2P4-5 A Driving Method for Reduction of Ringing Duration of High Power Ultrasonic Pulse Source

強力超音波用パルス音源における残留振動抑制の為の駆動法の検討

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1. Introduction

The high power ultrasonic wave is using resonance of solid to make high amplitude, and it is applied in various industrial fields such as bonding and processing. However, since the frequency is used in the resonance state, the followability of the vibration amplitude to drive voltage change is low. It is necessary to track the resonance frequency at all times in response to a change in the load. According to processing conditions, it is necessary to change amplitude. There are restrictions on use.

In this research, especially for the purpose of improving followability, suppression of residual vibration, with reference to the driving method of the pulse sound source which has been advanced by the application of the ultrasonic signal. We will study the applied voltage waveform to generate high power ultrasonic waves with high followability and well suppression of residual vibration. In our previous study, we found some residual vibration suppression points[2], And now we found them all, to control the drive voltage waveform, so the frequency and amplitude can be arbitrarily converted.

2. Research method

2.1 Experimental device.

In this study, we observe the waveform with the device shown in Fig. 1

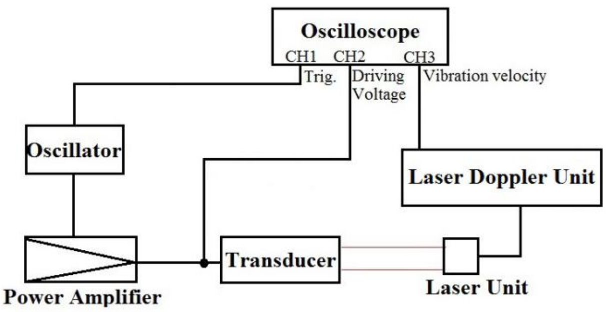

Fig.1 Laboratory equipment

2.2 Study of drive voltage waveform

Consider drive voltage for generating multiple ultrasonic pulses without residual vibration. First, for the monopole pulse, a voltage waveform with a slope at the rising edge was adopted [1]. According to the experiment, when the waveform of the drive voltage is a rectangular wave, the residual vibration is large. But if the constant-slope voltage waveform such as half-sine and triangular wave, it can suppress the residual vibration. On suppression of residual

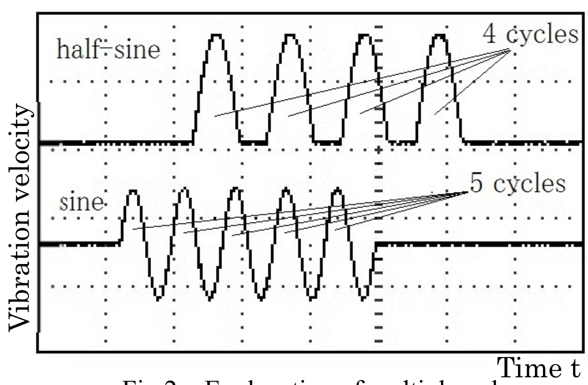

Fig.2 Explanation of multiple pulses

vibration when multiple pulses are applied. Here we use sine and half-sine as shown in Fig.2.

In this case, it is called “multiple pulses” when more than two cycles.

2.3 Relation between suppression of residual vibration and number of drive voltage’s cycles

In order to generate pulsed vibration with small residual vibration, we applied experimental application of multiple pulses driving voltages. From several trial experiments with different cycles of waveforms, we found that multiple pulses is more likely to suppress residual vibration than monopole pulse. In case of multiple pulses, adjust the application time and applied cycle number, it is more easier to find conditions for suppressing residual vibration. Here, if the number of cycles to be applied is n, corresponding residual vibration suppression conditions number are mn (m is an integer).

For example, 6 cycles of driving voltage was applied to a ultrasonic transducer with a resonance frequency of 61kHz. When the frequency of the drive voltage was set from 30.5kHz (½ times the resonance frequency) to 61kHz. As shown in Fig. 3, there were only 6 residual vibration suppression points, and if the frequency is not match, it makes residual vibration large. In addition, there were six points at 61 kHz (1 time)~ 120 kHz (2 times). Also, there were 6 points at 20 kHz (⅓ times) ~ 30.5 kHz (½ times). 6 points were found at 15 kHz (1/4 times) ~ 12 kHz (1/5 times) and 6 points at 12 kHz (1/5 times) ~ 10 kHz (1/6 times). The vibration amplitude was so small at 1/6 or less of the resonance frequency, so that these frequencies are not be considered here.

We tried from 3 cycles to 10 cycles, when the drive frequency is in the range of 1 / k to 1 / (k - 1) times the resonance frequency (k is an integer), We assumed that the number of suppression points coincided with the number of cycles n which are applied [2].

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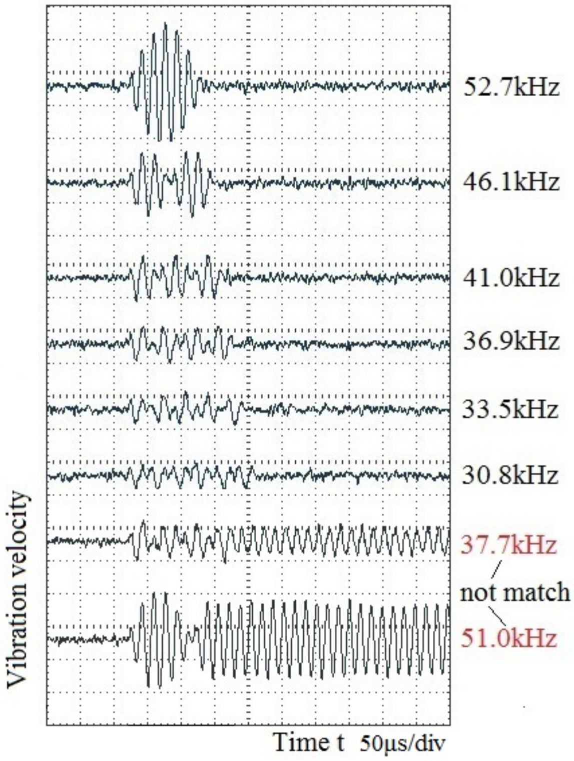

Fig.3 All suppression points and some not suppression points situation from 30.5kHz to 61kHz , for 6 cycles applied

3. Experimental result

3.1 Regularity of Residual Vibration Suppression Points

From the above mentioned, the distribution of residual vibration suppression points has regularity. If the frequency of the applied voltage is set to 1/2, 1/3, 1/4, 1/5, 1/6 of the resonance frequency can be a boundary. It can be seen that the number of suppression points are coincide with the number of cycles applied between the two boundaries.

3.2 Relationship between resonance frequency and amplitude

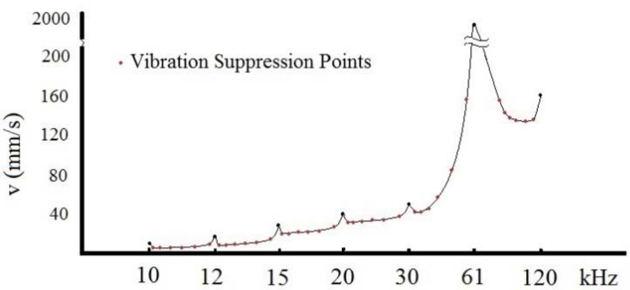

Fig.4 the relationship between the drive voltage frequency and the vibration velocity for 6 cycles.

In the case of the resonant frequency of the transducer, the amplitude is the largest. Experimental results show that the amplitude increases if the frequency of voltage to be applied closer to the resonance frequency. On the other hand, it can be seen that the amplitude increases in the case of 1/2 resonance frequency and 1/3 resonance frequency and so on, the boundaries. Fig.4 shows the relationship between the magnitude of the amplitude and the frequency of the applied voltage. That's why we said

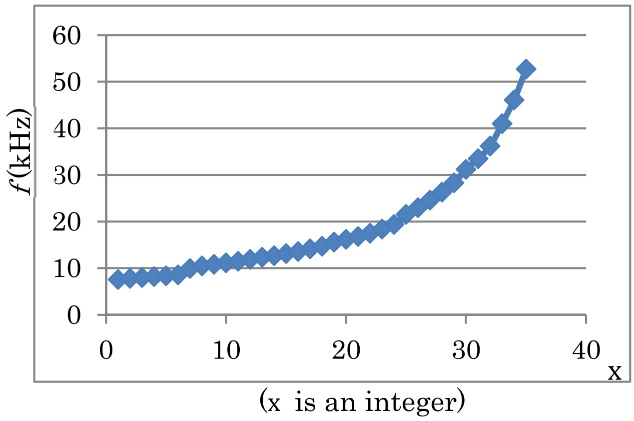

Fig.5 Display of 6 cycle residual vibration suppression points

the frequency and amplitude can be arbitrarily converted.

3.3 Searching the regularity between residual vibration suppression points and drive voltage frequency

Here, the regularity of the suppression of the residual vibration with cycle numbers was experimented. When multiple cycles are applied, if the applied voltage period is set to an integral multiple of $T = 2\,l\,/\,v$ (s) (l is the length of the x-axis specimen, v is the displacement in the z-axis direction), It was found that there are the same number of suppression points as the number of cycles of the applied waveform. In order to express regularity of distribution, we arranged data as shown in Fig.5. If we attempted approximation by a polynomial, and the approximate curve expression of the suppression point was obtained as follows:

$$f = 0.1073x^4 - 5.1505x^3 + 89.122x^2 - 162.28\ x + 7762 \quad \text{(Hz)}$$

4. Conclusion and future challenges

When the frequency and the number of cycles of the driving voltage be controlled, It became clear that the points where the residual vibration can be suppressed are regularly obtained. In the future, we will study the physical reason and what the research can practical use in high power ultrasonic field.

References

1.K.Takasaki,K.Imano,H.Inoue: Generation and sound field observation of monopole ultrasonic pulse,SICE,169-1,pp.1-9(1997)
2.G.Wang,S.Tarvainen and Y.Watanabe:Study on Residual Vibration Control of High Amplitude Ultrasonic Transducer, The 38th Symposium on Ultrasonic Electronics (USE2017) TAGAJOU, MIYAGI、3P4-5
3.K.Uchino : Atsuden/ denwai akuchuēta, Japan Industrial Technology Center 、 1988 、 pp.103-133(1988)
4.K.Chiharu,T.Yoshiro,T.Takehiro,N.Kenetsu:Prevention of Residual Vibration of a Piezoelectric Actuator, Proceedings of Symposium on Ultrasonic Electronics (10), 175-176, 1989-11-07