Experiments of Ultrasonic Vibration Aided Drilling of GH4169 Ni-based Superalloy

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Abstract: Ultrasonic vibration drilling on GH4169 Ni-based superalloy was mainly studied in this paper. The surface morphology, chip shape, and the influence of the spindle speed and amplitude on the surface roughness of the hole were studied. The results showed that GH4169 Ni-based superalloy drilling processing with the ultrasonic vibration generator, transducer, horn and drill bit can achieve a well combination of traditional processing and ultrasonic processing in the CA6140 lathe. The surface roughness and the chip morphology are better after drilling with ultrasonic vibration. On the choice of processing amplitude, 15μm is best. In addition, on the choice of spindle speed, the processing effect is well when spindle speed is in range of 125-320 r/min.

Keywords: ultrasonic vibration drilling; GH4169 Ni-based superalloy; ultrasonic amplitude; spindle speed

1 Introduction

Drilling is one of the important parts of all processing technology[1]. It is an important method for cold working. It is very difficult to drilling GH4169 Ni-based superalloy, because of high strength, large plastic, cutting resistance and cold hardening, etc.. Recently, a method of ultrasonic vibration was applied to the drilling process[2], which is used to improve the drilling process[3]. During the drilling process, the high frequency and low amplitude vibration is added, which is called ultrasonic vibration assisted drilling(UAD) [4]. Compared to ordinary drilling(OD), ultrasonic vibration assisted drilling has many advantages, such as improving the hole surface quality, reducing the burr generation[5], high processing efficiency, low temperature[7], processing cutter is difficult to be damaged. Due to reducing the tool wear, UAD is very suitable for the processing of metallic materials. At present, the technology of ultrasonic vibration machining include the turning vibration, vibration drilling and composite processing

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and other aspects of development and achieved certain achievement. But there are still many uncertain factors in ultrasonic vibration drilling, such as the amplitude of ultrasonic vibration, the influence of the spindle speed on the surface quality of the hole, which needs further research and exploration.

In this experiment, the sleeve and flange devices were used and horn corresponding flange plate were fixed by screw bolts, a drill chuck is connected at the top of the horn to clamp the drill. After drilling, the holes were split with wire cutting, and Micromeasure profiler and super depth 3D display system was used to show hole surface roughness and chip morphology. Ultrasonic vibration drilling with different amplitude and spindle speed is used in the experiment, the reasonable amplitude and the spindle speed are obtained, and the inner surface roughness of the hole can be reduced effectively.

2 Experiments and results

2.1 Test material and processing method

Test specimens of GH4169 Ni-based superalloy (in order to facilitate drilling and processing effect comparison, e the 40mm diameter of the rod material was divided into many segments the length of which is15mm). The selected bit is cobalt high speed steel material, the steel is W6Mo5Cr4-V2Co5 (M35), and the diameter is 6mm. The steel material chosen for this kind of drill bit is added 5% to 8% cobalt on the basis of general high speed steel, which significantly improves the hardness and heat resistance of the drill bit, and the toughness is better, and the application is wide. The diagram of test specimens of GH4169 Ni-based superalloy and drill bit is show in Figure 1 below.

Fig.1. Test specimens of GH4169 Ni-based superalloy and drill

The American-manufactured BRANSON 2000bdc power generator, transducer, horn and own-designed sleeve, flange, drill chuck, drill were assembled on CA6140 lathe for drilling test. Firstly, the horn was inserted into the sleeve, and then fixed the horn through sleeve flange. In the end, clamped the bolts between the sleeve's and the horn's flange. The tail of the sleeve extends into the tailstock, clamped by drill chuck of the lathe. Sleeve is fixed on the lathe by center frame, in order to install the drill chuck and the drill. During the procession of drilling, each coaxial centerline of horn, drill bits and spindle should meet certain requirements: the center line of lathe tailstock and spindle center line must coincide, ensuring a unified central line system, so that the bit could drill the specimens accurately, and prevents the influence on hole machining accuracy in the drilling process caused by the drill bit deflection and other issues of shape change, surface quality, etc.. After generator is powered, the transducer and the booster converse electrical signal to mechanical vibration signal, which causes the ultrasonic vibration of drill bit for ultrasonic vibration drilling. The amplitudes selected in this experiment are 15μm, 20μm and 25μm; while the spindle speeds are 125r/min, 200r/min, 320r/min and 400r/min. In the process of drilling test pieces, conduct ordinary drilling first, then ultrasonic vibration assisted drilling. The schematic diagram of ultrasonic vibration drilling device is shown in Figure 2 below.

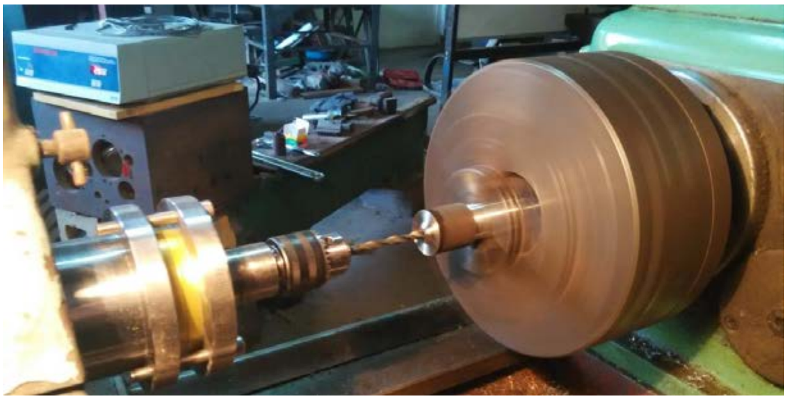

Fig.2. Schematic diagram of ultrasonic vibration drilling device

After processing, In order to facilitate using 3D profiler and super depth 3D display system for measurement, the processed holes needs to cut open with wire cutting. The hole's surface morphology, chip morphology and roughness are all observed, analyzed and measured on the instrument. Through selecting and graph-processing the data, the effects of amplitude and spindle speed on the hole surface roughness can be examined.

2.2 Surface topography of machined holes

Measuring the surface roughness of the hole is a key link to determine the surface quality. Firstly, in order to analyze the morphology of the hole surface, the effective test area should be selected. If the test area is large, testing time is long, or exist certain deviation due to the placement of the human factors, coupled with the trial outer surface is concave, the obtained roughness value will be too large. Through analysis of experiment, the selection test surface length for 100 μm is more appropriate, which could fully reflect the surface morphology of micro hole machining.

From Figure 3 (a), we can see that without ultrasonic vibration, the surface is uneven to a large extent and processing defects appear, the surface roughness coming out to 2.16 μm. The surface roughness gradually increase because of the generation of heat in the duration of the drilling process[8]. Figure 3 (b) is the illustration of the surface morphology after the ultrasonic vibration drilling. Comparing with Figure 3 (a), the peaks and troughs change smoothly in the morphology of the hole with ultrasonic vibration, and the surface roughness is 1.98μm.

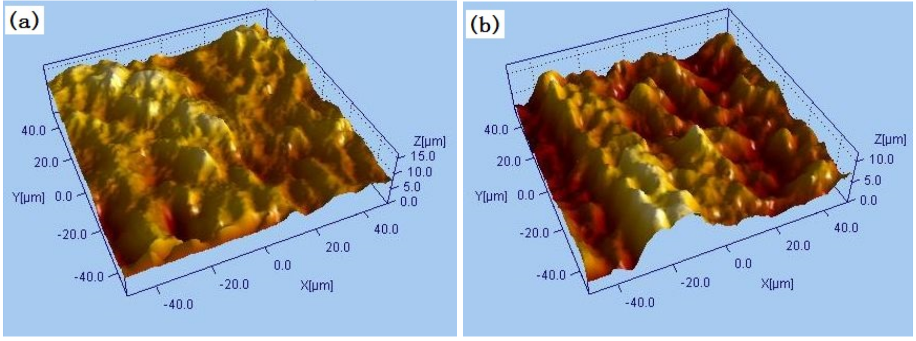

Fig.3. The hole surface topography without and with ultrasonic vibration

That is due to high frequency intermittent drilling caused by vibration, it will change the contact form between drill and specimens from the ordinary one in which the drill squeezes and slips during the process, .In this form, drill works on the specimen with impact load, each instantaneous impact makes the material tend to be brittle, therefore, it can reduce the amount of destruction. Otherwise, as the pulse-shaped drilling time of the cutting force is very short, the drill bit is difficult to obtain much heat, so it can also lower the drilling temperature, avoiding machining precision reduction and thermal deformation in common drilling. Finally, ultrasonic vibration drilling chip is more conducive to discharge, lowering the possibility of scratch on the hole wall. Thus all of these reduce the surface roughness, and form a good surface morphology ultimately.

2.3 Drilling chip formation

Chips have great influence on the quality of hole machining, figure 4 reflects the different forms in super depth 3D display system, extending 20 times, with and without ultrasonic vibration and ultrasonic vibration assisted drilling. From Figure 4 (a), we can see that without ultrasonic vibration drilling, chips show irregular state with obvious jagged edge. The chip surface appears with scaly rift, which is due to the intensified wear of drill bit caused by continuous contact between the drilling bit and the hole during the drilling process. Figure 4 (b) shows that, contrast to the cutting chip morphology of common drilling, ultrasonic vibration drilling cutting chip shape is more regular, the thickness is slightly thinner, and the processing of texture is relatively clearer. All of that is because the ultrasonic vibration can result in intermittent drilling, which allows drill discontinuous contact. During the drill cutting, the bottom of the chip will generate oxide layer, preventing the bond of the cutting chip bottom and tip, which in further reduces the friction coefficient between drill and test piece, making the chip shape more regular. The chip form in common drilling is not good. During the common drilling process, chip is more easily to get winding when the spindle speed rises, thereby reducing drilling machining quality of the specimen, and affecting the safety of the operator. While the ultrasonic vibration drilling, is easy for cutting and removing chip with regular shape. It is difficult to see the phenomenon of flying debris, which is relatively safer. By contrast, ultrasonic vibration drilling is better.

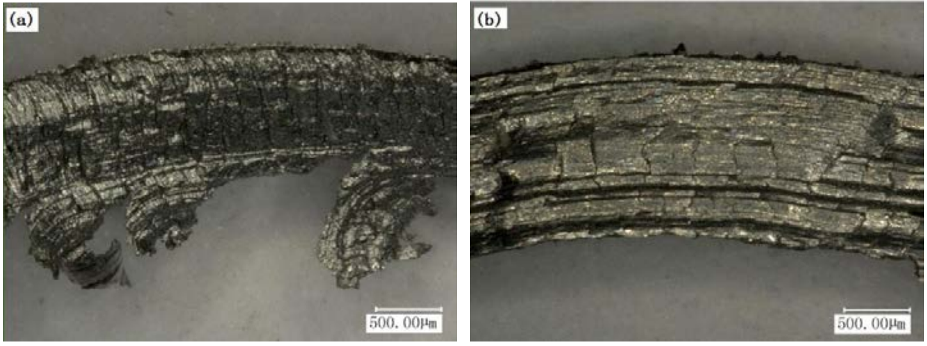

Fig.4. The chip formation without and with ultrasonic vibration

2.4 Influence of amplitude on surface roughness of hole

The amplitude of ultrasonic vibration drilling has an obvious influence on the surface roughness of the hole. In a certain range, as the amplitude increases, the roughness decreases [7] the surface quality is getting improved at the same time. But if it is beyond the range, it will lead to the increase of roughness.

Figure 4 shows the effect of the material on the surface roughness of the part in the absence and the addition of the ultrasonic vibration amplitude. Through measuring the hole surface roughness of five processed specimens, in which the first specimen is processed without ultrasonic vibration drilling, other four tests pieces are in the processing of 10 μ m, 15 μ m, 20 μ m, 25 μ m amplitude, two groups of data is analyzed and compared. The data in fig. shows that the surface roughness is 2.16 μm and its surface quality is lower at the speed of 320r / min, without ultrasonic vibration. While in the addition of ultrasonic vibration, as the amplitude is smaller, the separation between the chip and the bit is not obvious, causing relatively larger pressure between them, which increased friction, and heightened the surface roughness of the hole. With the increasing of amplitude, the surface roughness degree of hole gets reduced, improving surface quality. However, it is not the higher, the better. In the procession of over-high amplitude, specimen and bit have obviously intermittent, not closely contact. There is even emergence of the contact between drilling bit and hole point. Over-high amplitude is also easily to produce amounts of heat [9], leading to increase roughness.

Therefore, the amplitude of the choice for ultrasonic vibration processing is essential. The appropriate amplitude enables to reduce the temperature, to remove the chip in time during the hole drilling process. Figure 5 shows that when the frequency of machining holes is 15 μm, surface roughness comes out to be the lowest.

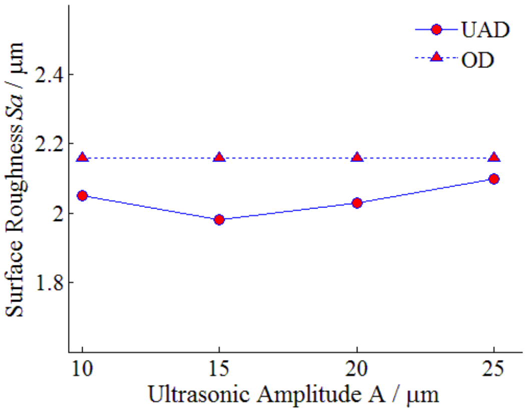

Fig.5. Relationship between surface roughness and ultrasonic amplitude

2.5 Influence of spindle speed on surface roughness of hole

The surface quality of hole with ultrasonic vibration drilling is better than that with ordinary drilling [9]. Visible from Figure 6, the tests are carried out using different spindle speed drilling test pieces, figure 6 reflects the impact of spindle speed on the surface of the hole. When the spindle speed of the lathe is 200r/min, the effect of ultrasonic vibration is the most obvious. Either spindle speed is too low or too high, it will increase the surface roughness degree. The over-low speed would lead to the retention of the chip, so that the drill bit will be affected by the chip cutting in the drilling , increasing the edge wear of drill bit, further heightening the surface roughness of the hole. On the other hand, the over-high speed will cause the increase of the cutting power in the drilling process, producing relative friction heat, increasing wear, changing the surface of the hole in the high temperature, decreasing the surface quality of the hole.

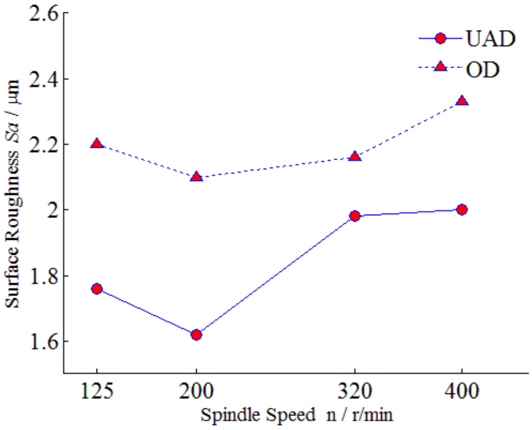

Fig.6. The relationship of surface roughness with the change of spindle speed

During the process of ultrasonic vibration drilling, rotation of the specimen, drilling of the bit and chip removal occurred simultaneously. In the certain range, when the spindle speed is not exceeding 320r/min, the surface quality of the hole gradually increases as spindle speed increases, and the chip is also gradually enhanced at the same time. Because of the aggregation of chips in the hole, the surface roughness increases with the increase of the speed. Figure 6 shows that the speed between the 125r/min~320r/min makes the value of roughness maintained under 2 μm standard, and with the further improvement of spindle speed, more than 320 r/ min, surface quality will be further reduced. Therefore, the optimal range of spindle speed control is 125~320r/min.

3 Conclusions

1) Compared with ordinary drilling, ultrasonic vibration drilling could effectively improve the pore surface morphology, making surface morphology uniform, and both the peaks and troughs change gently.

2) When the amplitude is 15 μm, the spindle speed is 320r/min in ultrasonic vibration drilling, the surface roughness of the hole lowers from 2.16μm to 1.98μm, about 8.3% off. The chips are easy to discharge, and the shape is more regular.

3) Compared with other amplitude, when the amplitude is 15 μm, surface quality is the best**.** In the choice of ultrasonic vibration assisted drilling speed, the 125~320 r/min should be controlled. When the spindle speed is 200r/min, the surface roughness of the hole is the lowest, and the surface quality of the hole is decreased after more than200r/min.

Acknowledgements

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