zone [22, 31]. However, the cutting fluid penetrated into the interface of sawtooth and chip through micro textures and formed a stable lubrication film. Thus, average shear strength at the sawtooth-chip interface $\tau_c$ of TCS was reduced in comparison with CS. As mentioned above, the sawing force of TCS was reduced on account of the combined effect of micro textures under the lubrication condition of cutting fluid.

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**Fig. 15** The worn surface morphologies and corresponding EDS maps of the CS: (a)-(c) SEM images of the worn surface; (d) Fe element; (e) Ni element; (d) Na element; (d) O element
Furthermore, the cutting fluid and sawtooth-chip interface can form a capillary structure [32]. Compared with smooth surface, the micro textured surface can better play the role of capillary action on the sawtooth-chip interface. The micro textures made the cutting fluid penetrated into the sawtooth-chip interface easier and reduced the effective contact zone, which effectively reduced the sawing force, sawing temperature, and machined surface roughness and decreased the sawtooth wear. The pressure in the micro textures was lower than the external pressure and the cutting fluid actively flowed into micro textures, which was mainly due to the chip flowed on the sawtooth surface with high speed [22]. Then, the cutting fluid flowed out from the micro texture, and formed a stable lubrication film on the sawtooth-chip interface as shown in Fig. 17. In consequence, the micro textured circular saw blade (TCS) exhibited a better cutting performance in comparison with traditional circular saw blade (CS). Figures 15 and 16 illustrate the wear and adhesion of TCS after sawing 304 stainless steel pipes 15 times were relatively reduced compared to CS. In addition, Figures 11, 12, 13, and 14 show the morphologies and section profile height of machined surface. It indicated the machined surface roughness, the burr and adhesion height, and the depth of the plows on the machined surface of TCS were reduced in comparison with CS, which was mainly due to the combined effect of micro textures and cutting fluid.

Fig. 16 The worn surface morphologies and corresponding EDS maps of the TCS: (a)–(c) SEM images of the worn surface; (d) Fe element; (e) Ni element; (f) Na element; (g) O element
The cutting performance of micro textured circular saw blade was improved effectively, owing to decreasing the tool-chip contact length, sawing force, and sawing temperature, reducing the wear and adhesion of the sawtooth surface, and improving the quality of the machined surface. However, the worn on the corners of the sawtooth edge was serious, and the sustainability of high-speed steel sawtooth needs to be improved. And the next study, the finite element method will be adopted to analyze the influence of micro textures distance and shape on tool contact stress, cutting force, and machined surface quality in details.

5 Conclusions

In this paper, linear micro textures that parallel to the sawtooth edge were fabricated on the surface of the high-speed steel W6Mo5Cr4V2 circular saw blade. Sawing 304 stainless steel pipes tests were carried out with the micro textured circular saw blade (TCS) under the lubrication condition. The following conclusions can be obtained:

(1) The largest sawing arc length and sawing force were occurred on the circular saw blade sawing outward from the inner wall. Then, the second largest sawing arc length and force appeared on the circular saw blade first contact with the inner wall. When the circular saw blade was sawing to middle position of the pipes, the sawing arc length and sawing force were smaller and more stable.

(2) In the sawing process, micro textured circular saw blade (TCS) showed better cutting performance in comparison with traditional circular saw blade (CS) in terms of (i) reduced cutting forces and cutting temperatures, (ii) improved the quality of machined surface and decreased the number of burrs, (iii) reduced the wear and adhesion of sawtooth surface.

(3) The coupling effect mechanisms were found; on the one hand, the effective sawtooth-chip contact length was reduced due to the micro textures fabricated on the sawtooth surface; on the other hand, cutting fluid can be better penetrated into the micro textures and formed stable lubrication film in sawtooth-chip contact interface.

Author contribution Yang Lu: formal analysis, methodology, data curation, writing original draft. Jianxin Deng: conceptualization, supervision. Qinghao Sun: supervision. Dongliang Ge: investigation. Jiaxing Wu and Zhihui Zhang: writing-review and editing.

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Data availability The authors declare that data and materials are authentic and available.

Declarations

Ethical approval The authors declare that this manuscript was not submitted to more than one journal for simultaneous consideration. Also, the submitted work is original and has not been published elsewhere in any form or language.

Consent to participate and publish The authors declare that they participated in this paper willingly and the authors declare to consent to the publication of this paper.

Conflict of interest The authors declare no competing interests.

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