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Numerical Studies of Thermo Acoustic Prime Mover on the Application of Renewable Energy

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***Abstract* – Thermo acoustic Prime Movers (TAPMs) work on the principle of conversion of heat energy to sound energy which is used to drive engine by the variation of pressure created by acoustic power. In order to develop a system theoretical knowledge about the dimension of a prime mover, working gas and operating temperature are required. This paper presents the studies of influence of working fluid in Thermoacoustic Prime mover using Delta EC software. The analysis indicates that the variation of resonant frequency, Amplitude of the acoustic wave depends on the properties of working gas(es).**
***Keywords:* Standing Wave, Thermo acoustic Prime Mover, Working Gas, Charge Pressure, Cryo Cooler, Gas Mixture**

I. INTRODUCTION

Recent developments in space technology and industries indicate the need of Cryocoolers with high performance and long term reliability with minimum maintenance schedules. Conventional Cryocoolers such as GM, Stirling, etc., do not meet these demands due to the moving components both at ambient and cryo temperature that lowers their efficiency [1].

Pulse Tube Cryocoolers although eliminates moving parts at cryogenic temperatures, still there are moving components at ambient temperature. The TAPMs are a solution due to the total absence of moving components. A typical thermoacoustic engine consists of a heater, stack (equivalent to the regenerator of a cryocoolers), heat exchangers and resonator. The appropriate phase relationship of intrinsic pressure and velocity components lead to the conversion of heat energy to acoustic oscillations.

The TAPM was first used by Swift and Radebaugh in 1990 [2] to drive a Pulse Tube Cryocooler. As on date, this field is well developed by several experimental and theoretical studies with the focus of developing highly reliable thermoacoustic prime movers [3].The development of a TAPM should be guided by numerical modeling and this may be carried out by several techniques such as solving energy equations, enthalpy flow model, DeltaEc, CFD etc.

However, in this work, we present the Delta EC analysis of single ended and twin ended prime mover, where both geometrical and operational parameters have been varied. Also experimental studies have been carried out on the standing wave twin TAPM, built in our laboratory [4]. The theoretical results predicted by Delta EC are reasonably in good agreement with experimental studies.

II. STANDING WAVE PRIME MOVER MODEL

Fig. 1 shows the schematic diagram of the simulation model of the symmetric standing-wave thermoacoustic prime mover. The system includes the resonance tube, hot buffers, hot heat exchangers (HHE), stacks, and cold heat exchangers (CHE), which were symmetrically arranged on the both sides of the resonance tube. the stacks and heat exchangers were prepared with stainless steel and copper plates respectively, using 0.5 mm thickness plates, while the space between two plates were 1.0 mm.

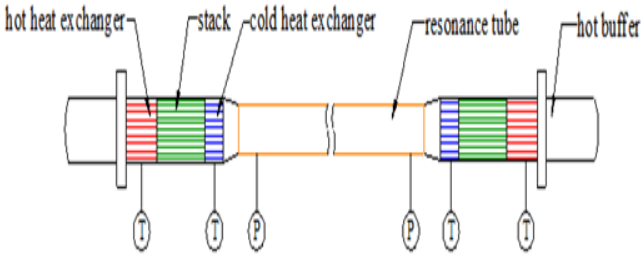

Fig.1 Schematic diagram of the simulation model of the symmetric standing-wave thermoacoustic prime mover

Fig. 2 shows the cross section of the stacks and heat exchangers. The plates were separated from each other by the thin sticks. The oscillating gas flows in the spaces between the plates.

The hot heat Exchangers were insulated with ceramic fiber. The resonance tube was a copper tube of 1.5 m length. Dimensions of the main parts of the thermoacoustic prime mover are presented in Table I.

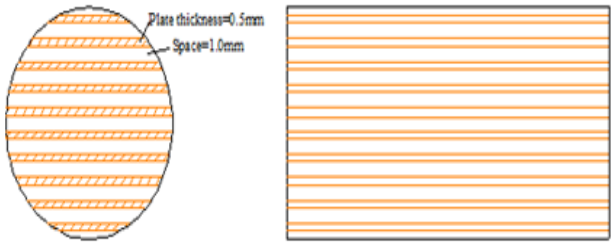

Fig. 2 Cross section of the stacks and heat exchangers

III. RESULTS AND ANALYSIS

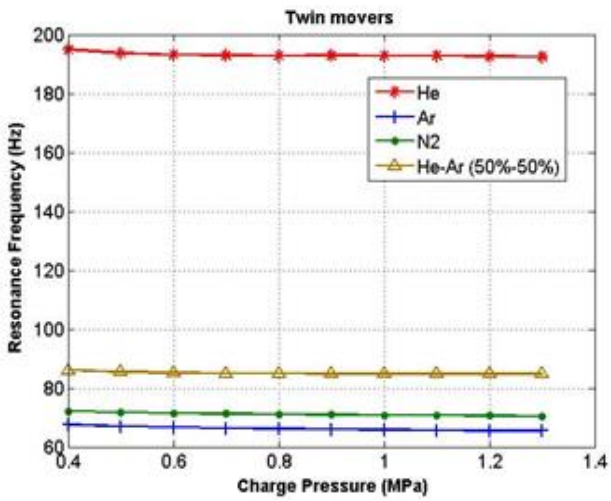

Fig. 3 Resonance frequency – Charge pressure Characteristics

A. *Working Gas and Charge Pressure*

The effects of the working gas with different charge pressures on the performance of the movers were simulated. The system charge pressure was varied from 0.4 MPa to 1.3 MPa. The ambient temperature was 300K. The input power of each heater was kept at 1 kW. The wall temperature of the cold heat exchanger was assumed constant at 300K. The working gases were helium, argon, nitrogen and He-Ar mixture (50%-50%) in different cases, respectively.

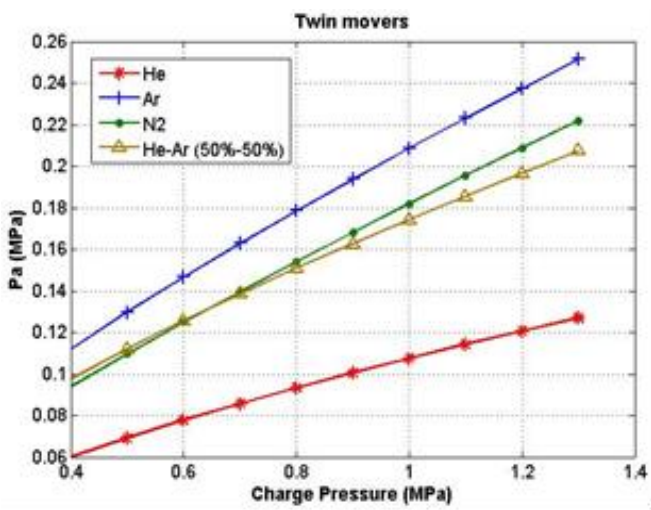

Fig. 4 Variation of Pressure amplitude with Charge Pressure

The minimum resonance frequency can be achieved using argon gas due to its lowest acoustic speed. The resonance frequency of the 1/2 wavelength standing thermoacoustic prime mover can be expressed by

$$f = \frac{a}{2L} = \frac{\sqrt{\gamma RT}}{2L}$$

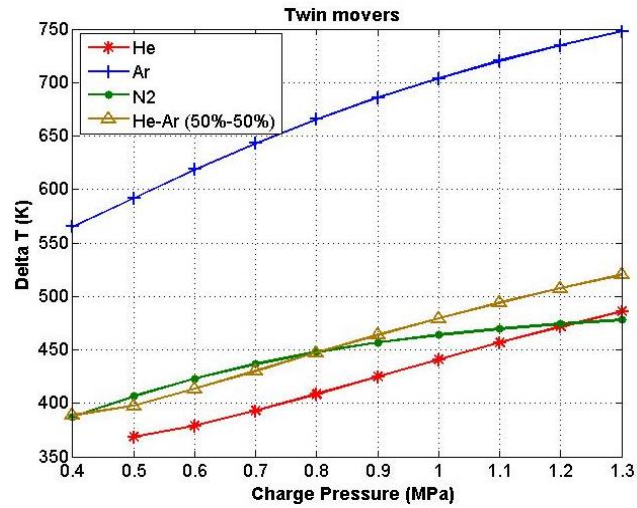

Fig. 4 Variation of Delta T with Charge Pressure

The pressure amplitude and onset temperature difference (Delta T) of the mover increased with the charge pressure of the working gases. The maximal pressure amplitude of the mover can be achieved using argon gas; however, the higher Delta T was also essential for this gas.

TABLE I DIMENSIONS OF THERMO ACOUSTIC PRIME MOVERS

Items	Hot buffer	HHE	Stack	CHE	Resonance tube
Inner diameter (mm)	51	51	51	51	38
Length (mm)	110	80	200	40	1500

IV. CONCULSION

The performance of the standing-wave thermoacoustic prime mover has been simulated using DeltaEc program. The effect of the working gas on the performance of the movers have been analyzed and compared. Simulation results indicate that the working gas with different charge pressures are critical for the performance of the movers. The results also indicate that the mixtures can improve the Delta T and pressure amplitude compared to pure argon gas and pure helium gas, respectively.

REFERENCES

[1] G. W. Swift, "Thermo acoustic engines", *The Journal of the Acoustical Society of America*, Vol. 84, No. 2, pp. 1145-1180, June 1998.

[2] G. W. Swift, "Analysis and performance of a large thermo acoustic engine," *The Journal of the Acoustical Society of America*, Vol. 92, No. 3, August 1998.

[3] S. W. Zhu and Y. Matsubara, "Theoretical and experimental study of acoustic engines", *Proceedings of 7th International Conference on Stirling Cycle Machines*, November 5-8 at Waseda University, Tokyo, 1995.

[4] S. L. Zhou and Y. Matsubara, "Experimental research of thermoacoustic prime mover", *Cryogenics*, Vol. 38, No. 8, pp. 813-822, August 1998.