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Study on the experiments of the relationship between the geometric dimensions of flexural vibration disk and its vibration characteristics

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Properties

ABSTRACT

Purpose: The vibration characteristics of flexural vibration disk in ultrasonic honing system were studied systematically through experiments.
Design/methodology/approach: The vibration of flexural vibration disk was tested using the acoustic system of ultrasonic honing.
Findings: The results showed that the amplitude of vibration disk increases with the reducing of its thickness, when the disk was thin disk (the ratio between the thickness and radius was less than or equal to one fifths) the vibration of disk was flexural vibration, the good vibration effect could be obtained. The maximal amplitude could reach 20.5µm,at the same time, the number of the wave crests and size could be obtained. There exist amplifying characteristics in the vibration of the disk. When the diameter of disk was not changed, the resonant frequency would decrease with the reducing of the thickness of disk. The resonance could be excited at different frequencies. The corresponding maximal amplitude value provides certain reference value for the dimensional design and application of flexural vibration disk.
Research limitations/implications: From analysis, the ratio between diameter and thickness of flexural vibration disk has direct effect on amplitude. The rational diameter and thickness of flexural vibration disk should be selected according to specific machining conditions and the size requirements of the whole honing equipment during the course of design of ultrasonic honing acoustic system.
Originality/value: The studied on relationship between geometric dimensions of flexural vibration disk and its vibration characteristics were made.
Keywords: Non-destructive testing; Ultrasonic machining; Flexural vibration; Disk; Vibration characteristics

1. Introduction

Ultrasonic vibration honing is an effective method for machining the internal surface of hardened and brittle ceramics precisely. In the every segment of ultrasonic honing system, the effect of the flexural vibration disk on the machining quality and efficiency is the largest. How to optimize and design the flexural vibration disk is the problem that was being paid more attention in practical production. Flexural vibration disk is widely used in ultrasonic honing. The resonance frequency of flexural vibration disk is related not only with its material but also with it's size including thickness and diameter [1-2]. When the resonance frequency is defined the ratio between the thickness and diameter is determined. While the thickness of flexural vibration disk is dependent on the size of the whole honing equipment, so for the defined the honing there is a corresponding relation between it's resonance frequency and the ratio between thickness and diameter. That is to say, the size of flexural vibration disk is of great importance to the size design for the whole honing equipment. The study of relationship between the geometry size and vibration characteristics has the very essential actual significance for the optimization and design of the ultrasonic honing acoustic system.

2. Experimental method and conditions

2.1. Experimental method

The vibration of flexural vibration disk was tested using the acoustic system of ultrasonic honing; the testing system was shown in Fig. 1. The acoustic system of ultrasonic honing was mainly composed of energy transducer, coning amplitude rod, flexural vibration disk and flexible rod and oil stone seat subsystems. The former three subsystems were used in this experiment, and the energy transducer and coning amplitude rod were manufactured according to the related theoretical formula. In order to observe the vibration characteristics of flexural vibration disk during the reducing the thickness, and find out the thickness range of good vibration, the thickness of the flexural vibration disk was reduced gradually and 1 to 2 mm every time.

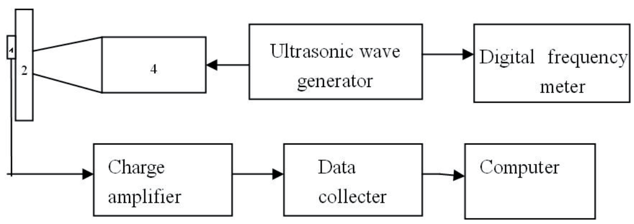

Fig. 1. The schematic diagram of testing system of characteristics of flexural vibration disk; 1.Acceleration sensor 2.Vibration disk 3. Coning amplitude rod 4. Energy transducer

In order to test the vibration characteristics of flexural vibration disk, the testing points were fixed according to a given rule. That is to say, in order to test the amplitude of different points and fix the sensor the screw thread hole were processed. At the same time in order to reduce the effect of screw thread hole on vibration characteristics of flexural vibration disk, the screw thread holes were scattered along circumference uniformly (as shown in Fig. 2) and were numbered from 1 to 8. The radial distance between adjacent screw thread holes was equal; 2 mm to the edge of flexural vibration disk were left.

2.2. Experimental approach

After being connected energy transducer with amplitude rod, the trial vibration of amplitude rod could be tested by adding the ultrasonic wave generator. Adjust the power of generator to 30W, the frequency of vibration to resonance frequency of amplitude rod, check the small head touched by screw thread knife or metal foil with water and look if there was atomization. If there was atomization, then the vibration of amplitude rod was well. Smooth from big head to small head of amplitude rod, the vibration became more severe which could be felt by hand. There shouldn't have whistle during the testing course, or the tightening and rational of connection of system should be checked.

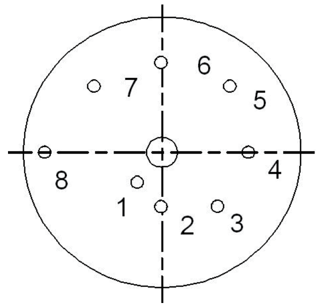

Fig. 2. The schematic diagram of flexural disk

Mounted the flexural vibration disk and sprayed a layer of fine sand evenly on it that was used to observe the vibration of flexural vibration disk. After that, mounted the acceleration transducer in the flexural vibration disk, which was used to measure the amplitude value of different points in flexural vibration disk under different frequency and power. To reduce the thickness of flexural vibration disk by 2mm, and measure the amplitude value in turn. At last, the graphs of vibration characteristics of flexural vibration disk were drawn according to the measured data.

2.3. Experimental conditions

Ultrasonic wave generator: T66MC, Output voltage of power: 220V, Output frequency:50Hz, The adjusting range of frequency 18kHz-22kHz. Digital frequency meter: YM3371Piezoelectric acceleration transducer: B&KYD10, Charger sensitivity (160Hz) 0.00145PC/ ms-2Charge Amplifier: 2635 Data acquisition: P6K

Flexural vibration disk: 8mm≤t≤26mm 52mm ≤D≤136mm Material: 45#

Coning amplitude rod material: 45# Energy transducer: piezoelectric ceramic.

3. Experimental results and analysis

The effect of ratio between thickness and diameter of flexural vibration disk on vibration value was estimated the vibration value of flexural vibration disk was related with ratio between thickness and diameter. When the diameter was fixed and the thickness was reduced from 24mm to 10mm, the flexural vibration disk began to vibration weakly (the measured vibration amplitude value was very little, and could not be felt by hand, the sprayed fine sand did not move), vibration began to intense gradually until to resonance vibration (fine sand on the flexural vibration disk was dispersed by vibration at low power, and formed good wave node and wave loop). For the flexural vibration disk with diameter of 132mm, when the thickness was larger than 16mm, the vibration signals were very weak; the maximum amplitude value was less than 4.57um(as shown in Fig.3(a)(t=18mm A=4.57μm), the vibration signal of the fifth sampling point); when the thickness was less than 16mm, vibration began to intense, for the every corresponding thickness value, the resonance appeared by adjusting ultrasonic wave generator (when the thickness was reduced to 13mm, and resonance appeared, the vibration signal of the fifth sampling point was shown in Fig. 3b). When the thickness of the flexural vibration disk was reduced to 11mm, the power was 20W and the frequency was 19.6KHz, resonance could be obtained. When the power was set to 50W, the vibration became very intense, the whistle could be heard when the flexural vibration disk was pressed lightly by hand, the amplitude was very difficult to be measured. If the thickness was less than 11mm, the vibration amplitude was difficult to be measured too. Seen from that the amplitude could increase with the increasing power or the reducing thickness.

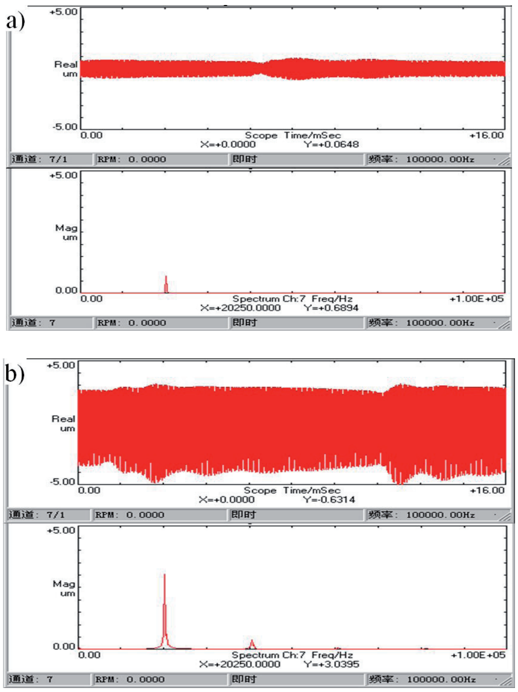

Fig. 3. The graphs of time history spectrum of disks with diameter of 132mm and different thicknesses at the state of vibration

So in order to measure amplitude precisely, the thickness of flexural vibration disk was fixed from 11 to 16mm and power was 20W. For the disk whose diameter was 100mm, when the thickness was greater than 10mm there was no obvious vibration, the good vibration could be obtained with the reducing thickness. For the disk whose diameter was 60mm, only it's thickness was reduced to 8mm the good vibration could appear. While when the thickness was 10mm and diameter was 52mm, there was no flexural vibration, the measured time history at the central point was not a constant amplitude graph entirely, and it's shape seemed to be standing wave composed by waves with different frequencies and amplitudes. From above analysis, the ratio between diameter and thickness of flexural vibration disk has direct effect on amplitude. The rational diameter and thickness of flexural vibration disk should be selected according to specific machining conditions and the size requirements of the whole honing equipment during the course of design of ultrasonic honing acoustic system.

The effect of ratio between thickness and diameter of flexural vibration disk on vibration characteristics was found it could be found that the time history graphs of vibration was constant amplitude curve basically which met the characteristics of flexural vibration [4] from the time history and spectrum graphs of disk whose diameter was 132mm and thickness 13mm (as shown in Fig.3b). The vibration mode could be drawn according to corresponding amplitude in spectrum graph (Fig.4c). Mode graphs of disks with different thicknesses were obtained (Fig.4a, b, d) by using the same method. From the graphs the change of amplitude along the radial direction could be seen. Besides the amplifying characteristics existed in the flexural vibration disk could be seen from the spectrum graphs of disk. Because the tested amplitude of energy transducer was 4-5um, the amplifying multiple of coning amplitude rod was 2.39, even the energy loss could not be considered, and the maximum amplitude of vibration was 10-12um. From the time domain graphs (Fig.3(b)(t=13mm A=20.15μm)) the amplitude of disk face could reach 20.15um. This showed that the flexural vibration disk has amplifying characteristics. The wave loop is referred to the circle at which the amplitude is the largest, while the nodal circle is referred to the circle at which the amplitude is the smallest (from strict sense, the amplitude is zero). The certain relationship between the position and size of nodal circle and ratio between thickness and diameter could be gotten using the dispersion of fine sand. That is to say, the smaller the ratio was, the more the number of nodal circles was. In this experiment the power of generator was set to 50W, there was two nodal circles on the disk with diameter 136mm and thickness from 11 to 16mm. When the thickness of disk with diameter 132mm was greater than 16mm(the ratio between thickness and diameter was greater than 1/10), there were no nodal circles. There were two nodal circles on the disk whose diameter is 108mm and thickness is from 10 to 8mm. There was only one nodal circle on the disks whose diameters were100mm and 60mm and thickness is 11mm and 8mm respectively. When the vibration disk was given, the number and size of nodal circles were fixed. Also it was found that for a disk the shape and number of nodal circle would change with the change of power and frequency. Besides, to specify the number and size and dispersion of disk is of great importance for the installment of flexible rod. If the flexible rod was installed at the wave loop, the ideal vibration of flexible rod and oilstone could be obtained, or the vibration was very weak.

The effect of diameter of flexural vibration disk on resonance frequency was estimated the resonance frequency decreases with the reduction of the thickness of disk. For the disk with diameter 132mm which could be considered as the load of amplitude rod, when the thickness was reduced from 24 to 12mm, the resonance frequency of energy transducer, amplitude rod and disk system decreased from 20.75KHz to 19.5KHz. It would be seen that when the frequency was 20KHz, the amplitude of the disk with thickness of 14mm was much greater than disks of other kind, while when the frequency was reduced to 19.75KHz the amplitude of disk with thickness of 12mm was close to the

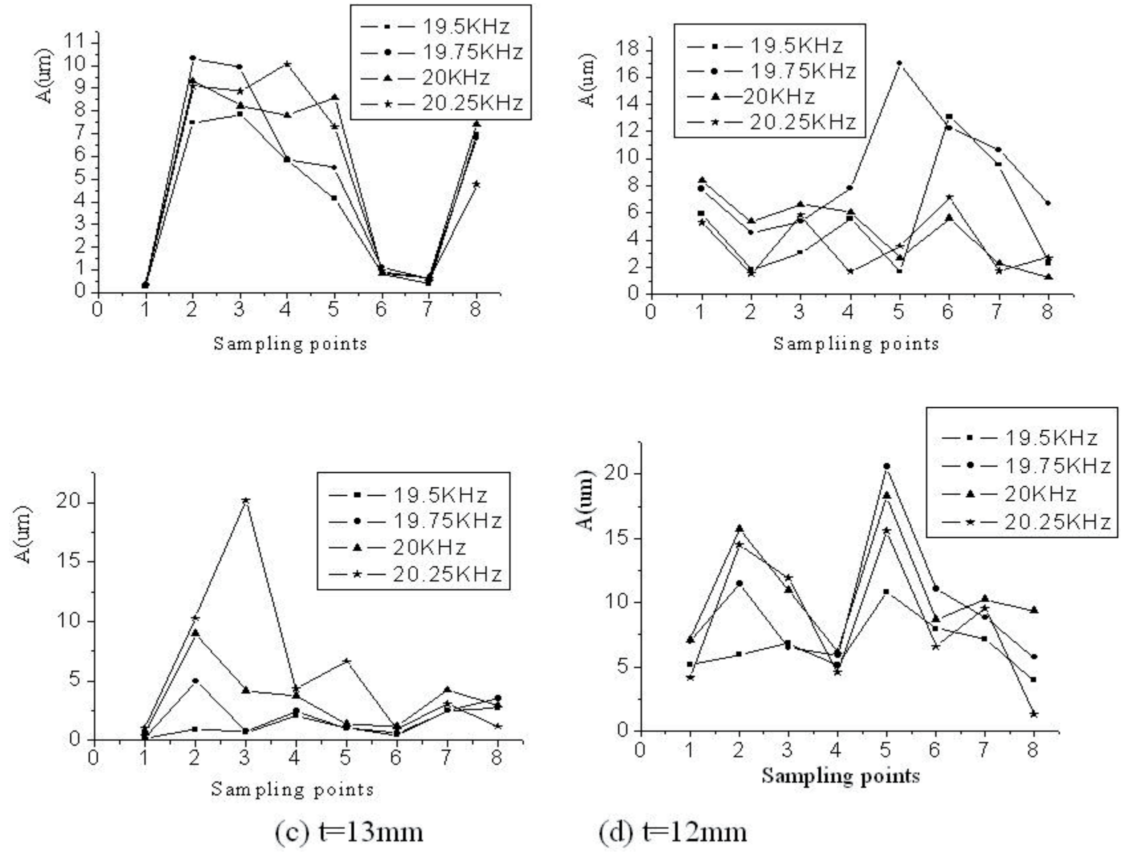

Fig. 4. The vibration mode curves of disks with diameter of 132mm and different thicknesses

amplitude of disk with thickness of 14mm, when the frequency was reduced to 19.5KHz, the amplitude of disk with thickness of 12mm exceeded the amplitude of disk with thickness of 14mm.from the vibration modes of disks with different thicknesses at the frequency of 20, 19.75 and 19.5KHz in Fig.4. Mentioned above showed that the resonance frequency decreased as the thickness of disk reduced. The same changing rule existed in disks with different thicknesses. This accorded with the result that the intrinsic frequency of disk changes with the changing of thickness derived by theoretical formula. It was also found that when the design frequency of amplitude rod was 20KHz, the resonance with vibration could be obtained at the frequency of lower than 20KHz. The reason was that the vibration disk had more than once resonance frequencies. The second resonance frequency should be the result of coupling of amplitude rod with the other phase vibration modes of vibration disk. So when the size of disk was specified, its second phase resonance modes could be made full use of. Then one disk could be used many times, which could reduce the number of disk.

4. Conclusions

The following conclusions were made through the experimental research and analysis of the characteristics of flexural vibration disk of ultrasonic vibration honing system:

1) When the disk is thin disk (the ratio between thickness and diameter was less or equal to 1/10), the vibration was flexible vibration, the amplitude increased with the reduction of thickness, the good vibration effect could be obtained, the maximum amplitude could reach 20.5um, amplifying characteristics existed in the system.
2) The disks with different ratios between thickness and diameter have different numbers and sizes of nodal circles (wave loops). There is a trend that the less the ratios were, the more numbers of nodal circles.
3) When the diameter of flexible vibration disk was fixed, the resonance frequency decreased with the reduction of thickness.

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