Design and an Experimental Investigation of Two Stage Pulse Tube Refrigerator

Akshat Agrawal[1], Abhishek Soni[2]
[1](Mechanical Engineering Department, MITM Indore, India)
[2](Mechanical Engineering Department, MITM Indore, India)

ABSTRACT : *The objectives of the present work is describes the analysis, design and an experimental working model of two stage pulse tube refrigerator. By using the Experiment set-up cooling Behavior of the refrigeration system and refrigeration power have been investigate. A minimum temperature of 233.1K at 15.36 W refrigeration power achieved by this two stage pulse tube refrigerator with the system pressure of 7 bar (Abs) and operating frequency of 2.Hz. The 1st stage cold head reaches a lowest temperature of 255.4 K after 220 min and the 2nd stage cold head attains 233.4 K after about 200 min.*

Keywords *– Analysis, Cryocooler, Pulse tube, Regenerator*

1. INTRODUCTION

Many types of cryocoolers for the lower temperature region are carried out as coolers in series. One cooler is used to precool the next stage. However, a precooling stage reduces the Flow to the final stage, hence has the tendency to reduce the cooling power. In this paper we address the question of when and how multi staging in pulse tube coolers improves the coefficient of performance and under which conditions this improvement can be optimized. In order to avoid complicated mathematical or numerical calculations we assume that the only irreversible process in the regenerator is heat conduction. So the flow resistance of the regenerator is zero and the thermal contact between the fluid and the matrix is perfect. If in addition the heat capacity of the regenerator matrix is very large (so the gas temperature is constant in time but varies with position) and the working fluid is an ideal gas then, in the steady state, the average enthalpy flow in the regenerator is zero.

The present work reports the design, development and experimental investigation of two stage U-type pulse tube refrigerator. Air is used as working substance for the performance investigation as helium is not readily available. The geometrical parameters have been kept constant and operating parameters have been varied to evaluate the performance of two stage pulse refrigerator.

2. EXPERIMENTAL SETUP AND DETAIL

The schematic of the experimental set-up is as shown in the Fig. 1. The whole experimental set-up can be divided into five units namely the compressor unit, the pressure wave generating unit, the cold box unit, the data acquisition system and the vacuum module. The compressor unit consists of the compressor, and the Filter drier. The low-pressure working fluid is compressed to a high pressure in the compressor. The working fluid then passes through the filter drier where the oil and other fine impurities are removed. The suction and discharge ends are connected to a solenoid valve that is actuated by an electrical frequency varying unit.

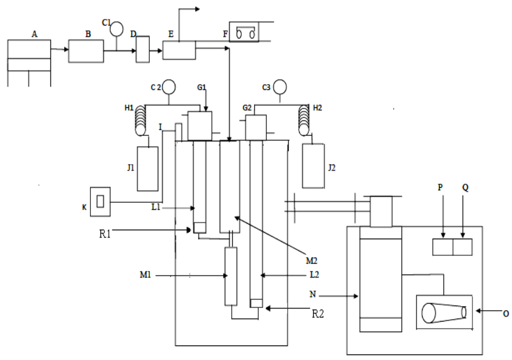

Fig. 1- Schematics of Experimental setup, A- Two stage Air Compressor, B-Air reservoir, C-Pressure gauge, D-Filter drier, E-Solenoid valve, F-Cyclic timer, G- water jacket, H-Inertances, I-feed trough, J-buffer volume, K-Temperature indicator, L-Pulse tube, M- Regenerator, N-Diffusion pump, O-Rotary Pump, P-Pirani Gauge, Q-Paining Gauge, R-Temperature sensor.

The pulse tubes and regenerators are fabricated from stainless steel tube with outer diameter, wall thickness and lengths as follows: 1st stage pulse tube 19mm×1mm ×270mm; 1st stage regenerator 24mm×1mm ×130mm; 2nd stage pulse tube14mm×1mm ×390mm and 2nd stage regenerator 19mm×1mm ×150mm.The 1st stage regenerator is filled with 1000 discs of 150 mesh phosphorus bronze screens and 2nd stage regenerator is filled with 1100 discs of 150 mesh stainless steel screens.

3. RESULT AND DISCUSSION

3.1 COOL DOWN CHARACTERISTIC CURVES OF TWO STAGE PULSE TUBE REFRIGERATOR.

The cool-down characteristics of the two stage cooler are displayed in Figure 2.The settings of the solenoid valve with the help of cyclic timer were optimized here for the lowest temperatures at the 1st stage and 2nd stage cold heads. The 1st stage cold head reaches a lowest temperature of 255.4 K after 220 min. The 2nd stage cold head attains 233.4 K after about 200 min at 2 Hz frequency and 7 bars pressure under no load condition.

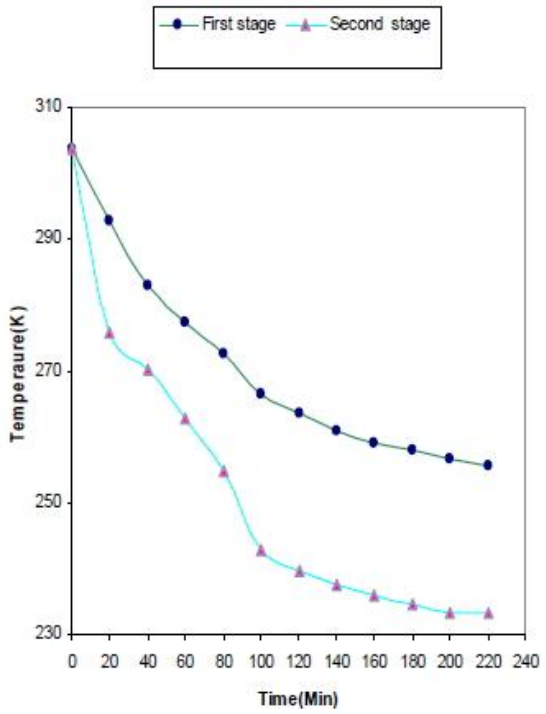

Fig. 2- Cool down curves of two stage pulse tube refrigerator, f =2Hz, Ph=7 bar

3.2 VARIATION OF COLD HEADS TEMPERATURE AT DIFFERENT VALUES OF FREQUENCY

Experiments were conducted with frequencies of 0.9 Hz to 2 Hz with Air as working fluid. The result is shown in figure-3 Pulse tube refrigerator works at low frequencies. Frequency defines the diffusion depth in the working fluid and the regenerator material. When frequency is increased diffusion depth decreases and the heat storage in the regenerator degrades. High operating frequency means a big pressure drop in the regenerator, which leads to a poor performance. Hence low frequencies (0.9Hz to 2 Hz) were used. It was observed that with a frequency of 2 Hz lower no load temperature could be achieved. This can be attributed to the fact that higher frequency increases time averaged enthalpy flow.

Fig. 3 shows that the cold heads temperature decrease with increases the frequency up to certain value. The optimum frequency for the present geometry configuration is found 2Hz at high pressure 7 bars (abs) at the inlet of the pulse tube. The lowest cold end temperatures of 233.1 K and 255.4 are observed under no load condition for the same operating parameters.

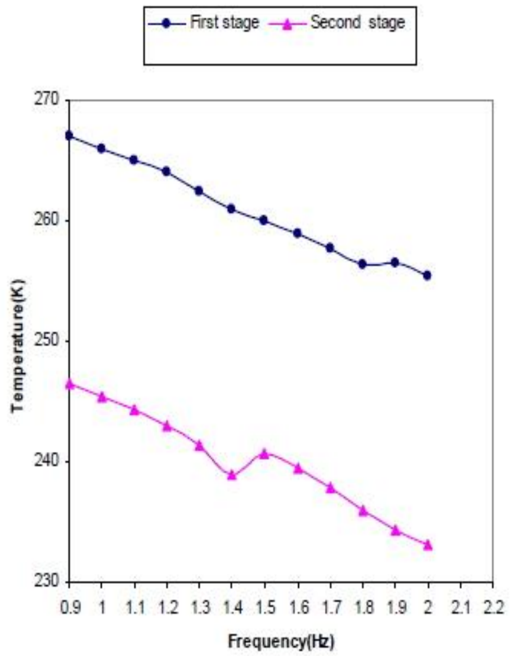

Fig. 3- Variation of cold head temperature with frequency

4. CONCLUSION

Experimental investigations have been carried out on a two-stage, pulse tube Cryocooler with U-type configuration. The following are the major conclusions of the work:

A minimum temperature of 233.1K at 15.36 W refrigeration power achieved by this two stage pulse tube refrigerator with the system pressure of 7 bar (Abs) and operating frequency of 2.Hz..

The 1st stage cold head reaches a lowest temperature of 255.4 K after 220 min and the 2nd stage cold head attains 233.4 K after about 200 min at 2 Hz frequency and 7 bars pressure under no load condition.

The Cold end temperature decreases with the increase in inlet high pressure at particular frequency and geometric condition.

REFERENCES

[1] Kasthurirengan, G. srinivasa, G.K.Karthik and K.A.Shafi ,Experimental and theoretical studies of two stage pulse tube refrigerator operating down to 3 K, *International journal of heat and mass transfer* 52 *(p)*, 986-995.

[2] Y.L.Ju and L.Wang, On the numerical design of new type of 4 K GM/PT Hybrid Refrigerators, *cryogenics*, Vol.42 2002 p.533S.

[3] K.A.Shafi, N.K.Mohammed and B.Upendra, Investigation of a two stage pulse tube cryocooler operating dowen to 2.5 K, p1255-1260

[4] Balkrushna.A.Shah, *Design, analysis And experimental investigation of basic Pulse tube refrigerators* M.E.Dessertation Report, MED, L.D.college of engineering.