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Development of complex vibration source using longitudinal vibration transducers and diagonal slits –Case of considering vibration of flange–

縦振動子と斜めスリットを用いた複合振動源の開発
–フランジの振動を考慮した場合–

Naoki Saegusa ‡, Takuya Asami, and Hikaru Miura (Coll.of Sci. & Tech.,Nihon Univ.)
三枝直樹‡，淺見拓哉，三浦　光(日本大学)

1. Introduction

Conventionally, ultrasonic vibration applied during welding is almost linear in one direction, which may result in large damage to the welded object and reduced weld strength. Previously, we have shown that by making the vibration direction planar, the damage to the welded object is smaller than when the vibration is only linear, and that the weld strength can be improved [1,2].

The purpose of this study was to develop a new complex vibration source using two longitudinal vibration transducers and diagonal slits.

We have previously shown that a planar vibration locus can be generated by simultaneously inputting longitudinal and torsional vibration resonance frequencies [3,4].

However, the flange used to fix the vibration source in place causes difficulties. When a torsional vibration resonance frequency is input, the propagated longitudinal vibration does not become a node, and further work is needed to effectively fix the vibration source to a jig.

In this study, a method for fixing a complex vibration source without suppressing the longitudinal and torsional vibration that propagates through the whole source was examined to optimize the circumference of the flange for making use of transverse vibration in the flange.

2. Design of complex vibration source

2.1. Constitution of complex vibration source

Figure 1 shows the complex ultrasonic vibration source. The source consists of a uniform rod with a diameter of 15 mm and length of 115 mm (A2017 aluminum), an exponential horn with a narrow end face diameter of 15 mm, a large end face diameter of 30 mm (A2017), and two 39-kHz bolt-clamped Langevin-type longitudinal vibration transducers (Honda Electronics, HEC-3039P4B), one on each end next to the exponential horns. The vibration transducers and exponential horns are each 1/2 wavelength of the longitudinal vibration, and the uniform rod has a resonant length of one wavelength of the longitudinal vibration. The uniform rod was provided with 10 diagonal slits (width 0.4 mm, depth 4.0 mm) angled 35° with respect to the length direction of the rod. The position of the diagonal slits was 1/4 of the length of the uniform rod, that is, the position of the node of the longitudinal vibration. The flange used to fix the vibration source in place was integrated with the exponential horn and installed at the position of the node of the longitudinal vibration. Point A in Fig. 1 indicates the center position of the complex vibration source.

E-mail: csna19016@g.nihon-u.ac.jp,
asami.takuya@nihon-u.ac.jp,
miura.hikaru@nihon-u.ac.jp

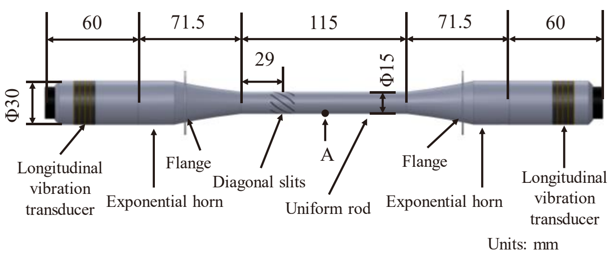

Fig. 1. Complex ultrasonic vibration source.

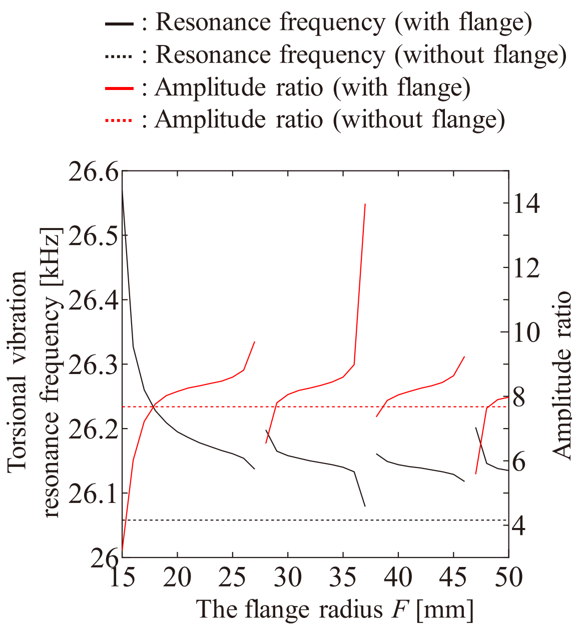

Fig. 2. Relationship between the flange radius F, torsional vibration resonance frequency, and amplitude ratio.

2.2. Examination of flange radius

The flange radius F of the complex vibration source was examined. The examination was carried out using the finite element method and the piezoelectric analysis software in COMSOL Multiphysics. The analysis model had the same dimensions as shown in Fig. 1. The analysis was performed by fixing the flange in place and varying its radius F from 15 to 50 mm.

Figure 2 shows the results. In the figure, the horizontal axis represents the flange radius F, the left vertical axis represents the torsional vibration resonance frequency, and the right vertical axis represents the vibration amplitude ratio (= torsional vibration displacement amplitude / longitudinal vibration displacement amplitude) at point A of the source. The black curve shows the torsional vibration resonance frequency in each dimension, the broken black curve shows the torsional resonance frequency without the flange, the red curve shows the amplitude ratio of torsional to longitudinal vibration amplitude in each dimension, and the broken red curve shows the torsional to longitudinal vibration amplitude without the flange. The results are presented according to the node circles in the flange, which are numbered 1 through 4 from the left.

Here, we consider that it is preferable to construct the vibration source without a flange even though a flange is used in the subsequent experiment.

From the figure, it was found that the larger the flange radius F, the lower the torsional vibration resonance frequency and the higher the amplitude ratio of torsional to longitudinal vibration. Also, the flange radius F is considered to be appropriate at F = 20–25 mm, 29–36 mm, and 40–45 mm, where the torsional vibration resonance frequency and the amplitude ratio are stable.

2.3. Examination of vibration displacement distribution

The vibration displacement distribution of the complex vibration source was examined with the piezoelectric analysis software in COMSOL Multiphysics.

Figure 3 shows the distribution of the vibration amplitude along the central axis of the complex vibration source at the whole source's torsional vibration resonance frequency (26.1 kHz) when the radius of flange F is 32 mm. In the figure, the horizontal axis shows the distance from the center of the flange and the vertical axis shows the vibration displacement amplitude along the central axis of the complex vibration source normalized by the maximum value. The figure shows that the flange transverse vibration occurred at node 2.

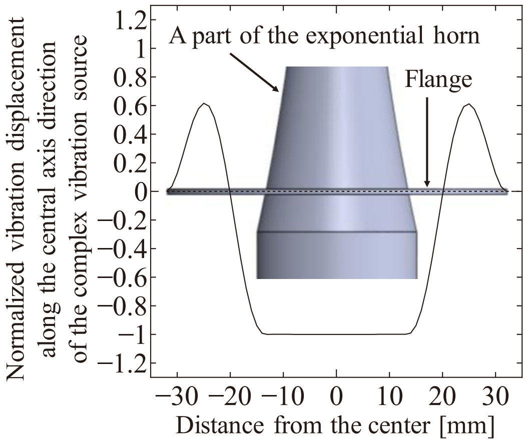

Fig. 3. Vibration amplitude distribution in flange along the central axis direction of the complex vibration source. The flange radius F is 32 mm and the frequency is 26.1 kHz along the z direction of the flange.

3. Conclusions

In this study, the radius of the flange of the complex vibration source was optimized using the finite element method. The results showed that the larger the flange radius F, the lower the torsional vibration resonance frequency and the higher the amplitude ratio of torsional to longitudinal vibration.

In the future, a jig for holding the complex vibration source will be fabricated and the vibration characteristics of the source will be examined.

Acknowledgement

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References

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