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Generation of High-Power Ultrasonic Monopole Pulse for Application Ultrasonic Machining

単極性超音波パルス音源の超音波加工への応用

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1. Introduction

In rotary Ultrasonic machining, rotating tool with diamond abrasives are ultrasonically vibrated in the axial direction while the spindle is fed toward the work piece material at constant pressure. By ultrasonic vibration grinding method enables a reduction in the apparent grinding resistance, leading to improvements in the machining surface roughness, quality and lifetime of tools compared conventional CNC machining.

Ultrasonic machining improves surface quality, this is especially important when a subsequent polishing process is required to achieve the necessary part specifications. The more precise the part's surface shape and roughness are after grind process, less time it will take to polish. Ultrasonic transducers especially bolt-clamped Langevin type-ultrasonic transducer (BLT) in use through as its generating devices for high-power ultrasonic. The spindle of ultrasonic machines consists of BLT that provide maximum vibration amplitude in a half-wavelength resonance by specific frequency. However conventional ultrasonic grinding Which use in continuous wave by resonance frequency causes physical damages such as braking, cracking and chipping. We consider that reason of physical damages is occurred by characteristics of impact force and ringing.

In this paper, we process to generate ultrasonic monopole pulse with minimized ringing in order to design suitable ultrasonic transducer and horn for improving surface roughness and quality of hard brittle advanced material.

2. Summary of principles of ultrasonic monopole pulse generation

In a previous study, needed driving voltage waveform of ultrasonic monopole pulse must not containing of resonance frequency component of ultrasonic transducer. First process to avoid a rectangular waveform afterward a half sine waveform having inclination when its rising and falling is applied as the driving voltage waveform. A ringing measuring means measures occurred voltage each driving voltage waveform by Transient response analyzing. Figure 1 shows a half sine waveform.

$$\begin{cases} F(t)=\sin(\omega_0 t) & -\frac{2}{T}\leqq t\leqq\frac{2}{T} \\ F(t)=0 & (t<\frac{2}{T}>\frac{2}{T}) \end{cases} \quad (1)$$

Equation (1) becomes (2) by Fourier-transform.

$$F(\omega)=\frac{\sin(\omega_0+\omega)\cdot\frac{T}{2}}{\sin(\omega_0+\omega)}-\frac{\sin(\omega_0-\omega)\cdot\frac{T}{2}}{\sin(\omega_0-\omega)} \quad (2)$$

To satisfy |F(ω)|= 0, equation leads equation (3)

$$\omega=n\,\omega_0\ (n=2,3,4,\cdots) \quad (3)$$

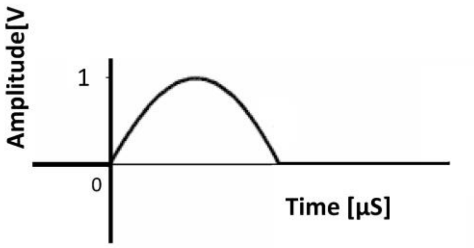

Fig.1 Half-sine driving voltage waveform

Therefore, equation (3) leads $\omega_0=\frac{\omega}{n}$ can be avoid resonance frequency in theory thus we suppose to suppress ringing by this driving voltage waveform.

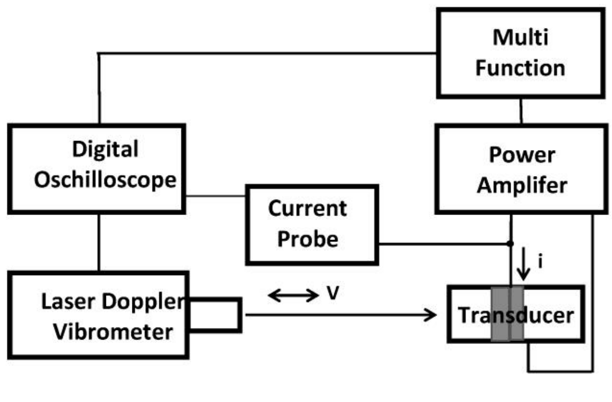

Fig.2 Experimental setup of ultrasonic monopole pulse generation system

3. Experiment

Figure 2 shows the experimental setup.
A half-sine voltage waveform from a multi-function generator was applied to the transmitting ultrasonic transducer through power amplifier.
A disk type of PZT consisted of BLT with 61.5kHz resonance frequency and Quality factor 150 is selected in this experimental. The vibration amplitude (vibration velocity) is transmitted by digital oscilloscope via obtained voltage of laser Doppler Vibrometer. Experimental conditions of input voltage of driving waveform and pulse time shows as below.

Applied input voltage	:1～100 V_{p-p}
Pulse width	:23.6[μs]
Frequency of Pulse ($f_0/2$)	:31.29 [kHz]
Duty ratio of pulse	:7.86 x 10^{-10}

4. Result of experiment

Figure 3 is experimental result for input voltage of driving waveform when maximum vibration amplitude is obtained with minimized ringing. When applied Input voltage $88V_{p-p}$ is obtained maximum vibration amplitude. Figure 4 shows the maximum vibration amplitude 108mVp-p and conversion result in vibration velocity is obtained 54.96[nm/sec.] in experimental condition of input voltage $88V_{p-p}$.

5. Conclusion

We applied different type of driving waveform such as Haver-sine, Gaussian, Lorenz and Ramp waveform however, half-sine waveform produced maximum vibration amplitude with minimized ringing from tested results. The ultrasonic monopole pulse was successfully generated from a conventional BLT by applying driving voltage having no resonance component. Reduced ringing result also we processed in this experiment. Future work will involve investigating to produce suitable vibration velocity, design of ultrasonic transducer and horn in ultrasonic grinding for hard and brittle advanced material.

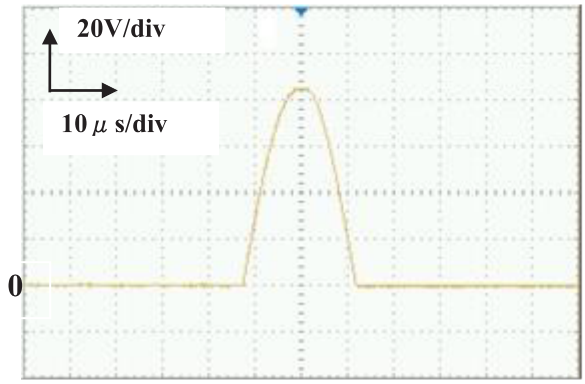

Fig.3 Received waveform of input voltage of driving waveform

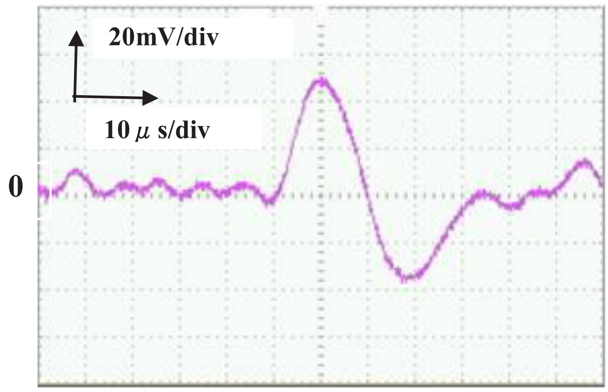

Fig.4 Experimental result of maximum vibration amplitude with minimized ringing.

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