Drilling Mechanism and Experimental Research on Ultrasonic Vibration Machining Technology

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Abstract. Drilling on 45 steel with ultrasonic vibration is studied in this paper, mainly refer to the ultrasonic vibration drilling mechanism, surface morphology and chip shape produced in the drilling process. In addition, the influence of the spindle speed and ultrasonic amplitude on the surface roughness of the hole was also studied. A well combination of traditional drilling processing and ultrasonic processing in the CA6140 lathe can be achieved with the ultrasonic vibration generator, transducer, horn and drill bit. The experimental results show that the surface roughness and the chip morphology are better after drilling with ultrasonic vibration than that without ultrasonic vibration.

Introduction

Drilling is an important part of all machining processes [1,2], and it is an important method for cold machining. It is widely used in production and application of 45 steel, so it is of great practical significance to choose 45 steel for ultrasonic vibration assisted drilling (UAD). 45 steel, also known as high quality carbon steel, is a kind of carbon regulating structure steel which is used commonly, with carbon content ranging from 0.30% to 0.60%.It is difficult to reach high surface quality for the conventional drill (CD) of 45 steel. A method that add ultrasonic vibration to the drilling process has been applied recently to improve drilling process [3,4].The vibration with high frequency and low amplitude is added in drilling process, which is called UAD[5,6].UAD has many advantages compared with CD, such as improving the surface quality, reducing the production of burrs, high processing efficiency and low processing temperature[7,8]. The cutting tool is not easy to damage in the process, which can reduce the wear of the tool and is very suitable for metal material processing. At present, the ultrasonic vibration machining technology has achieved certain achievements in the development of ultrasonic vibration turning, ultrasonic vibration drilling, boring and processing composite materials[9,10].However, there are still many uncertainties in the UAD process, such as the influence of the ultrasonic amplitude and the spindle speed on the surface quality of the hole, which needs further research and exploration[11].

The model of UAD

The test materials. In the experiment , 45 steel specimen was selected. In order to facilitate drilling and machining effect comparison, cut the bar with a diameter of 40mmand the length was 15mm, and the surface debarring was processed, as shown in figure 1. The two-flute cobalt high speed steel drills with a diameter of 6 mm were used in this study. The point angle of the drilling is 118 ^{o} and the selected steel number of drill bit materials is w6mo5cr4-v2co5 (M35).The steel material used in this type of drill is to add 5% to 8% cobalt on the basis of the general high speed steel.The hardness and heat resistance of the bit are improved obviously and the toughness is good, making it is widely used to drilling 45 steel

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Fig 1: The 45 steel material and drill used in the test

Test methods. The power generators, transducers, horn are designed and manufactured, and sleeves, flanges, drill chucks, drills were used to make assembly connections. The test woekpieces are drilled on a CA6140 type lathe. In the first place, insert the horn into the sleeve and fix the horn through the sleeve and the flange. Then the flange of the horn is clamped by bolted between the sleeve and the flange.The end of the sleeve extends into the tailstock of the machine and is clamped with the drill chuck of the machine.The sleeve is fixed on the machine using a center frame. Finally the drill chuck and drill bit are installed.When drilling, the concentricity of the centerline of the horn, drill, and spindle must have certain requirements.The centerline of the lathe tailstock coincides with the centerline of the spindle rotation, and the centerline of the system is unified to ensure that the drill bit drills the workpiece accurately. The ultrasonic generator generates an electrical shock signal, and the ultrasonic transducer convert the electrical signal to a mechanical vibration signal that causes the drill bit to vibrate ultrasonically.UAD device is shown in figure 2.

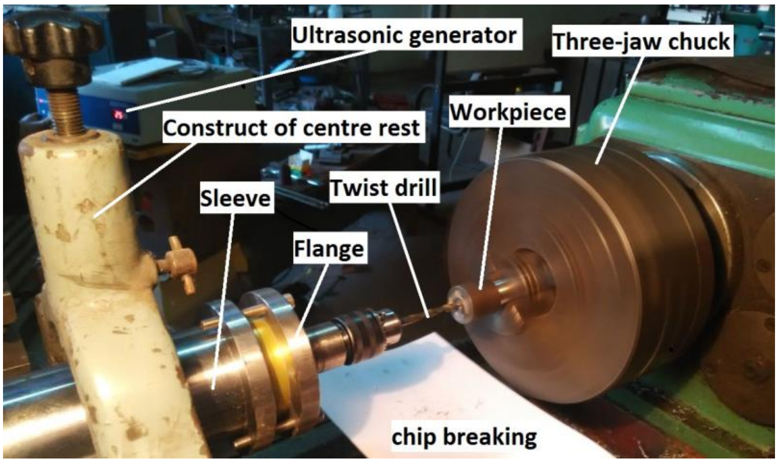


Fig 2: The ultrasonic vibration drilling device

In order to facilitate the measurement with the three-dimensional profiler and the super depth 3D display system, the workpieces are cut by wire cutting after drilling. The microscopic topography of the hole surface and the chip shape were observed on the instruments, and the image is analyzed. Then the surface roughness of the holes are measured, and the effective data is selected for chart processing. At last, the effect of amplitude and spindle speed on the surface roughness of the holes is examined.

Experiment results and discussion

The micro-topography analysis of hole surface. Measuring the roughness of the inner surface of a hole is a crucial part of determining the surface quality. The 3D profiler display system is used to clearly show the inner surface roughness of the hole, as shown in figure 3.

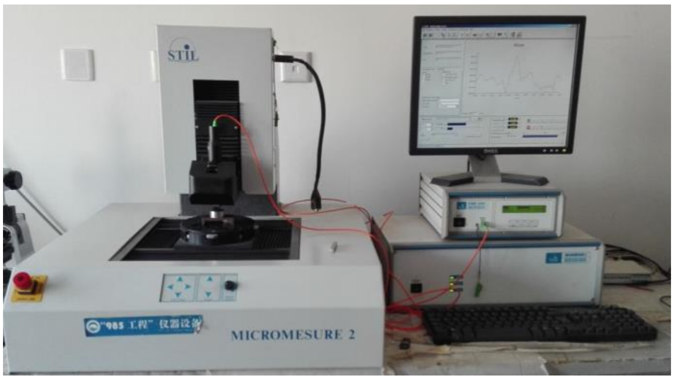
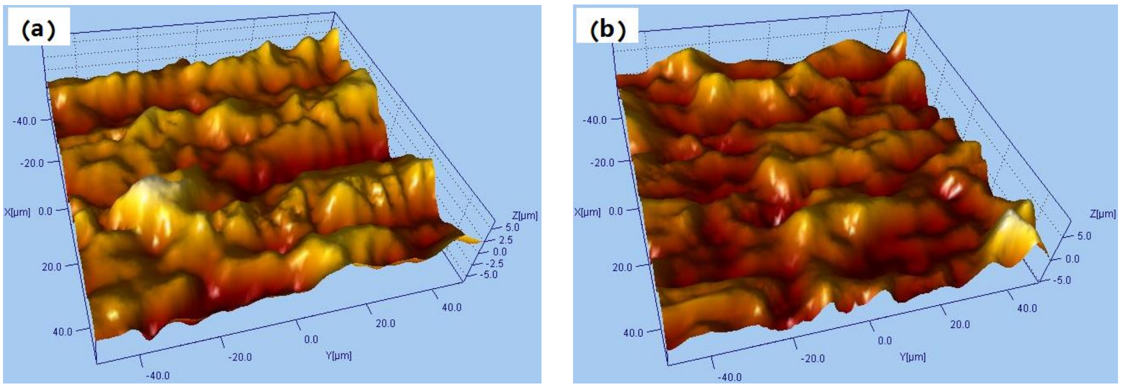


Fig 3: The 3D profiler display system

Firstly, an effective test area should be selected when analyze the surface roughness of the hole surface. If the test area is too large, long time will be cost to measure. In addition, there is a certain deviation due to human factors. The roughness value obtained will be larger for the reason that the outer surface of theworkpiece is concave. It was fond that 100μm issuitable to be selected as the length of the test surface, which can fully reflect the micro-morphology of the inner surface of the processed hole. In the processing parameters selection, the spindle rotation speed is 320r/min and the amplitude is 20μm. The microscopic topography of the hole surface is compared and analyzed.



(a) CD (b) UAD

Fig 4: 3D surface topography

From figure 4(a), we can see that the microscopic topography of surface with CD is not uneven, and the fluctuation is large. It has processing defects and the surface roughness is 1.76 μm. This is due to the continuous contact between the drill bit and theworkpiece surface during drilling, and the heat generated during the machining process is gradually increased, resulting in an increase in the surface roughness of the hole. Figure 4(b) shows the surface morphology of the holes with UAD. Comparing with figure 4(a), the morphology of the holes after ultrasonic vibration is more uniform, the change of peak and trough is relatively smooth, and the surface roughness is 1.41 μm. This is due to the fact that ultrasonic vibration is used for high-frequency intermittent drilling, and the contact form between the drill bit and the workpiece is changed, which is different from that of CD. The drill bit acts on the workpiece with impact load. Each momentary impact causes the material to be brittle, and the amount of damage produced is reduced. The drill bit is not easy to generate a large amount of heat, so the drilling temperature is reduced. Hot deformation of the workpiece caused by high temperature during CD is avoided, so the machining accuracy is reduced. At the same time, UAD is more conducive to chip evacuation and reduces the possibility of scratching the hole wall by the chip, so as to reduce the surface roughness, and finally form a good surface morphology.

Effect of amplitude on surface roughness. Amplitude is an important factor affecting the quality of the inner surface of the drilling holes in UAD, and different amplitudes have different effects on the surface roughness.In the experiment, the 45 steel was processed by CD and UAD with different amplitudes. The amplitudes were selected as 10μm, 15μm, 20μm, and 25μm, and the surface roughness of the holes was analyzed as a function of amplitude.

The amplitude of UAD has a significant effect on the surface roughness of the hole. Under a certain range, the roughness decreases as the amplitude increases, and the surface quality increases. But if it exceeds a certain range, the roughness increases.

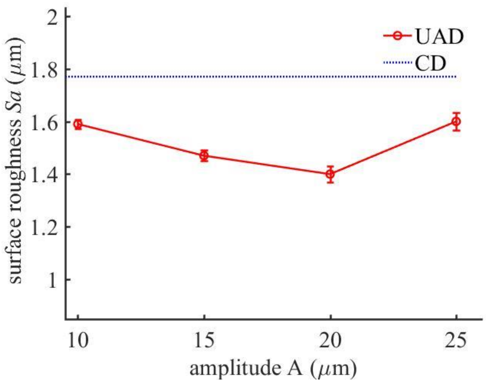


Fig 5: Relationship between surface roughness and ultrasonic amplitude

The curve of the surface roughness of the hole is plotted as a function of the amplitude, so that the rule of surface roughness variation with the amplitude of the hole can be more intuitively displayed. Figure 5 reflects the effect of the amplitude on the surface roughness of the part 45 steel. Five specimens of machined holes were measured. The first specimen was drilled without ultrasonic vibration. The amplitudes of the other four specimens were 10μm, 15μm, 20μm, and 25μm. As can be seen from the data in the figure, when the rotational speed is 320r/min, the roughness of the part is 1.76μm without the ultrasonic vibration and the surface quality is low.With the addition of ultrasonic vibration, the smaller the amplitude, the less separation between the chip and the drill bit, and the relatively greater pressure between the two, which results in an increase in friction, and the surface roughness of the hole is still high. As the amplitude increases, the surface roughness of the hole decreases and the surface quality increases. But it's not right that the higher the better. When beyond a certain amplitude, there is obvious intermittent contact between workpeice and the drill bit in the vibration drilling process. The vibration is not tight, even the drill bit and the hole surface contact on a point. The larger the amplitude is prone to generate a lot of heat, resulting in increased roughness.

Therefore, the choice of amplitude is very important for ultrasonic vibration machining. The proper amplitude will reduce the temperature generated during hole drilling, and the chips will be eliminated in time. Figure 5 shows that when the amplitude is 20μm, the surface roughness is the lowest.

The influence of spindle speed on the surface roughness. Spindle speed is another important factor affecting the quality of the inner surface of the drilling hole in UAD. Different spindle speeds have different effects on the surface roughness of the machined hole. In the experiment, different spindle speeds were selected for 45 steel drilling with CD and UAD. The amplitude is taken as 20μm, and the spindle speed is selected as 200r/min, 320r/min, 400r/min, 500r/min.

Figure 6 shows the influence of the spindle speed on the hole machining surface. When the spindle speed of the lathe is 400r/min, the ultrasonic vibration has the most obvious processing effect. If the spindle speed is too low or too high, the surface roughness will increase to varying degrees.This is due to the fact that if the speed is too low, the chips cannot be removed in time, which causes the drill bit to be affected by the chips during drilling. At the same time, the wear of the cutting edge of the drill increases, further increasing the surface roughness of the hole. If the rotational speed is too high, the cutting power will increase. During the drilling process, relative frictional heat will be generated. At the same time, the wear of the drill bit will increase relatively, and the surface of the hole will change under high temperature, so that the surface quality of the processed hole will decrease.

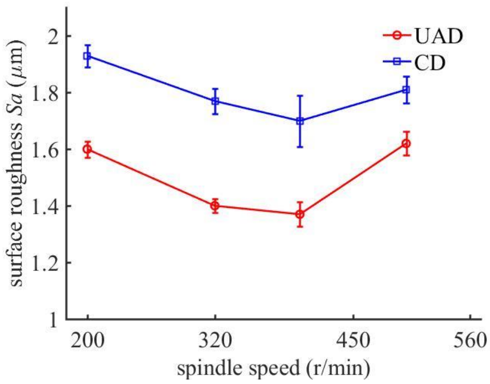


Fig 6: The relationship of surface roughness with the change of spindle speed

In the UAD process, the rotation of the workpiece, the feed of the drill bit, and the chip removal occur simultaneously. When the spindle speed does not exceed 400 r/min, the surface quality of the hole is gradually increased as the spindle speed is increased, and chip removal is gradually enhanced. Because the accumulation of chips has a great influence on the surface roughness of the hole, the surface roughness decreases with the increase of the rotation speed. Figure 6 shows that the roughness value can be kept below the standard of 1.4μm when the rotating speed is between 320r/min and 400r/min. With the further increase of the spindle speed, the surface quality will be further reduced when exceeding 400 r/min. Therefore, the optimal range of spindle speed control is 320~400r/min.

Conclusions

Compared with CD, under the same processing parameters, UAD of 45 steel can effectively improve the micro-morphology of the inner surface. The surface micro-morphology is more uniform, and the crest and trough change smoothly. When the spindle speed is 400r/min and the amplitude is 20μm, the inner surface roughness decreases from 1.76μm to 1.41μm, which is reduced about 19.8%. Chips are easy to discharge and have a more regular shape. Compared with other amplitudes, the inner surface of the 45 steel has the best quality when the amplitude is 20μm. In UAD, the speed selection should be controlled at 320 ~ 400 r/min. When the amplitude is 20μm and the spindle rotation speed is 400r/min, the surface roughness of the hole is the lowest, reaching to 1.37μm. If the spindle rotation speed exceed or lower than 400r/min, the surface quality of the hole decreases.

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