Effect of hybrid texture on cutting performance of WC/Co-based coated tools 
turning aluminum alloy

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Abstract: When cutting aluminum alloy with WC/Co coated tools, severe adhesion and wear exist on the tool-chip contact interface, which are the major factors leading to failure of cutting tools. To address this problem and extend service life of cutting tools, this study introduced surface textures into coated tools, trying to integrate the anti-friction properties of micro-textures with the wear resistance properties of coatings to improve tribological characteristics of tools surface. Firstly, hybrid texture consisting of micro-scale pits and micro-scale grooves were fabricated on the rake surface close to the main cutting edge of carbide tools by picosecond laser. Subsequently, the textured tools were deposited with hard-coatings CrAlN via physical vapor deposition (PVD) technology and the hybrid textured CrAlN coated tool (MPG-T) was obtained eventually. Other texture combinations included micro-scale pits and micro-scale grooves distributed in the tool-chip contact zone. Wet cutting experiments were carried out on these prepared tools. Results showed that compared with micro-scale pitted coated tool (MP-T), micro-scale grooved (MG-T) and conventional coated tool (CCT), MPG-T tool performed better in cutting forces, friction coefficient, tool adhesion and wear on the rake face and the flank face, chip morphology. Moreover, the corresponding synergistic mechanisms of hybrid texture and coatings were proposed. It’s suggested that applying the results to actual industries can enhance the cutting performance of coated tools in machining of aluminum alloy.

Keywords Hybrid texture · CrAlN coatings · Cutting performance · Adhesive wear

1 Introduction

Aluminum alloy has been widely used in aerospace industries, automobile manufacturing owing to its advantages in good welding performance and excellent corrosion resistance. However, the drawbacks of low melting point and high ductility tend to bring out a limitation in tool machinability, which make chips more likely to adhere on the tool surface, lowering tool resistance and the quality of products[1,2]. Therefore, in order to alleviate the defects, a variety of approaches in enhancement of cutting tools in the recent years have been applied to reduce friction and wear between the tool and chip, such as cutting fluid[3], PVD coatings[4], surface texturing[5,6].

It is well known that hard coatings, as an effective way to improve surface morphology of cutting tools, plays a significant role in advancing the cutting performance and prolonging the durability of tool due to its high corrosion resistance, good chemical stability and high hardness. Thus, a variety of hard coated cutting tools have been extensively applied in modern industry and frequently used in the processing of difficult-to-cut material and high speed cutting[7]. In particular, PVD CrAlN coatings fabricated on cemented carbide materials has received substantial attentions over the years, which obtains a huge improvement in the durability of cutting tools due to better heat resistance, wear resistance and

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anti-adhesion[8]. Nevertheless, the hard coatings usually retain a high friction coefficient and residual stress at the mating surfaces after deposition. Thereby, the adhesion force between coatings and substrate is not sufficient to support for a long time, which causes coatings cracking and peeling rapidly, accelerating tool wear[9].

To solve the difficulties described above, surface pre-treatment of substrate tends to be carried out to improve tool surface microstructure and optimize tool performance. Laser surface texturing (LST)[10], lithography[11], sandblasting[12] and other surface engineering methods are chosen to increase the contact area between coatings and surface of cutting tools, reducing the mechanical stresses and heat adhesive wear. Among these techniques noted in the literatures, LST is a better option characterized by controllable morphology, local processing, strong flexibility and etc. Therefore, LST is more attractive and thus widely used in the preparation of cutting tools. In the metal materials removal process, cutting fluid is difficult to enter into the cutting zone with extreme normal pressure and temperature, and cannot provide effective lubrication and cooling effects. Micro-scale textures may be used as channels to transport and supply cutting fluid. Besides, textures also have some advantages in anti-adhesion and friction reduction determined by shorting tool-chip length, trapping wear debris and cutting fluids[13], and even forming hydrodynamic effect[14]. Many researches have shown that application of micro-textures on the tool surface is immensely beneficial. For example, Ahmed et al.[15] investigated the effect of varied texture shapes and orientations on the WC/Co tool surface by utilizing a femtosecond laser, and the results shown that when cutting AISI 304 stainless steel, square textured tools, compared with the conventional tool, obtained superior cutting performance: maximum reductions of 58%, 100%, and 24% in cutting force, feed force, and coefficient of friction, respectively. Enomot et al.[16] produced nano-/micro-grooves on the tool surface in different directions, it was found that anti-adhesion performance was improved, and the tool with micro-grooves parallel to the main edge performed better than others. Kümmel et al.[17] also reported that micro-dimples stabilized the formation of built-up edge (BUE) and that micro-channels increased the wear resistance significantly compared with the conventional tool when cutting AISI 1045. Rathod et al.[18] developed novel square and circular micro-textured cutting tools and observed a reduction in machining force, tool wear and chips morphology, and the possible physical mechanisms were that micro-textures could be oil reservoirs and helped in forming a surface oil film to provide continuous lubrication for machining. Sivaiah et al.[19] applied hybrid texture (the combination of circular pits and linear grooves alternately) to the tool surface under the cutting conditions of minimum quantity lubrication (MQL), favorable machinability was found in terms of cutting forces, cutting temperature, and tool wear of the hybrid textured tool, and excellent surface quality of workpiece materials machined was observed.

In addition, some scholars have also explored benefits of the combination of micro-textures and coatings on rake faces of cutting tools. Deng et al.[20] machined elliptical nano-scale textures on the rake face of tools by femtosecond laser, and then deposited WS$_2$ solid lubricant on the tool. This study found superior tool performance of textured tools in terms of cutting force, cutting temperature and friction coefficient compared with the conventional tools. And the cutting tests of TiAlN WC/ Co micro-grooved textured tools were carried out in the regime of full and starved lubrication. It was proved that the textured coated tool can contain wear debris, increase load carrying capacity and store oil under liquid lubrication condition, thus reducing friction and improving wear resistant [21]. Chouquet et al.[22] studied the friction and wear properties of textured diamond-like tools in the cutting fluid condition, and the results showed that the textures had a strengthening positive effect on the friction coefficient and wear rate of the tool.
From the above literatures, it is very found that the researchers mainly focused on texture or coatings fabricated on the tool rake face and presented a comparative analysis with conventional cutting tools. Only few studies attempted to explore the combination of the two techniques of hybrid texture and coatings applied on the cemented carbide tools. Moreover, the cutting performance of micro-textured coated tools with different morphological characteristics and the synergistic mechanisms between micro-textures and coatings have yet not been studied. Therefore, to achieve the above purposes and enhance the anti-adhesive properties of coated tools, a hybrid texture consisting of micro-scale pits and micro-scale grooves was fabricated by picosecond laser and then coated with PVD CrAlN coatings. Then, Wet cutting experiments on aluminum alloy were carried out. This work predominantly paid attention to investigating cutting performance which was evaluated from the aspects of cutting force, friction coefficient on the tool-chip interface, tool anti-adhesion and wear and chip morphology. To exhibit the differences, the experimental results obtained were made a contrast with single-textured coated tool and untextured coated tool.

2 Experimental details

2.1 Preparation of micro-textured coated tools

In this study, tungsten carbide/cobalt (WC/Co) cemented carbide made from Toshiba Tungaloy from Japan was selected as the tool material. The dimensions of cutting tools were 16x16x4.76mm³ with a nose radius of 0.4mm. Chemical composition, physical and mechanical properties of the tool are listed in Table 1. The rake faces of these cutting tools were finished by grinding and polishing to the roughness $Ra$ of less than 0.02μm, and then cleaned with alcohol in an ultrasonic cleaning machine for 18 min and dried in a pre-vacuum dryer for 15 min. After pre-treating, some of them were textured on the rake faces using Nd: YAG picosecond laser (MLPS-3w, Beijing Laize, Ltd., China) involving micro-scale pits, micro-scale grooves, hybrid texture consisting of micro-scale pits and micro-scale grooves with a depth of 20±3μm before CrAlN coatings deposition, which were parallel to the main cutting edge. Other geometric features are shown in Figure 1, and the processing parameters of these textured tools are as below: wavelength of 1064nm, pump current of 4.7A, frequency of 500kHz, and scanning speed of 1200mm/s.

After laser ablation, CrAlN coatings with a depth of 5±0.3μm was deposited on the rake faces of the textured and untextured cutting tools by magnetron sputtering. Prior to CrAlN deposition, these fabricated tools were cleaned to remove burrs in an ultrasonic cleaning machine for 18 min and dried in a pre-vacuum dryer for 15 min. The base pressure of the chamber was pumped to below 3x10⁻³Pa, then pure Cr targets and CrAl composite targets with nitrogen gas (N₂) were introduced into the chamber as reactive atmosphere to make the coatings. The main current was adjusted to 200A, the durations for heating were 60 min. The new solid substances were generated by experiencing the physical processes of ionization and recombination reaction with the supplied reaction gases, which were deposited on the surface of the tool to form a thin and dense hard film. Finally, the micro-scale pits coated tool (MP-T), the micro-scale grooved coated tool (MG-T), the hybrid texture consisting of micro-scale pitted and micro-scale grooved coated tool (MPG-T) were obtained. For comparison, a conventional CrAlN coated tool (CCT) without textures was used, Figure 2 shows the micrographs of the rake faces of these samples with CrAlN coatings after the surface textured treatment of the cemented carbide substrate. The measurements were implemented by an Ortho optical microscope (Leica DM750) and an ultra-depth-of-field electron microscope (VHX-2000C).
2.2 Cutting tests

Cutting experiments were carried out on the CS6140 lathe. The lathe and main components are shown in Figure 3. The equipped tool holder (MTJNR2525M16) parameters are as follows: rake angle $\gamma_e = 6^\circ$, clearance angle $\alpha_o = 6^\circ$, inclination angle $\lambda_s = 7.2^\circ$. The workpiece materials used were aluminum alloy in the form of a round bar with a length of 150mm and a diameter of 30mm. The mechanical properties and chemical composition of the workpiece materials are given in Table 2 and Table 3. All cutting experiments were carried out at the given conditions in Table 4. These cutting parameters sufficiently reveal the differences for the tools cutting performance. And an emulsion-type cutting fluid was adopted (Bikam Technology Co., Ltd.) at a flow rate of 5L/min, each experiment was tested 3 min to ensure the reliability of the experimental data. The root-mean-square value of the cutting forces was measured by using piezoelectric quartz dynamometer (Kistler9293A, Switzerland) in the experiments. After turning, the worn surfaces on the rake faces and the flank faces were observed by scanning electron microscope (SEM) and Ortho optical microscope, and the chemical composition and proportion in the wear track of the tool surfaces was identified by energy dispersive x-ray spectroscopy (EDS).

3. Results and discussion

3.1 Cutting force and coefficient of friction

Figure 4 displays main cutting force $F_z$ and radial force $F_y$ of the four textured coated tools (CCT, MP-T, MG-T, MPG-T) as a function of varying cutting speeds in cutting fluid environment, respectively. The root-mean-square values of cutting forces were obtained using the dynamometer. Each point on the curve represents the average value in the stable cutting process of three times repeated experiments. As can be seen, Figure 4 illustrates that cutting forces of textured tools remained lower for MP-T, MG-T and MPG-T tool compared with CCT tool, and the smallest cutting force was obtained by the MPG-T tool. It was evident that cutting forces followed a decrease trend with increasing cutting speed under the same cutting conditions, which seems that micro-scale textures and cutting speed had a great influence on cutting force. During the continuous machining, increasing cutting speed led to an increase in cutting heat, causing the softening of the workpiece materials. The flow stress of workpiece machined decreased due to the increasing temperature of secondary shear zone that helps in the reduction of the cutting force as rising cutting speed [23]. In case of the speed of 120m/min, the radial forces of MP-T, MG-T, and MPG-T tools were reduced by 11.82%, 9.09%, and 25.15%, respectively, compared with that of CCT tool. Main cutting forces had a similar trend, with a decrease of 2.99%, 1.3%, and 9.25% respectively. Furthermore, cutting forces of MPG-T tool got the minimum value, followed by MP-T, MG-T, and CCT tools, which indicates that the morphology of micro-texture played a significant role in cutting performance of tools.

Figure 13 (a) shows schematic diagram of cutting forces between the rake face and the shear face during turning. Thus, the relationship between the tool geometric angle and the two cutting components can be found [24]:

$$F_y/F_z = (\beta - \gamma_e)$$

(1)

According to Eq. (1), Eq. (2) can be easily deduced. Thus, the average coefficient of friction at the
tool-chip contact surface can be computed based on the following formula:

$$\mu = \tan(\beta) = \tan(\gamma_o + \arctan(F_y/F_z))$$

(2)

where $\gamma_o$ is the rake angle, $\beta$ is the friction angle, $F_y$ is the radial thrust force, $F_z$ is the main cutting force.

Figure 5 shows the average friction coefficient between the tool-chip contact surface at varied cutting speeds in wet turning of aluminum alloy. It can be seen that at a speed of 120m/min, the friction coefficients of the MP-T, MG-T, and MPG-T tools were reduced, compared with that of CCT tool. And the maximum reduction (21.60%) of friction coefficient was observed by MPG-T tool compared with CCT tool, followed by MP-T and MG-T tools with 11.18% and 9.46%, respectively. It can be noted that the average friction coefficients of the cutting tools decreased with the increasing speed, indicating that the hybrid texture and hard-coatings CrAlN had a great positive effect on the friction properties of cutting tools, particularly at the high speed. Therefore, the coated tools with respect to cutting performance can be greatly improved by the micro-scale textures. Furthermore, the hybrid texture had a better function compared with CCT and the single-textured tools. In the machining process, the friction coefficient was deeply affected by morphology on the tool rake surface and the lubrication state of the contact surface[25]. The micro-textures perpendicular to the chip flow direction can promote cutting fluid penetrating into the tool-chip contact zone and also reduce the actual tool-chip contact area.

3.2 Tool wear

Tool wear is an important factor to check the cutting performance of tools, thus we observed the worn faces of cutting tools after 3 min wet cutting at the speed of 120m/min. The maximum wear ($V_{B_{max}}$) was measured utilizing the software Image J over four textured coated cutting tools at the given conditions shown in Figure 6. As compared with CCT tool, tool life of MPG-T, MP-T, MG-T were equivalent to an increase of 230%, 134%, and 108%, respectively. It can be seen that $V_{B_{max}}$ on the flank surface of MPG-T tool maintained the smallest, followed by MP-T, MG-T, and CCT tools. Thus, it was believed that MPG-T tool showed higher flank wear resistance supported by the hybrid texture and CrAlN coatings among all types of cutting tools. MP-T and MG-T tool also reduced the flank wear and thus extended the service life over CCT tool. The hybrid texture existing on the rake face limited tool-chip contact length and thus increased the heat dissipation[26]. Moreover, the micro-scale grooves in the hybrid tool assisted in reaching of cutting fluid to the tool-chip contact zone and micro-scale pits act as oil storage[27], which formed lubrication film at the contact zone as well as reduced friction to ease the flank wear of tool surface.

For better understanding the adhesion and wear mechanisms of four kinds of tools, wear morphology on the rake face is analyzed. Figure 7 shows the SEM micrographs and the corresponding EDS analyses on the worn surface of the CCT tool after 3 min wet cutting at the speed of 120m/min. As expected, severe adhesion, wear and the breakage of cutting edge happened on the rake face in Figure 7 (a-c) can be clearly seen, which were the factors influencing the higher cutting force for CCT tool observed in section 3.1. From Figure 7 (d), the composition Cr of CrAlN coatings on the tool surface below the yellow dividing line was sporadic distribution. And matrix element W of the cutting tool in Figure 7 (e) was found, proving the exposure of substrate surface. Meanwhile, it revealed that the shedding coatings near the rake face emerged and CCT tool began to directly contact the chip and the workpiece, accelerating heavy adhesive wear. Besides, the EDS analysis of point A (Figure 7 (e))
detected a large amount of composition Mg of workpiece materials, which indicated heavy adhesion on the worn area due to low thermal conductivity and high affinity of aluminum alloy. Besides, softened chips were heaped on the corner radius, leading to the formation of built-up edge (BUE). Meanwhile, in Figure 7(e), we can also see that there was very little Na element on the tool-chip contact area after cutting, thus CCT tool almost had no lubrication fluid to alleviate serious friction under the full emulsion-type cutting fluid.

Figure 8 and 9 show the SEM micrographs and the corresponding EDS analyses on the worn surfaces of the MP-T and MG-T tool after 3 min wet cutting at the speed of 120m/min, respectively. As shown in Figure 8(a, b), MP-T tool adhesion and wear on the rake face was significantly reduced when compared with CCT tool. The micro-scale pits near the main cutting edge were filled with microparticles formed as wear debris, which showed that the micro-scale pits provided a possible space for wear debris entrapment in the machining process (Figure 8(c, f)). Thus, micro-scale pits helped in reducing the friction forces on the tool-chip interface. It was shown that adhesion and adhesive wear on the surface of the MP-T tool seen in Figure 8(d) were decreased and they mostly occurred near the main cutting edge of MP-T tool. The relatively weak adhesive strength of coatings and substrate near the main cutting edge was the possible reason. The distribution of element Cr of the CrAlN coatings layer observed in Figure 8(d), which revealed the unobvious phenomenon of coatings delaminating. The micro-scale grooves parallel to the main cutting edge can transport and reserve cutting fluid between the contact surfaces, which reduced the cutting temperature and the coefficient of friction between the two relatively sliding surfaces (Figure 5), and with the cutting speed increasing, the coefficient of friction decreases. As shown in the points A, B (f, g) in Figure 9(b, c), the EDS spectra confirmed that the micro-scale grooves near the cutting edge also were filled by debris, which exhibited that the micro-scale grooves could be considered as the storage of chip in the machining process and thus fewer chip adhered on tool surface. It can be seen that compared with MP-T, more adhesion and wear zone were seen distributing near the cutting edge (Figure 9(a), (d), (e) and (h)), which suggested that higher adhesion cutting stress and cutting heat were generated in the sticking region. In general, the single-textured tools, MP-T and MG-T tools outperformed CCT tool in anti-adhesion and friction reduction.

Figure 10 shows the SEM micrographs and the corresponding EDS analyses on the worn surfaces of the MPG-T tool after 3 min wet cutting at the speed of 120m/min. In Figure 10(a) and the enlarged micrograph (b), similar wear pattern and milder adhesion of MPG-T tool can be seen clearly compared with MP-T and MG-T tools, and the worn length and wear area of MPG-T tool were also reduced, which indicated that hybrid texture was responsible for the better lubrication performance of tool-chip interface. The EDS scan of MPG-T tool on the rake face indicated higher Cr element percentage after wet cutting in Figure 10(e), and this suggests less CrAlN coatings delamination and better adhesive strengthening of coatings-substrate interface. Thus, it was believed that hybrid texture indeed helped in strengthening wear resistance of the tool. Figure 10(g) and (h) presented the element analysis of Al and Mg on the rake face, which illustrates the presence of magnesium microparticles in the hybrid texture that was also visible from Figure 10(c) and (d). Na element was observed in Figure 10(g), which showed that textures help in carrying and spreading the cutting fluid, contributing to the reduction of friction and wear of tool.

Figure 11 shows the images on the worn rake faces after wet cutting of CCT tool (Figure 11(a)), MP-T tool (Figure 11(b)), MG-T tool (Figure 11(c)) and MPG-T tool (Figure 11(d)) at different speeds. It can be seen from Figure 11 that with the cutting speeds of the four kinds of coated tools increasing, the adhesion and wear phenomena became more serious. During the machining process, a large amount of the energy was converted into heat due to the mechanical movement to remove workpiece materials,
which increased temperature in the machining region. The softened chip was bonded on the rake face of the tools. Repetitive adhesion and peeling of chip led to tear of the coatings and even the substrate materials. As shown in Figure 11, there is a small amount of lamellar adhesive layer on the rake surface of the four tools at the lower cutting speed of 60m/min. Among all type of cutting tools, it was found that the CCT tool with a flat contact surface suffered severest adhesion. As the continuous speed increased, cutting heat generated between the tool and the chip/workpiece resulted in an increase of the softening chips that welded on to the surface of the tools. When the shear strength was higher than the adhesive strength, it can be seen that the micro-particles on the tool surface were removed, and this led to the adhesive wear\[28], forming some irregular circular pits, especially in Figure 11 (b). At the cutting speed of 120m/min, surface adhesion and wear of MPG-T tool are shown in Figure 11 (d). The area of adhesion and wear was smaller and far away from the main cutting edge of the tool, for which more heat dissipation area and chip storage function of hybrid texture may be the main reasons.

3.3 Chip morphology

Chip morphology is of vital importance because the formation of chips in metal processing provides researchers with information about cutting mechanics. For example, tribological status between tool-chip contact surface can be detected by the shape and size of chip\[29].

The chips obtained by four kinds of tools during the process of stable cutting at the speed of 120m/min are shown in Figure 12. The average curl diameters of the four tools (CCT, MG-T, MP-T and MPG-T tools) were 3.465mm, 2.810mm, 2.645mm, 1.999mm, respectively. Shorter contact length on the tool-chip interface contributed to the less curled radius chips\[15]. Compared with CCT tool, the chip diameter and pitch of MG-T, MP-T and MPG-T tool were smaller and easy to break, especially MPG-T tool, which was beneficial to thermal transmission. Harsh friction of tool-chip interface caused curled chips with larger diameter. Therefore, textures had a huge improvement in stable plastic deformation of workpiece materials. For MPG-T tool, under the conditions of liquid lubrication cutting, the hybrid texture provided a good lubrication and fluid control sliding zone for chips with a smaller bending radius\[30]. It has been proved beyond doubt that the introducing of hybrid texture promoted the bending and breaking of chips.

As shown in Figure 13(b), the resultant force $F_r$ of the friction force $F_f$ and the pressure $F_n$ on the rake surface were opposite in direction and not on the same straight line, which resulted in forming of the bending force and thus facilitated spiral chips. Meanwhile, textures helped in reduction of the actual contact area between the chips and the tool surface during the process of chips sliding across the rake face, leading to the reduction in friction force $F_f$ in direct contact with the surface of the cemented carbide tool. And the bending moment formed by friction is opposite to the direction of chip curling, so the curl diameter of the chip was reduced, lowering the cutting temperature to inhibit the adhesion of the workpiece on the tools surface during the metal removal process\[25].

3.4 Mechanisms for the effect of hybrid texture on coated tools

Based on the experimental results described, it can be found that the wet cutting performance of CrAlN coated tools are greatly improved by textures, especially for MPG-T tool consisting of micro-scale pits and micro-scale grooves alternately arranged. Due to the concave morphology of textures was retained after the deposition of coatings, the tools are equipped with the functions of friction reduction
and wear resistance of the hard coatings, as shown in Figure 14 (a, b). The linear micro-scale grooves of hybrid texture largely assist in guiding the cutting fluid to the high-pressure contact zone because of capillary effect and quickly diffuses to the surrounding micro-scale pits. And micro-scale pits are considered as storage pools for lubricating oil [30], which supports in controlling the temperature and this combined cooling effect results in significant reduction in adhesion and wear of the tool [19]. Combined with the results analyses of section 3.2, it seems that the rake face of MPG-T tool formed a thin oil film (Figure 14 (b)) and obtained hydrodynamic lift force, relieving decreased cutting forces with a rising cutting speed to some extent [31]. Thereby, the pressure-bearing capacity of the tool is increased [32]. Furthermore, the actual contact area between chips and tool surface is reduced with the existence of textures, reducing friction force between the sliding surfaces compared with CCT tool. Therefore, the hybrid textured coated tool showed better anti-adhesion performance than that of other coated tools. In addition, such a hybrid texture also facilitated reducing the contact length between the tool and chip and increased the function of debris storage of texture, thus reducing damage to the tool surface [33].

On the other hand, the introducing of laser textures pre-treatment changes the microstructure on the tool surface, which promotes the adhesive strength of CrAlN hard coatings on the WC/Co cemented tool [34]. As previously mentioned in section 3.2, compared with the textured tool, coatings on the surface face of CCT tool were easier to delaminate. Thus, continuous cutting caused the exposure of the substrate of cutting tool and negatively influenced the service life. However, other textured coated cutting tools reduced the adhesive wear of the tool, which is similar to the results of Zhang et al. [35]. According to the literatures [36,37], the coatings-substrate adhesive strength of the textured coated tools was stronger. One explanation for this is the mechanical anchoring effect of the coatings to the substrate. The laser ablation technology removed the tool materials, increasing the actual contact area between the coatings and the tool surface. Moreover, the processing of PVD coatings had a thermoelastic effect and the growth of defects generated by high kinetic energy particles with high residual stress. Hybrid texture can disperse residual stress and thus strengthen adhesive strength between coatings and substrate [38]. Furthermore, Hybrid textured surface act as a barrier against slipping of CrAlN coatings layer, hindering the progression of adhesive wear to some extent.

4 Conclusion

In this study, hybrid texture combining micro-scale pits and micro-scale grooves utilizing LST was fabricated on the rake surface of cemented carbide tool, and then CrAlN coatings was deposited to study the synergistic effect of texture and coatings. Wet cutting experiment of aluminum alloy was conducted to evaluate the effectiveness of cutting performance of MPG-T tool, the following conclusions are obtained:

- For MPG-T tool, compared with CCT tool, the radial force $F_y$ and the main cutting force $F_z$ significantly were reduced by 25.15% and 9.25%, respectively, and the average coefficient of friction was decreased by 21.60% at the speed of 120m/min. One explanation might be that tool-chip contact area was reduced and chip debris was entrapped inside the textures.
- Textured coated tools improved the tribological properties on the surfaces in the cutting process, and MPG-T tool exhibited better anti-adhesion performance with the cutting speed increasing. It is possible that the relatively sliding surfaces formed a lubrication film and accelerated heat dissipation. By the comparison of the maximum wear (VB_max) on the flank face of four coated tools, MPG-T tool was prolonged its lifetime because of the wear resistance of coatings and the friction
reduction of hybrid texture.

- The chip morphology confirmed that shorter and smaller radius chips formed when cutting with textured coated tools. Furthermore, MPG-T tool obtained the more favorable chips.
- The adhesive strength of coatings and substrate was increased due to mechanical locking effect with the help of hybrid texture. Meanwhile, textures also alleviated the residual stress emerged during the deposition of PVD coatings, which extended the service life of coated tools.

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Conflicts / Competing Interests

We declare that we do not have any commercial or associative interest that represents a conflict of interest in connection with the work submitted.

Availability of data and material

The datasets used or analyzed during the current study are available from the corresponding author on reasonable request.

Code availability

Not applicable.

Authors’ contributions

Conceptualization: Yonghong Fu; Methodology: Yun Zhou; Formal analysis and investigation: Yun Zhou, Zetan Yang; Writing - original draft preparation: Yun Zhou; Writing - review and editing: Yonghong Fu, Jie Yang, Zetan Yang; Funding acquisition: Yonghong Fu; Resources: Yonghong Fu; Supervision: Yonghong Fu.
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