Research on Ultrasonic Vibration Rolling of Aluminum Alloy

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Abstract: Ultrasonic vibration rolling is the process of collision, extrusion and friction between the rolling head and the workpiece surface, which causes the plastic deformation and plastic flow of the workpiece surface material, which makes the convex peak of the material surface be filled with flattened valleys. Therefore, the surface quality of the workpiece can be improved by a new processing method that is relatively conventional. In order to study the effects of different cutting methods on the surface quality and surface microhardness of aluminum alloys, ultrasonic vibration assisted rolling aluminum alloy technology was introduced in this paper, and three groups of control experiments were designed, namely: aluminum alloy ordinary cutting experiments, aluminum alloys ordinary rolling test and aluminum alloy ultrasonic vibration assisted rolling test. The influence of cutting three factors on the surface roughness Ra and surface microhardness of aluminum alloy was studied. The experimental results show that the surface quality and surface microhardness of ordinary rolled aluminum alloy are better than that of ordinary cutting. Ultrasonic vibration assisted rolling significantly improves the surface quality and microhardness of aluminum alloy compared with ordinary cutting. Three cutting factors affecting the surface roughness of ultrasonic vibration assisted rolling Aluminium alloys. Importance: The amount of cutting depth is greater than the cutting speed, which is greater than the feed rate; the effect of three cutting factors on the microhardness of the aluminum alloy surface. The amount of cutting depth greater than the feed speed is greater than the cutting speed.

1 INTRODUCTION

Today, the national defense, aeronautics, and astronautics industries have developed rapidly, and the materials that have been applied to military defense and aerospace have also been further developed. A large number of conventional materials such as aluminum alloys are gradually being replaced by aerospace materials (such as titanium alloys) and new composite materials with superior overall performance. However, aluminum alloys are the most widely used type of nonferrous metal structural materials in the industry, and it is still necessary to further study them, especially the processing properties of aluminum alloys. As customers place higher demands on the quality of parts and components, the quality control of aluminum alloy products becomes very important.

Rolling is a surface hardening process. After rolling, the physical state of the workpiece changes, but the chemical composition of the surface material does not change. Rolling processing took place decades ago. In 1929, Germany had already had the idea of rolling processing[1]. Since then, U.S. researchers have applied roll-rolling ingenuity to the manufacture of railways. The exploration of this technology is in the wake of the Soviet Union following the Americans. Roller strengthening technology is also used in railways[2]. Until the 1950s, China invented the screw rolling technology, so that rolling technology has been widely explored in China[3]. Due to the wide application prospect of rolling technology, a large amount of manpower and material resources have been invested, making the rolling hardening technology develop rapidly. In the rolling process research, foreign researcher Ryhzov. E. V. found through experiments that the surface roughness of steel workpieces can be reduced from

Rz3.2-6.4pm to RzO.4-0.2pm through the vibration rolling process. Roughness is hardly affected by wear scars[3]. Former Soviet Union Markovikov and India's Pande et al. first introduced ultrasonic vibration assisted processing technology into surface hardening techniques such as surface rolling [4]. The University of Nottingham, UK, performed ultrasonic cold deep-rolling on TC4 titanium alloy workpieces. The results showed that the surface roughness was greatly reduced, the surface hardness increased by 25.8%, and the surface formed a residual compressive stress of 800-1200 MPa[5]. Nowadays, traditional rolling processing technology cannot fully meet the development of today's science and technology, and it needs to be combined with other processing technologies on this basis. In recent years, ultrasonic rolling technology has been widely used in aerospace and other fields.

Ultrasound-assisted rolling has the following advantages over traditional rolling processing:

(1) Little friction and little elastic pressure;

(2) The surface finish will be better if the conditions of accuracy can be;

(3) The surface hardness is greatly increased, thereby improving the surface wear resistance;

(4) Corrosion resistance and fatigue strength are improved;

(5) The ultrasonic-assisted rolling trajectory is easy to control, so that it can reduce the vibration during processing.

In order to study how to reduce the surface roughness value and improve the surface quality in the process of aluminum alloy machining, the ordinary cutting experiment, the ordinary rolling experiment and the ultrasonic vibration assisted rolling experiment were designed respectively, and the excellence of the three processing methods was compared. The effect of three factors of cutting on the surface quality and surface microhardness of aluminum alloy during the process of ultrasonic vibration assisted rolling aluminum alloy bar material was studied.

2 ULTRASONIC VIBRATION ROLLING PRINCIPLE

Ultrasonic vibration rolling processing device

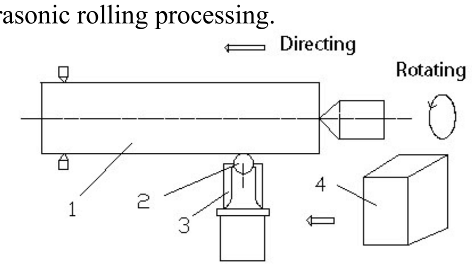
(1) Ultrasonic generator: It converts industrial alternating current into ultrasonic frequency voltage signal [6].

(2) Transducer: Converts high-frequency voltage signals into high-frequency mechanical vibrations.

(3) Rolling heads: cylindrical rollers and spherical balls are used.

(4) Horn: Amplify the amplitude of the transducer. Classification: Ladder, Cone, Cylindrical, Index, and Catenary.

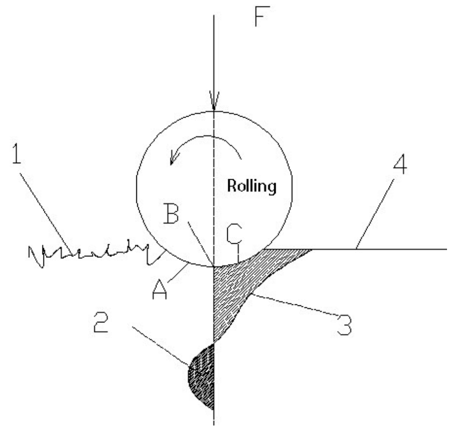
Working principle: The ultrasonic generator outputs ultrasonic frequency energy, the transducer converts the ultrasonic frequency electric energy into high-frequency mechanical vibration, and the horn enlarges and transmits the amplitude to the rolling head, so that the parts are subjected to ultrasonic rolling processing.



1- Aluminium alloy bar stock 2- Rolling head 3- Horn 4- Ultrasonic generator.

Fig. 1 Ultrasonic Vibration Rolling Device.

In many materials, most of the surfaces that have been processed are uneven, and there are many irregular peaks and troughs of different heights and widths. The essence of rolling is to use a rolling tool made of hard material of a certain shape, and then apply a certain pressure on the surface to be machined (ultrasonic rolling is provided by the transducer to provide high-frequency mechanical vibration), and then it is driven by the machine tool freely rolling, changing the material distribution of the workpiece surface, as shown in Fig.2, in the grinding zone A area, the roller and the cutting surface contact and gradually compacted, in the plastic deformation zone B area, the pressure is greater than the yield point of the material, local plastic deformation, after the maximum load under the roller, elastic recovery in the smooth area of the C area, the roller and the surface slowly separated. Rolling machining is such an action that is carried out repeatedly and the workpiece surface is processed into a smooth surface. The distribution of the stress tensor causes the bottom of the trough to rise, the crest of the unevenness to fall, the crests and troughs to be ironed and filled, and the surface tends to be smooth. Analysis of notch impact test results shows that the rolling allowance increases gradually and the toughness increases, and it gradually decreases after reaching the maximum value. This is the most important feature of ultrasonic rolling process, through the toughness of the area, eliminating the roughness of the surface [7].



1 - Surface to be rolled 2 - Residual tensile stress 3 - Residual compressive stress 4 - Rolled surface.

Fig.2 Rolling principle.

3 EXPERIMENTAL SETUP AND METHODS

(1) Experimental equipment

One CKA6150 lathe, one W1974 signal generator and one HSA4052 power amplifier, ultrasonic vibratory rolling vibrator (lateral amplitude: 2.1um; longitudinal amplitude: 11um), rolling tool heads, fixtures, etc.

(2) Measuring equipment

MarM300C Surface Roughness Tester, DureScan50 Vickers Microhardness Tester

(3) Workpieces

Specifications are Φ30×200mm# 6063 aluminum alloy rods.

(4) Pre-cutting experiment

Tool: Mitsubishi Carbide Insert (Model TPGX080204)

Select a set of machine cutting parameters（cutting speed：150r/min, cutting depth: 0.05mm, feed speed: 0.04mm/r）to pre-process the aluminum alloy bar, and measure the surface roughness and surface micro-hardness several times to average. The pre-roughness Ra is 1.173 and the micro-hardness Hv is 68.9.

3.1 Comparative Experiment

This In order to study the effects of different processing methods on the surface quality and surface microhardness of aluminum alloys, three groups of control experiments were designed: aluminum alloy ordinary cutting experiments, aluminum alloy ordinary rolling experiments and ultrasonic vibration assisted rolling aluminum alloys experiment. In order to save materials, the aluminum alloy bar processed in the experiment was subjected to a section test, that is, multiple groups (4 groups) of tests were performed on the same bar, and the length of each section was 30 mm. When measuring surface roughness and surface microhardness, three sets of data need to be measured and averaged, i.e., one set of data is measured every 120°.

Table 1: Difference test methods on aluminum alloys.

Parameters	Cutting speed (r/min)	Cutting depth (mm)	Feed speed (mm/r)
1 2 3	150	0.05	0.04/0.08/0.12/0.16

In the table1:

1- Ordinary cutting experiment
2- Ordinary rolling test
3- Ultrasonic Vibration Aided Rolling Test.

3.2 Single Factor Experiment

Effect of cutting speed/cutting depth/feed speed on surface roughness Ra and surface microhardness of aluminum alloy with Ultrasonic Vibration Aided Rolling.

Table 2: Ultrasonic Vibration Aided Rolling Test.

Parameters	Cutting speed (r/min)	Cutting depth (mm)	Feed speed (mm/r)
1	100/150/200/250	0.05	0.05
2	200	0.04/0.05/0.06/0.07	0.05
3	150	0.05	0.04/0.08/0.12/0.16

4 EXPERIMENTAL RESULTS AND ANALYSI

In order to compare the superiority of different cutting methods, the surface roughness Ra and surface microhardness measured for three different processing methods are shown in Table 1-2. As can be seen from Fig.3, as the feed rate increases, the surface roughness Ra of the aluminum alloy gradually increases under the three different processing methods, and the surface quality deteriorates. As the feed rate increases, the surface roughness Ra of the ordinary rolling test (general rolling) and the ultrasonic vibration assisted rolling test (ultrasonic rolling) has a significant increase compared to the ordinary cutting (general cutting). Therefore, it can be seen that The rolling method is not suitable for improving the surface quality of aluminum alloys at large feed rates. Comparing the three curves in Fig.3, the surface quality of ordinary rolling aluminum alloy is better than that of ordinary cutting. Ultrasonic vibration-assisted rolling greatly improves the surface quality of aluminum alloy at a lower feed rate than 0.04mm/r. When the aluminum alloy surface roughness Ra value decreased by about 77.277%, at a larger feed rate of 0.16mm/r still reduced by 23.439%, and after ordinary rolling, the surface roughness of aluminum alloy Ra value is low, that is, the surface Under the condition of better quality, ultrasonic vibration assisted rolling still further reduces the surface roughness Ra of aluminum alloy and improves the surface quality of aluminum alloy. When the feed rate is 0.04mm/r, the surface roughness Ra of aluminum alloy decreases by about 28.032. %, at the feed rate of 0.16mm/r still reduced 6.553%, which reflects the superiority of using ultrasonic vibration rolling aluminum alloy.

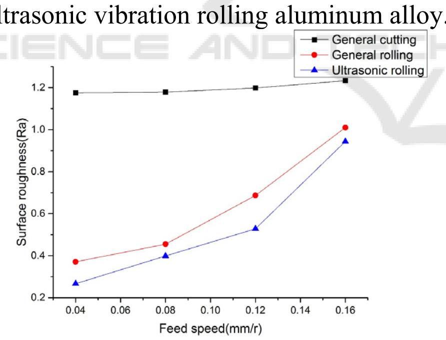


Fig. 3 Effect of feed rate on surface roughness Ra under different processing methods.

As shown in Fig.4, as the feed rate increases, the surface microhardness of the aluminum alloy gradually decreases with three different processing methods, and the fatigue resistance of the aluminum alloy surface deteriorates. Comparing the three curves in Fig.4, the microhardness value of the ordinary rolling aluminum alloy surface is small, the surface microhardness value of the ultrasonic vibration assisted rolling and ordinary rolling is much higher than that of the ordinary cutting, so the ultrasonic vibration assists the rolling and Compared with ordinary cutting, ordinary rolling greatly improves the microhardness value of the aluminum alloy surface. After rolling, the fatigue strength of the aluminum alloy surface is greatly enhanced. Under different feed speeds, the micro-hardness of ultrasonic assisted rolling aluminum alloy surface is increased by about 27.831% than that of ordinary cutting. The average microhardness of aluminum alloy surface is about 23.939% higher than that of ordinary cutting, and the ultrasonic vibration is assisted. Rolling aluminum alloy surface microhardness value increased by about 3.139% compared to ordinary rolling.

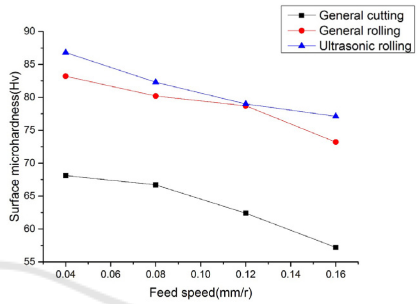


Fig. 4 Effect of feed rate on surface microhardness under different processing methods.

Under the single factor experiment method, the influence of ultrasonic vibration assisted rolling on the surface quality and surface microhardness of aluminum alloy under different cutting parameters was studied. As shown in Fig. 5, the surface roughness Ra value of aluminum alloy at the cutting speed less than 260r/min. As the cutting speed increases, the surface quality improves. The high cutting speed makes the contact time of the rolling head ball with the aluminum surface of the same place in the unit time become shorter, the scratch marks change from the line to the point, and the rolling is more even and stable, thereby reducing the surface roughness Ra value.

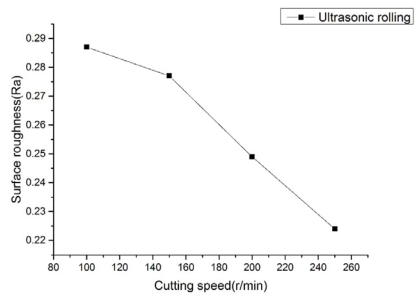


Fig. 5 Effect of cutting speed on surface roughness Ra of aluminum alloy assisted rolling with ultrasonic vibration.

It can be seen from Fig. 6 that when the back knife amount is less than 0.06 mm, the surface roughness Ra of the aluminum alloy decreases with the increase of the back knife amount, and the surface quality is improved. If you continue to increase the amount of back-side knives, the surface roughness Ra of aluminum alloys gradually increases. Therefore, to improve the surface quality of aluminum alloys, it is necessary to select an appropriate backing blade.

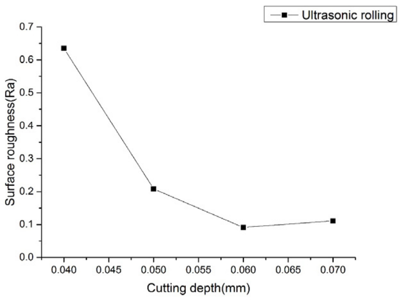


Fig.6 Effect of the back knife on the surface roughness Ra of ultrasonic vibration assisted rolling aluminum alloy.

As shown in Fig.7, when the feed speed is less than 0.12mm/r, the Ra value of the surface roughness of the aluminum alloy gradually increases as the feed speed increases, and the surface quality deteriorates. When the feed rate is greater than 0.12mm/r, the surface roughness Ra of the aluminum alloy increases sharply. Therefore, to improve the surface quality of the aluminum alloy, it is necessary to reduce the feed rate. However, in order to obtain better processing efficiency, Ra may be increased appropriately. Feed rate, but due to the feed rate on the surface roughness Ra value of aluminum alloy is not stable, so in the ultrasonic vibration rolling aluminum alloy should be careful to choose the appropriate feed rate.

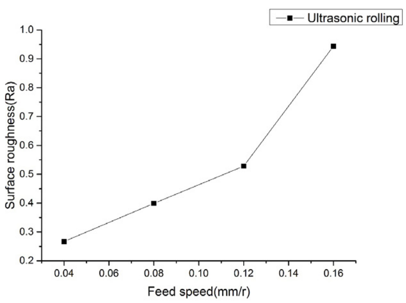


Fig.7 Effect of feed rate on surface roughness Ra of ultrasonic vibration assisted rolling aluminum alloy.

Under the single factor experiment method, the effect of ultrasonic vibration assisted rolling under different cutting parameters on the surface microhardness of the aluminum alloy was studied. As shown in Fig. 8, the microhardness value of the aluminum alloy surface with cutting speed was less than 260r/min. Increasing and decreasing, the surface fatigue strength becomes worse. When the cutting speed is less than 150r/min, the microhardness value of aluminum alloy surface is very high. When the cutting speed is greater than 150r/min, the microhardness value of aluminum alloy surface drops rapidly, and it can be seen that it can obtain better at low cutting speed. Aluminum alloy surface microhardness.

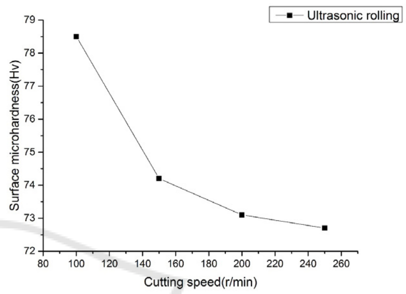


Fig. 8 Effect of cutting speed on microhardness of ultrasonically assisted aluminum alloy rolling.

As can be seen from Fig.9 when the back knife amount is less than 0.07 mm, the microhardness value of the aluminum alloy surface increases with the increase of the back knife amount, and the surface anti-fatigue strength is improved.

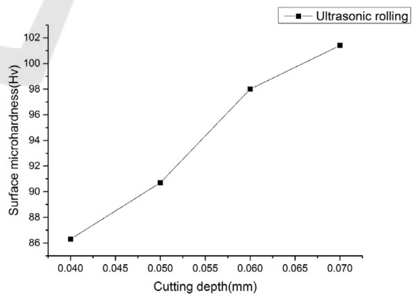


Fig.9 Effect of the back knife on the microhardness of the surface of aluminum alloy assisted by ultrasonic vibration.

As shown in Fig.10, when the feed speed is less than 0.16mm/r, the microhardness value of the aluminum alloy surface gradually decreases as the feed rate increases, and the surface fatigue strength deteriorates. Therefore, to improve the surface quality of aluminum alloys and improve the fatigue strength of the aluminum alloy surface, ultrasonic rolling is required at a small feed rate. However, in order to obtain better processing efficiency, the feed rate can be appropriately increased, but due to the The speed is inversely proportional to the microhardness value of the aluminum alloy surface, so it is necessary to carefully select the appropriate feed rate when ultrasonic vibration is used to roll the aluminum alloy.

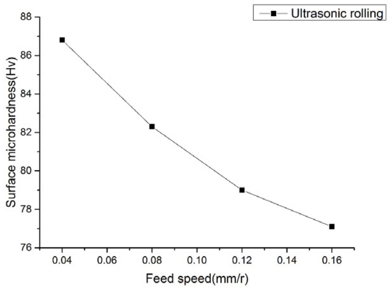


Fig.10 Effect of feed rate on microhardness of ultrasonically assisted rolling aluminum alloy surface.

5 CONCLUSIONS

Using three different processing methods to study the surface roughness and surface microhardness of aluminum alloys, the following conclusions were obtained:

(1) The surface quality and surface microhardness of ordinary rolled aluminum alloys are better than those of ordinary cutting. Ultrasonic vibration assisted rolling significantly improves the surface quality and microhardness of aluminum alloys compared to ordinary cutting.

(2) Rolling aluminum alloys is not suitable for improving the surface quality of aluminum alloys at higher feed rates.

(3) Ultrasonic vibration-assisted rolling improves the surface quality and surface microhardness of the aluminum alloy further than ordinary rolling.

(4) Three cutting factors affecting the surface roughness of ultrasonic vibration assisted rolling Aluminium alloys. Importance: The amount of cutting depth is greater than the cutting speed, which is greater than the feed rate; the effect of three cutting factors on the microhardness of the aluminum alloy surface. The amount of cutting depth greater than the feed speed is greater than the cutting speed.

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