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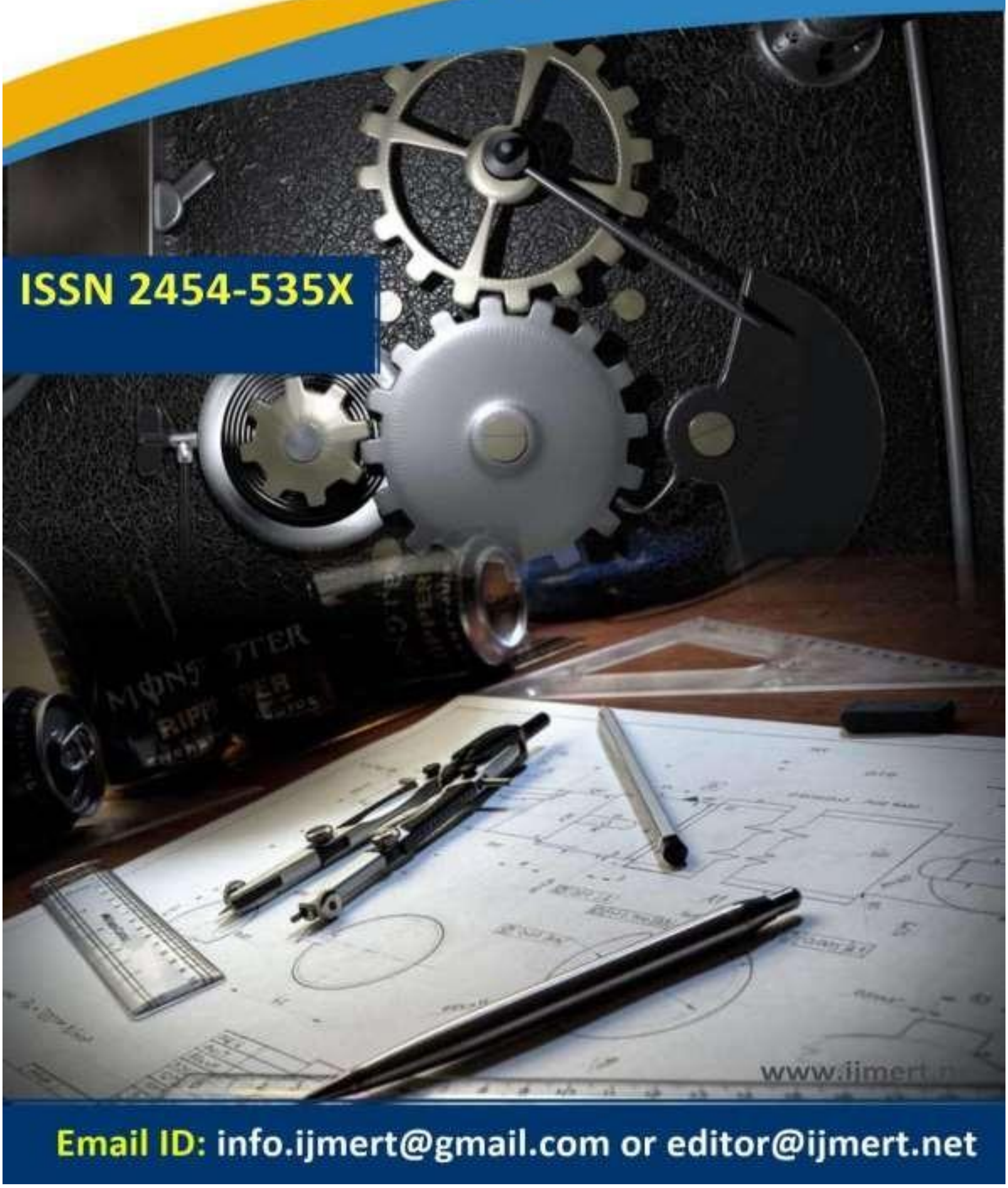

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Study on Moisture Stack for Low-Temperature - Oscillation of Thermoacoustic System-Effects of Stack Length on Oscillation Temperature and Sound Pressure

Shanker[1], Mahendra[2], Surrender[3], Shanker[4], Yadagiri Rao[5], Chakravarthy[6], &Vikram [7]

Graduate School of Life and Medical Sciences, Doshisha University, Kyotanabe, Kyoto 610-0321, Japan
Graduate School of Science and Engineering, Doshisha University, Kyotanabe, Kyoto 610-0321, Japan
Department of Electronic Systems Engineering, University of Shiga Prefecture, Hakone, Shiga 522-8533, Japan
*E-mail: ctuc1014@mail4.doshisha.ac.jp

ABSTRACT:

In a thermoacoustic system, heat and sound are converted in the area with the temperature gradient. It is common knowledge that adding water to the stack generates a low temperature oscillation and produces output comparable to that of a dry stack. The increase in the effective stack area, which aids in the thermoacoustic conversion caused by the addition of water, is assumed to be the cause. In order to ascertain the impacts of modifying the stack length under wet conditions on oscillation temperature and output sound pressure, experimental study is conducted in this paper. As a result, it is found that while the oscillation temperature is independent of the stack length, the output sound is.

KEYWORDS: low temperature oscillation; thermoacoustic; linear; gradient; vapor

INTRODUCTION

For ITES employees, setting priorities and striking a balance between their personal and professional lives is a challenge. Hybrid workplaces are thought to be the way of the future. Although hybrid employment has been around for a while, COVID-19 marked a significant shift in the workplace. This paradigm, which combines both in- and outside-the-cubicle labor, is also referred to as a hybrid mode of work. There are two types of work: in-office work and remote work. It is tough for employees to alternate between doing physical labor and working remotely. The primary goal of the study is to understand the elements that affect work-life balance in order to improve employee engagement in hybrid work environments

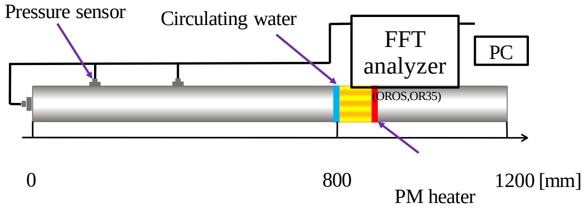

Figure 1. Experimental setup.

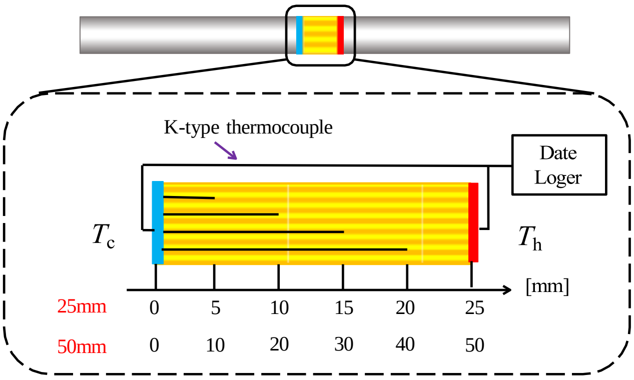

Figure 2. Temperature measurement system

EXPERIMENT

Experimental setup

The experimental system is illustrated in **Fig. 1**. A 1200 mm straight tube is constructed with a stainless-steel tube with a 42 mm inner diameter. A stack with the same diameter is set at the position of 800 mm distant from the end of the tube, and a prime mover (PM) is composed by two thermal exchangers. A honeycomb ceramic with a 0.65 mm flow-path radius is employed for the installed stack. The high temperature heat exchanger is an electric heater (PM heater) wound around the tube for heating the tube. A method to circulate water in the outer circumference of the tube is employed for the low temperature heat exchanger. Measuring from the end of the system, pressure sensors (product of PCB Co.) are set at 0, 150 and 550 mm to observe the pressure amplitudes in the tube. Furthermore, as shown in **Fig. 2**, the temperatures T_h and T_c at the hot and cold ends of the stack as well as the temperature in the stack are measured with K type thermocouples.

Using this system, the experiment is conducted under two conditions where the stack length is set 25 or 50 mm.

Experimental method

To keep the stack wet, the stack with the addition of 3 g water that fully exceeds the amount of saturated vapor in the tube is set in the tube. Then the electric input power to the heater is adjusted so that the temperature T_h at the hot end of the stack becomes the critical temperature for the oscillation. Thereafter, the change of the temperatures at both ends as well as the inside of the stack, the oscillation temperature and the output sound pressure are observed. Here the sound pressure at the end of the system tube which is the antinode of the pressure to exceed 10 Pa is defined as the oscillation of the system.

RESULTS AND DISCUSSIONS

In the case of 25 mm stack length, the oscillation temperature is 74°C and the output sound pressure at the steady state is 120 Pa. On the other hand, in the case of 50 mm stack length, they are 66°C and 215 Pa. From this result, it is seen that, while the oscillation temperature does not much depend on the stack length, the output sound pressure depends on the stack length.

The temperature distributions in the stack just after the oscillation starting and at the steady state are shown in **Figs. 3** and **4**. These results show that, excepting the values at 50 mm of Fig. 4, the temperature distribution in the stack is linear between the hot end and the cold end. The phenomenon peculiar to the moisture stack occurs due to the increased heat conductivity as well as the high temperature vapor generated by added water. By the way, the reason for the experimental result that the temperature gradient is not linear at the oscillation for the case of 50 mm stack is surmised that the heat does not fully transmit to the whole area of the stack yet before starting the oscillation, though the gradient shifts to linear after a while at the steady state.

The conversion between heat and sound in the thermoacoustic system takes place in the region where temperature gradient exists.[1)] Therefore, in Fig. 3 for the moment just after starting the oscillation, the conversion from heat to sound takes place in the 25 mm region from the hot end of the stack in both cases. On the other hand, at the steady state, as confirmed in Fig. 4, the sound energy is supposed to be produced at the entire area of the stack in both conditions.

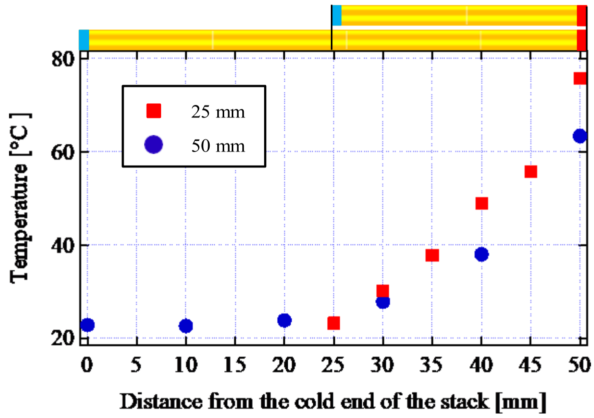

Figure 3. Temperature distribution in the stack immediately after starting oscillation

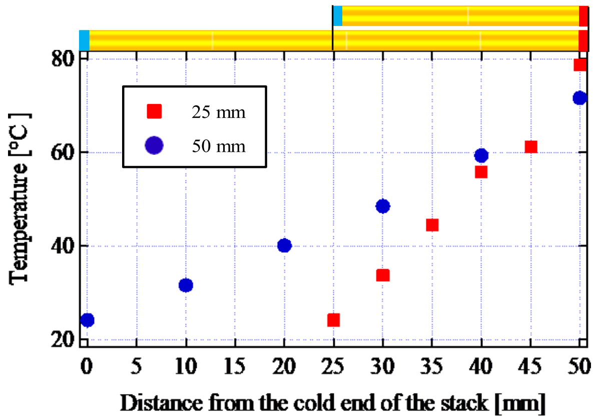

Figure 4. Temperature distribution in the stack at steady condition

To quantitatively confirm the above, the distribution of the generated power W is obtained by the following equations using the temperature gradient in the stack.

$$W = W_p + W_s, \qquad (1)$$

$$W_p = \frac{1}{2}\mathrm{Re}[h]\,\beta\omega P_0\xi_0\sin\theta\nabla T, \qquad (2)$$

$$W_s = \frac{1}{2}\mathrm{Im}[h]\,\beta\omega P_0\xi_0\cos\theta\nabla T, \qquad (3)$$

$$h = \frac{\chi_\alpha - \chi_\nu}{(1-\chi_\nu)(1-\sigma)}, \qquad (4)$$

where W_p is the thermoacoustic power produced by the traveling wave and W_s is that produced by the standing wave.[1)] Furthermore, □□ and □□ are the complex functions to express the heat diffusion and the viscosity in the sectional area of the stack, and □ is the Prandtl number.[1)] As an example, the calculated distribution of the produced power in the 50 mm long stack is shown in Figs. 5 and 6 for the moment just after starting the oscillation and the steady state, respectively. Comparing these distributions with the temperature gradient in the stack, the energy production is confirmed to take place primarily in the region where the temperature gradient exists. Furthermore, the integrated value of the produced power is listed in Table 1. This result shows that the total amounts of the produced power in the 25 and 50 mm stacks are comparable immediately after starting the oscillation. Namely, in the case of the moisture stack, the vicinity of the hot end is confirmed to contribute to the oscillation regardless of its length. On the other hand, when the stack is very long, the oscillation temperature is raised because the dissipation in the stack increases. Further, at the steady state of the wet condition, the output pressure proportional to the stack length is surmised to be obtained. Even in the wet condition, when the stack is excessively expanded, the produced quantity lowers because the temperature gradient becomes gentle. From these results, the optimum value is assumed to exist for the stack length to fit with the system.

Table 1. Integrated value of generated power.

Stack[mm]	Oscillation	Steady
25	0.0014[W/m^2]	0.31[W/m^2]
50	0.0012[W/m^2]	0.85[W/m^2]

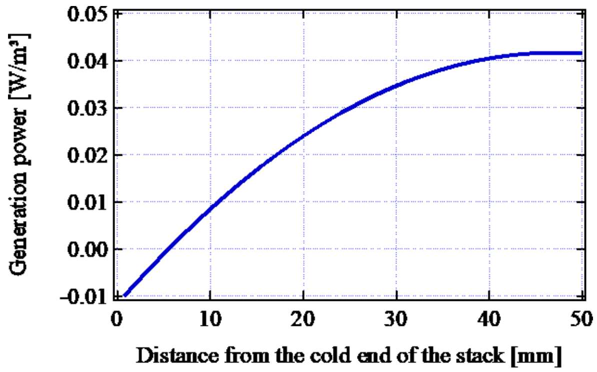

Figure 5. Generated power distribution immediately after starting oscillation

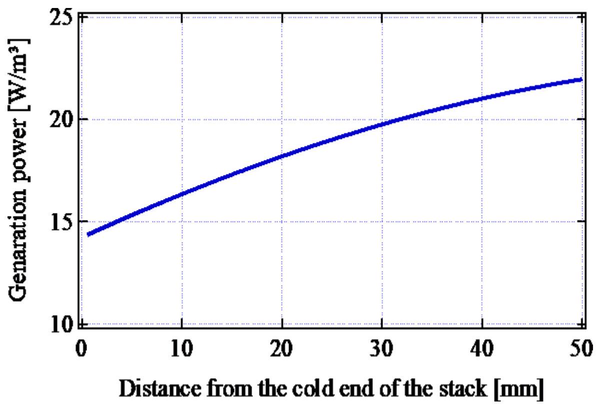

Figure 6. Generated power distribution at steady condition

CONCLUSION

The influences of the total length of the moisture stack on the oscillation temperature and on the output sound pressure were discussed. As the result, the energy production near the hot end of the stack and that in the entire area of the stack were confirmed to contribute to the oscillation temperature and the output sound pressure, respectively. However, since the excessive expansion of the stack makes the increased dissipation dominant, the optimum value is assumed to exist for the stack length to fit with the system.

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REFERENCES

[1] A. Tominaga. “Thermodynamic aspects of thermoacoustic theory”. *Cryogenics*, vol. 35, no. 7, pp. 427- 440, 1995.

[2] P.H. Ceperley. “A pistonless Stirling engine — The traveling wave heat engine”. *Journal of the Acoustical Society of America*, vol. 66, No. 5, pp. 1508-1513, 1979.

[3] T. Yazaki, T. Biwa, A. Tominaga. “A pistonless Stirling cooler”. *Applied Physics Letters*, vol. 80, No. 4, pp. 157-159, 2002.

[4] A.M. Khattak, I. Ahmed, Z. Anjum, M. Zamir, F. Jamal. “Some Contribution of Soft Pre-Open Sets To Soft W-Hausdorff Space In Soft Topological Spaces”. *Matrix Science Mathematic*, vol. 2, no. 2, pp. 25- 27, 2018.

[5] S. Sathishkumar, M. Kannan. “Topology Optimization of Integrated Combustion Engine Piston Using Fea Method (Cae Tools)”. *Acta Mechanica Malaysia*, vol. 2, no. 1, pp. 01-05, 2019.

[6] R. Rana, R. Kumar. “Performance Analysis of Aodv In Presence of Malicious Node”. *Acta Electronica Malaysia*, vol. 3, no. 1, pp. 01-05, 2019.

[7] A. Gautam, R. Batra, N. Singh. “A Study on Use of Rice Husk Ash in Concrete”. *Engineering Heritage Journal*, no. 1, pp. 01-04, 2019.

[8] Y. Ueda, C. Kato. “Stability analysis of thermally induced spontaneous gas oscillation in straight and looped tubes”. *Journal of the Acoustical Society of America*, vol. 124, No.2, pp. 851-858, 2008.

[9] Y. Takeyama, S. Sakamoto, Y. Watanabe. “Study on the setting position of a prime mover in the coaxial- type thermoacoustic cooling system: Comparison with the straight-tube-type thermoacoustic system”. *Japanese Journal of Applied Physics*, vol. 57, 07LE14, 2018.

[10] K. Tsuda, Y. Ueda. “Abrupt reduction of the critical temperature difference of a thermoacoustic engine by adding water”. *AIP Advances*, vol. 5, No. 9, 097173, 2015.

[11] D. Noda, Y. Ueda. “A thermoacoustic oscillator powered by vaporized water and ethanol”. *American Journal of Physics*, vol. 81, No. 2, pp. 124-126, 2013.

[12] R. Raspet, W.V. Slaton, C.J. Hickey, R.A. Hiller. “Theory of inert gas-condensing vapor thermoacoustic: Propagation equation”. *Journal of the Acoustical Society of America*, vol. 112, pp. 1414-1422, 2002.

[13] K. Tsuda, Y. Ueda. “Critical temperature of traveling- and standing-wave thermoacoustic engines using a wet regenerator”. *Applied Energy*, vol. 96, pp. 62-67, 2017.

[14] S. Kawaminami, S. Sakamoto, S. Fukuda, Y. Watanabe. “Step-type thermoacoustic system saturated with water vapor: Study for stabilization of low-temperature driving”. *Japanese Journal of Applied Physics*, vol. 56, 07JE12, 2017.

[15] S. Kawaminami, S. Sakamoto, K. Kuroki, Y. Watanabe. “Loop-tube-type thermoacoustic system saturated with water vapor–Observation of stability of low-temperature driving”. *Proceedings of symposium on Ultrasonic Electronics*, vol. 38, 2017.

[16] K. Kuroki, S. Sakamoto, Y. Takeyama, Y. Watanabe. “Study on the low-temperature driving of a thermoacoustic system: Comparison of temperature distributions in the stack with and without water supply”. *Japanese Journal of Applied Physics*, vol 58, SGGD13, 2019.