Design, Analysis and Fabrication of Thermoacoustic Refrigeration

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Abstract:

We basically have completed the design, fabrication of the system based on the principles of Thermoacoustic refrigeration. We have done numerical calculations and have fabricated the prototype model for the same and have noted down the experimental results.

Working:

Consider a parcel of gas in a channel between two plates, where the gas is acted upon by an acoustic standing wave. The thermoacoustic process can be conceptually simplified into four steps. First, the gas parcel undergoes adiabatic compression and travels up the channel due to the acoustic wave. The pressure increases by twice the acoustic pressure amplitude, so the temperature of the parcel increases accordingly. At the same time, the parcel travels a distance that is twice the acoustic displacement amplitude. Then the second step takes place. When the parcel reaches maximum displacement, it is has a higher temperature than the adjacent walls, assuming the imposed temperature gradient is sufficiently small.

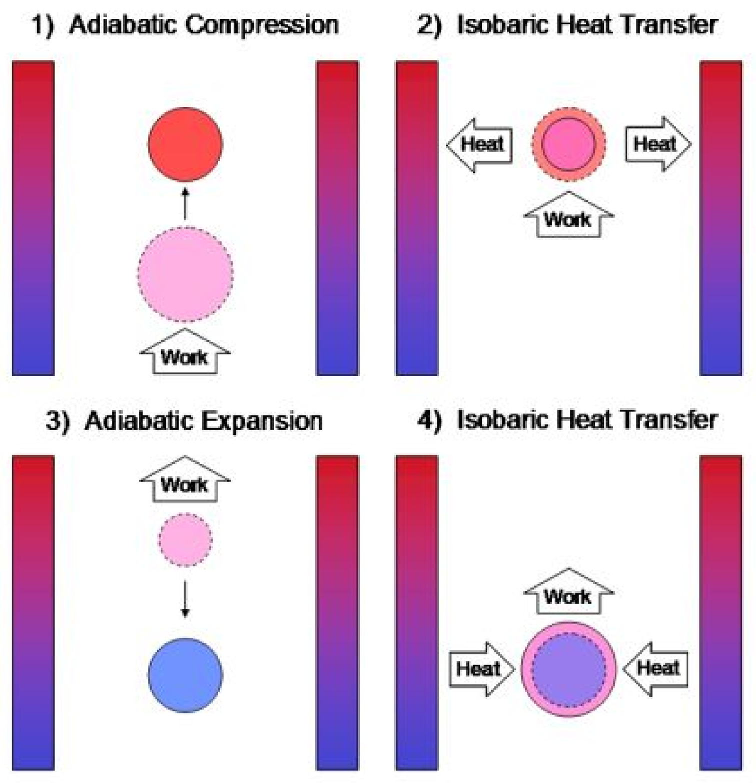
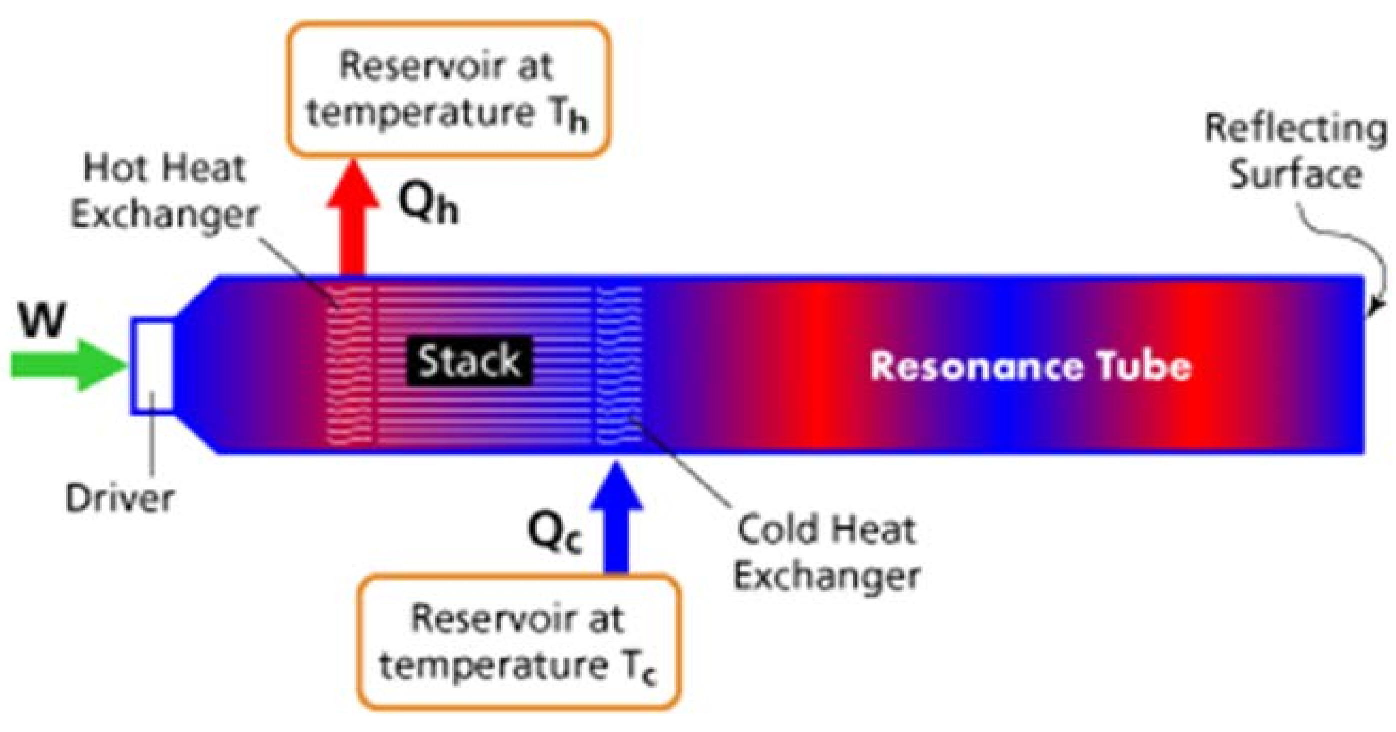


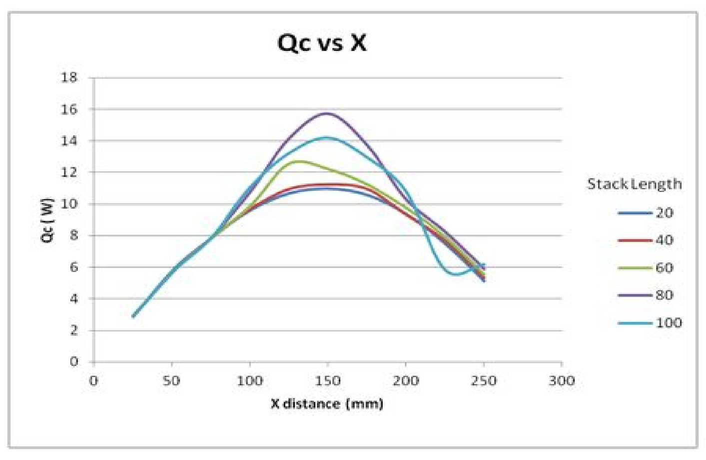
Fig. Simplified thermodynamic cycle experienced by a gas parcel in a thermoacoustic refrigerator.

Therefore, the parcel undergoes an isobaric process by which it rejects heat to the wall, resulting in a decrease in the size and temperature of the gas parcel. In the third step, the second half-cycle of the acoustic oscillation moves the parcel back down the temperature gradient. The parcel adiabatically expands as the pressure becomes a minimum, reducing the temperature of the gas. The gas reaches its maximum excursion in the opposite direction with a larger volume and its lowest temperature. Finally, in step four, the parcel's temperature has become lower than the local wall temperature so that heat flows from the wall to the gas parcel. The process then repeats so that small amounts of heat can be transported up the temperature gradient along the wall.

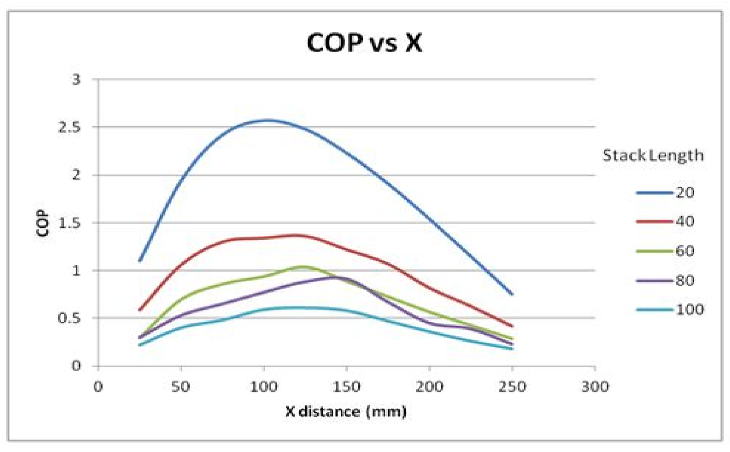


Analysis:

The analysis part includes the analytical calculations to be carried out to find the sack length and stack position in the resonator body. These parameters are vital for constructing a working TAR system and obtaining the require results.



Cooling power vs. stack center position for various stack lengths



Coefficient of performance vs. stack position for various stack lengths

Result:

Frequency	Temperature					Heat Rejected		Power input	COP	
	T_1	T_2	T_3	T_4	T_5	Q_s	Q_a	P	COP_s	COP_a
Hz	°c	°c	°c	°c	°c	W	W	W		
100	30	32	33	34	33	1.28	1.28	6	0.21	0.21
150	30	32	33	34	33	1.28	1.28	6	0.21	0.21
200	30	31	33	34	33	2.56	2.56	6	0.42	0.42
250	30	29	32	35	33	3.84	5.12	6	0.64	0.85
300	30	28	32	35	33	5.12	6.41	6	0.85	1.07
350	30	29	32	35	33	3.84	5.12	6	0.64	0.85
400	30	31	33	34	33	2.56	2.56	6	0.42	0.42
450	30	32	33	34	33	1.28	1.28	6	0.21	0.21
500	30	32	33	34	33	1.28	1.28	6	0.21	0.21

Table 1. Experimental Results for 1 bar gauge pressure

Frequency	Temperature					Heat Rejected		Power input	COP	
	T_1	T_2	T_3	T_4	T_5	Q_s	Q_a	P	COP_s	COP_a
Hz	°c	°c	°c	°c	°c	W	W	W		
100	30	32	33	34	33	1.28	1.28	6	0.21	0.21
150	30	31	33	34	33	2.56	2.56	6	0.42	0.42
200	30	30	33	34	33	3.84	3.84	6	0.64	0.64
250	30	29	32	35	33	3.84	5.12	6	0.64	0.85
300	30	27	32	35	33	6.41	7.69	6	1.07	1.28
350	30	29	32	35	33	3.84	5.12	6	0.64	0.85
400	30	29	32	34	33	3.84	5.12	6	0.64	0.85
450	30	30	32	34	33	2.56	3.84	6	0.42	0.64
500	30	31	32	34	33	1.28	2.56	6	0.21	0.42

Table 2. Experimental Results for 2 bar gauge pressure

1.COP obtained was more for 2 bar gauge pressure than 1 bar gauge pressure; hence we presume that with the increase in pressure the COP also increases.

2. COP obtained for temperature difference across the stack cold end face and ambient temperature is more than the COP obtained for the temperature difference across the stack.

Conclusion:

- After conducting the practical experiments, we found that our analytical analysis and practical results matched perfectly, hence the analysis was perfect.
- The design of TAR system was for a pressure of 1bar gauge and we operated it up to a pressure of 2 bar gauge successfully, hence we conclude that our design was justified.
- From the obtained results it can be concluded that the TAR system can work much more efficiently at higher pressures.
- We have successfully showcased a refrigeration system which eco-friendly and low on power consumption.