Research on Burr Formation of Aluminum Alloy Frame of Mobile phone by Milling

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Abstract. The characteristics and mechanism of burr formation in the milling of aluminum alloy mobile phone frame and the influence of cutting conditions on burr formation were studied. The 3D model of milling is established by DEFORM, and the mechanism of burr formation is analyzed. A three-edge end mill with a diameter of 6 mm was used to mill the aluminum alloy 6061 mobile phone frame, and the influence of cutting conditions on burr formation was analyzed. The results show that the burr size decreases with the increase of cutting speed, the decrease of feed speed and the decrease of cutting width. The burr formation is more stable and smaller in the down milling than in the up milling.

1. Introduction

Burr is a common phenomenon in cutting, which has a huge negative impact on production and processing [1]. In order to minimize the burr, scholars have studied the mechanism and control of burr formation. Gillespie and Bolter [2] classified metal cutting burr into Poisson burr, rollover burr, tear burr and cut-off burr according to the formation mechanism. Nakayama [3] has carried out cutting experiments on brass. The burr was divided into eight basic forms, and the influence of cutting conditions on the formation of burr was analyzed. Based on finite element software, Park and Dornfeld [4,5] studied the influence of the exit angle of the workpiece, the front angle of the cutter and the auxiliary materials on the burr formation process in 304L stainless steel. Deng et al. [6] established the finite element model in the process of orthogonal cutting, analyzed the burr quantitatively and studied the burr forming process.

The age of 5G has arrived. The screen area of the mobile phone is increasing, and it is developing towards thinner, lighter, more fashionable and luxurious. The selection and processing of mobile phone frame materials become extremely important. Aluminum alloys with good properties are widely used as metal frames of mobile phones. Now scholars are more inclined to study the burr formation in micro and slot milling, rather than the burr formation in vertical milling of the frame. Therefore, it is of great significance to study and analyze the burr formation of milling Al6061 mobile phone frame.

2. Formation mechanism of milling burr

Hashimura [7] found that the formation mechanism of metal cutting burr is not only affected by the cutting conditions, but also by the mechanical properties of the workpiece. The burr forming process is divided into eight stages. Due to a large amount of elastic-plastic deformation and complex process involved in the burr forming process, it is generally difficult to derive the closed analytical solution of the burr forming process. Therefore, the finite element simulation analysis is a reasonable method to study the forming mechanism of milling burr.
In order to make the simulation more realistic, a 1:1 geometric model was established according to the actual tool geometry. When the workpiece model was established, the thickness was constant and the length and width were reduced accordingly, which not only did not affect the simulation results but also saved the simulation time. The 3D model of the milling process was established by DEFORM. **Figure 1** is a screenshot of the milling process. The simulation can clearly observe each step of processing and analyze the process of the burr formation mechanism. In the milling process, the movement of the tool exiting the workpiece is the main factor of forming burrs. With the progress of cutting, the workpiece is extruded by the tool, then the surface is raised, and the chip will spiral up with the tool rotation. When the tool reaches the working end, the support strength of the material end is not enough, and the chip rotates around a certain point without breaking and remaining on the work, forming a burr.

**Figure 1.** Screenshot of the milling process

3. **Experimental method**
The workpiece material was the Al6061 sheet with a size of 180 mm × 90 mm × 4 mm. The cutting tool was made of tungsten steel. It was a three-edge end mill for aluminum. The length of the cutting tool was 50 mm, and the length of the cutting edge was 18 mm, and the diameter was 6 mm, and the helix angle was 45°, and the rake angle was 15°. The model DMN-540l CNC machining center was used for milling frame. The measurement of burr size and observation of burr shape was carried out with the 3-D digital microscope (VHX-2000; KEYENCE, Japan). Because the shape and size of the burr in different positions of each milling edge were different, 2D and 3D functions were used to measure the height of the burr in the same position respectively, and the maximum value of the two was selected as the measurement result of the burr height of the edge.

4. **Analysis of experimental results**

4.1 **Influence of cutting speed on burr formation**
To study the influence of cutting speed on the formation of burr, four groups of milling experiments were carried out at different cutting speeds of 2000 r/min, 4000 r/min, 6000 r/min and 8000 r/min. The cutting width was 3 mm, the feed speed was 1 m/min and the milling way was down milling. **Figure 2** shows the curve of burr size changing with cutting speed. It can be seen from the figure that the maximum burr height is 495.8 μm, which appears at the speed of 2000 r/min. The results show that the burr height decreases with the increase of rotating rate, and the burr size changes little when the rotating rate reaches a certain value. At the same time, the feed speed of each tooth decreases with the increase of rotating rate, and the actual cutting depth of the cutting edge also decreases accordingly, forming chips with larger deformation but smaller size, which are easier to separate from the workpiece. When the rotating rate is low, the deformation of the workpiece is small, the chips are
difficult to separate from the workpiece, resulting in higher burrs. In general, larger speed is more conducive to reduce burr.

Figure 2. The curve of burr size changing with cutting speed

4.2 Influence of feed speed on burr formation
Keeping the cutting width of 3 mm and the cutting speed of 8000 r/min unchanged, milling experiments were carried out with different feed speeds of 0.5 m/min, 1 m/min, 1.5 m/min and 2 m/min, and the influence of feed speed on the formation of burr was studied.

It can be seen from Figure 3 that the burr size changes with the feed speed. The maximum burr height is 207.9 μm, which appears in 1 m/min milling. With the increase of feed speed, the burr size increases, but with the increase of feed speed, the burr size changes little. This is because, in the milling process, the material of the cutting layer flows forward under the extrusion effect of the front face of the milling cutter, and the material accumulation phenomenon appears on the front face. With the increase of the feed speed, the cutting thickness increases continuously, forming thicker chips, and the material accumulation is more serious, at this time, larger burrs will be generated. When the feed speed continues to increase, the accumulation of chip materials does not increase indefinitely but changes little after reaching a certain level, and the burr size formed by residue does not change much.

Figure 3. The curve of burr size changing with feed speed

4.3 Influence of cutting width on burr formation
Four groups of different cutting width (1 mm, 2 mm, 3 mm, 4 mm) with the cutting speed of 8000 r/min and feed speed of 1 m/min were used for milling experiments to study the influence of cutting width on burr formation.
Figure 4 is the curve of change of burr size with cutting width. It can be seen from the figure that with the increase of cutting width, the increase of burr size is more obvious. The maximum burr size is 287 μm, which appears in the milling with the maximum cutting width of 4mm. When the cutting width is 1mm, the burr size is the smallest. With the increase of cutting width, the volume of the metal chips increases obviously, and the plastic deformation increases accordingly. The chip material flows forward under the extrusion of the front face of the milling cutter, and the larger size burr is formed by the accumulation of residual. At the same time, the cutting force increases with the increase of cutting width. The larger cutting force increases the deformation degree of the workpiece and forms wider and thicker chips. If the chips are not broken in time, the larger burrs will remain. The cutting width is an important factor that affects the burr formation in aluminum alloy frame milling. By reducing the cutting width, the burr formation can be better controlled.

4.4 Influence of cutting mode on burr formation
The cutting width of 3 mm and the feed speed of 1 m/min were unchanged. At different speeds of 2000 r/min, 4000 r/min, 6000 r/min and 8000 r/min, milling experiments in the way of down milling and up milling were conducted, and the influence of cutting mode on the formation of burr was studied.

Figure 5 shows the change curve of burr size with the down milling and up milling methods. Under the same cutting parameters, the burr size in up milling is relatively large. In up milling, the chips are cut from thin to thick by the cutter teeth. In the beginning, the cutter teeth can not cut into the workpiece, but one side extrudes the workpiece surface and slips, resulting in a serious cold hard layer on the surface, increasing the subsequent cutting force and chip deformation. The thicker chips are easy to remain and become larger size burrs at the latest. In the down milling, the cutting chips are cut from thick to thin, which avoids the extrusion and sliding phenomenon of the cutter, and there is no hard layer on the surface of the aluminum alloy material. The thicker cutting chips move upward with the cutter spiral after a long time of cutting extrusion deformation, which makes them easier to break, leaving only small size burrs. The burr forming size is relatively stable by using the down milling method.
5. Conclusion
Combined with the simulation and experimental results, the formation characteristics of the milling of the aluminum alloy 6061 mobile phone frame were analyzed. The results show that the burr size decreases with the increase of cutting speed, the decrease of feed speed and the decrease of cutting width. The size of the burr formed by the down milling is relatively stable. In order to reduce the burr size and ensure the machining efficiency as much as possible, the down milling method with higher cutting speed, appropriate feed speed, and smaller cutting width should be adopted.

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