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FEM Calculation of Piezoelectric Property on the Geometrical Configuration of a Sonochemical Reactor
圧電振動子を考慮したソノケミカル反応容器の音場計算

Nagaya Okada[1†] and Yoshiyuki Asakura[1] ([1] HONDA ELECTRONICS CO., LTD.)
岡田長也 [1†]，朝倉義幸 [1] （[1] 本多電子）

1. Introduction

Recently, chemical effects and physical effects caused by ultrasonic cavitation have been studied widely. The physical factors for the reaction field have been elucidated by many researchers, clarifying the relationship of chemical action to the shape of the sonochemical reactor, the shape and placement of the transducer, etc. However no investigation has been focused on measuring ultrasonic energy distribution for the industrial scale sonochemical reactors.

In order to have an industrial application of sonochemical action, the important factors that affect cavitaiton include ultrasonic frequency, acoustic power, ambient temperature, ambient pressure, and so on. Many researchers have investigated the frequencies ranging from 20 to 1200 kHz. It was widely noted that the sonochemical reaction efficiency was improved at a high frequency region from several 100 kHz. In these experiments, the irradiation volume ranged from 10 to 500 ml. Asakura et al. examined a sonochemical efficiency for a frequency of 45 kHz was improved using cylindrical sonochemical reactor in 70 mm diameter at a liquid height of 500 mm [1]. This result suggests that precise condition setting of sonochemical field may improve sonochemical efficiency value even at a low frequency.

This study presents an impedance of a transducer dependence on the geometrical configuration of a sonochemical reactor cell. The impedance of the transducer changed significantly when the standing wave field was resonant on an experimental basis [2] and on simulation [3]. The dependence between the impedance of the transducer and the sound pressure distribution in the sonochemical reactor cell was calculated by using the Finite Element Method (FEM).

2. Simulation Model

In the present study, the commercial available FEM software has been utilized (ANSYS, ANSIS Inc.). In the software, the sound field analysis and piezoelectric transducer analysis can be calculated at a same time.

The calculations had been performed for a cylindrical cell with 70 mm in diameter filled with water at 20 ºC. A bolt-clamped Langevin type transducer (BLT transducer) with a diameter of 45 mm was attached to the bottom of the cell. Ultrasonic waves with frequencies of 45 and 123 kHz were irradiated to the liquid through a SUS plat with 1.9 mm in thick.

From the symmetry of the cylindrical cell, a 2-D plane mode has been considered in the calculation. As a boundary condition, the reflectivity coefficient of the reactor's wall was considered. The changes of the impedance on the BLT transducer were evaluated as a function of the liquid height.

3. Results and discussion

The calculated spatial distribution of the pressure amplitude is shown as a function of the liquid height in **Fig. 1**. The BLT thickness was decided as 45 kHz resonant frequency at the liquid height of 100 mm. In **Fig. 1**, the calculated picture shows only a half of the 2-D plane mode, and the right side of the picture is the reactor's wall. The acoustic field is strongly affected by the liquid height. For the case of the liquid height above 220 mm, the clean horizontal stripes of the pressure antinodes and nodes are seen. On the other hand, when the liquid height is a few dozen mm, the horizontal stripes of pressure antinodes is disconnected. **Figure 2** shows the resonant frequency and the impedance of the BLT transducer as a function of the liquid height. The bottoms of the resonant frequency are always constant at 45 and 123 kHz while the liquid height is changing. When the liquid height is more than 320 mm, there is one pair of resonance and anti-resonance frequencies. However, as the liquid height decreases, the pairs of resonance and anti-resonance frequencies increase. The results suggest that the distribution of the impedance is minimized when the sound field is stable as a uniform sound pressure field with the standing wave. The distribution of the resonant frequency may be involved in an energy loss on its transducer.

E-mail: nagaya@honda-el.co.jp †

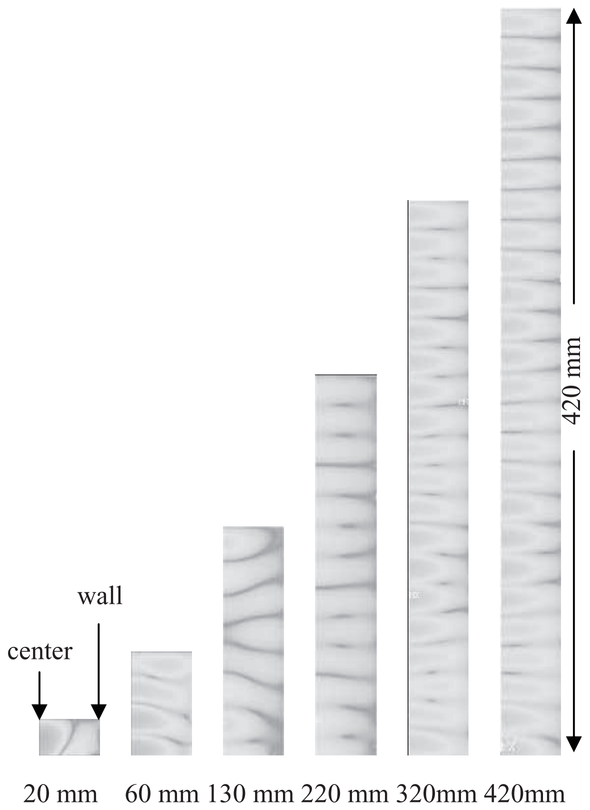

Fig. 1 Calculated spatial distribution of the pressure amplitude at 45 kHz.

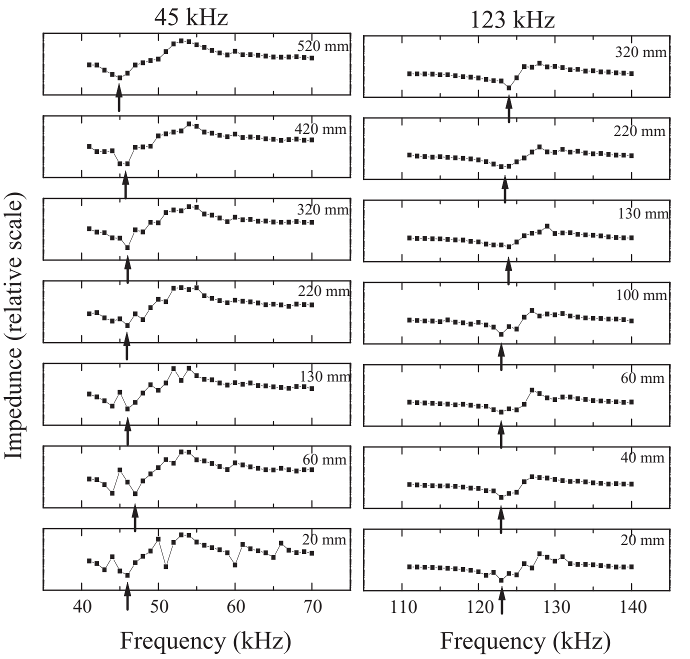

Fig. 2 Dependence of the liquid height on calculated resonant frequency and impedance of the BLT transducer driving at 45 and 123 kHz. Each graphs has same scale value. Arrow marks show the bottom of the resonant frequencies.

In **Fig. 3**, the variation in the ratio of ultrasound power to electric power with the liquid height on the experimental basis is shown [1]. The ratio for the 45, 129 and 231 kHz transducers decreased as the liquid height decreased. As the liquid level decreased, the generation of the heat in the transducer was attributed to its energy loss. **Figure 4** shows the calculated mean acoustic amplitudes in the liquids on the simulations. This graph shows a similar tendency that the efficiency of the ultrasound acoustic power decreases at the low liquid height region below a few100 mm on the experiments.

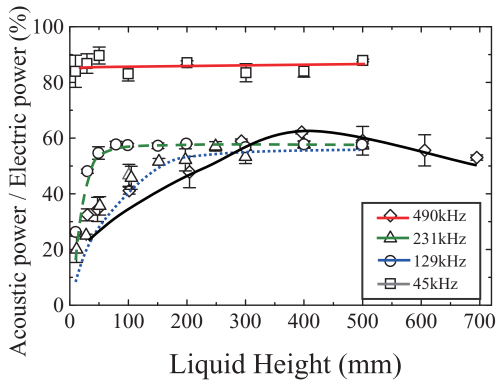

Fig. 3 Variation in the ration of electric power to ultrasound power with liquid height [1].

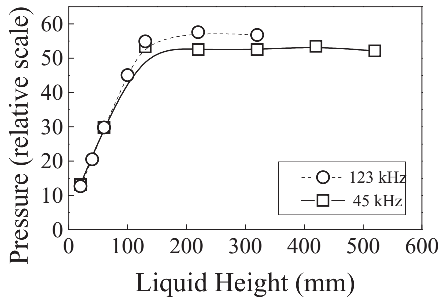

Fig. 4 Variation in the average sound pressure with liquid height for different frequencies on simulations.

Although studies with influence of the damping, cavitations and so on may be important for an advanced simulation, this results have suggested that the impedance changing may be used instead of measuring acoustic field.

4. Conclusion

The impedance of the transducer dependence on the sound pressure field condition was evaluated using the FEM method. The results suggest that the spatial distribution of the pressure amplitude can be read by the change of the impedance. It must be helped very much to understand the optimal design of the sonochemical reactor cell.

References

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