A Generalized Correlation for mass leakage through compressor for R-22, R-404A, R-407C

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ABSTRACT— This paper presents a study of mass leakage through compressor is experimentally investigated by using R-22,R-404A and R-407C. Experiments presented in paper were performed for various condensing temperature and evaporating temperatures. Four numbers of trials were conducted for each refrigerants. The experimental results were studied for mass leakage through the compressor for the mentioned refrigerants. It is observed that as the evaporating temperature increases mass leakage increases.

Keywords— Mass leakage, evaporating temperature, condensing temperature

I. INTRODUCTION

A vapour compression cycle consists of compressor, condenser, expansion valve for throttling and evaporator. Vapour compression uses circulating liquid refrigerant as the medium which absorbs and removes heat from space to be cooled and rejects that heat to elsewhere.

Compressor plays a crucial role it compresses the refrigerant from low pressure to relatively high pressure. For this electric power is supplied to carry out the compression process. Refrigerant enters the compressor as saturated vapour and is compressed to higher temperature and pressure. This compressed refrigerant is at superheated stage and it is at a temperature & pressure at which it is condensed. This condensed refrigerant is at saturated state and is next passed through expansion device, where refrigerant pressure and temperature is suddenly reduced and is a constant enthalpy process. Then the cool refrigerant is flow through evaporator to complete the refrigeration cycle, refrigerant vapor from evaporator is again routed into compressor.

Refrigerant system has a potential to leak because of the pressure difference between the system and the atmosphere. During the compression process the leakage of the refrigerant takes place. To find out this actual compressor behavior and theoretical compressor behavior is compared. For theoretical process 1-2 is constant enthalpy or isentropic process and 3-4 is constant enthalpy process. To find out the mass leakage through compressor three refrigerant behaviors is compared namely R22, R407C and R404A.

An approach to fault diagnosis of reciprocating compressor valves using Teager–Kaiser energy operator and deep belief networks. It is an approach to implement vibration, pressure, and current signals for fault diagnosis of the valves in reciprocating compressors. [Van Tung Tran, Faisal AlThobiani, Andrew Ball]

A comprehensive simulation model for a semi-hermetic CO_2 reciprocating compressor is presented. This model consists of a compression process model and frictional power loss model. Valve leakage and heat transfer sub models are included into the compression process model.[Bin Yang, Gaig R. Bradshaw, Eckhard A. Groll]

The simulator can predict complete performance of reciprocating compressor. It predicts the ideal behavior of compressor and it also incorporates various losses. This is because of leakages in compressor and heat transfer losses. [Aditya S. Bawane, Dr. V. K. Bhojwani, Mitali B. Deshmukh]

Mathematical model was developed to simulate the thermodynamic process in this transcritical CO_2 compressor. The internal leakage, heat transfer and flows through the suction/discharge valves together with valve motion were taken into account in the model. [Y Ma, B Zhang, H Hwang, X Y Peng, Z W Xing]

Experimental setup

The experimental setup is shown in figure. The test rig is a vapour compression cycle along with some additional components and instruments to maintain desired operating conditions and to measure various parameters at various locations in the system for study.

The test setup is hermetically sealed compressor in which refrigerant is compressed .The hermetical sealed compressor is run by single phase electrical supply.

Charged refrigerant is floe through suction port of the test setup. Once the compressor is started it compresses the refrigerant to high pressures.oil separator is used for separation of oil which is carried out by the refrigerant during compression process. The compressor consists of two thermocouples to measure compressor top shell temperature and discharge temperature of compressor. Refrigerant passes through the sell and tube condenser after the oil separator, in which cooling water is supplied with the help of water which is at room temperature.

Cooling water exchanges heat in shell and tube condenser. The refrigerant now is at a saturated state and is flow through sub cooler via liquid temperature controller where remaining liquid is condensed to fully convert refrigerant into liquid state before it goes into the expansion valve. This refrigerant passed through dryer to remove excess moisture content.

Receiver is a storage unit after the dryer. Mass flow rate measures the quantity of refrigerant used in the compressor. Refrigerant after the receiver was passed through evaporator. The glycol mixture was used as ant freezing agent in the cabin to see that the temperature does not fall beyond the range.

There were 7 temperature sensors to measure the temperature. The suction pressure and discharge pressure of compressor was charged by pressure switch and magnitudes were measured by transducer which was fixed at inlet and outlet of compressor. Two more transducer were used to sense pressure in water supply lines to condenser and sub cooler.

A PID (proportional-integral-derivative) controller was a control loop feedback mechanism used in this system. The three PID controllers was used to set discharge pressure of compressor, desired sub cooling of refrigerant and suction temperature of refrigerant before it enters the compressor.

Three refrigerants namely R22, R404A, R407C was used one after another for experimentation. For single condensing temperature evaporator temperature was varied. This completes one trial and such three more trials were conducted on setup for above mentioned refrigerants.

Fig 1.Experimental Setup

Data Reduction

From current experimental setup readings were taken for the calculation of mass leakage through compressor. The step by step formulas for the calculations are as follows

$$\dot{m}_R = Q_L/(h_1 - h_4) \quad (1)$$

$$W_T = \dot{m}_R * (h_2 - h_1) \quad (2)$$

$$\Delta W = W_A - W_T \quad (3)$$

W_A is the value taken from the actual setup.

Now,

$$-Q_R + W_A = \dot{m}_R * (h_2 - h_1)_A$$

$$Q_R = W_A - \dot{m}_R * (h_2 - h_1)_A \quad (4)$$

$$\Delta W = Q_R + \dot{m}_{leakage} * (h_2 - h_1)_A$$

$$\dot{m}_{leakage} = (\Delta W - Q_R)/(h_2 - h_1)_A \quad (5)$$

Results and discussion

Present experiment was performed for various condensing temperature range of 38.5°C to 45.6 °C on test rig shown in fig.1. For single condensing temperature evaporating temperature were varied from 2°C to 10°C and corresponding readings of total pressure drop, mass flow rate and refrigerant temperature after sub cooling were written down.

The values of W_A observed from experimental setup were used to calculate equation (3), (4) and (5) respectively.

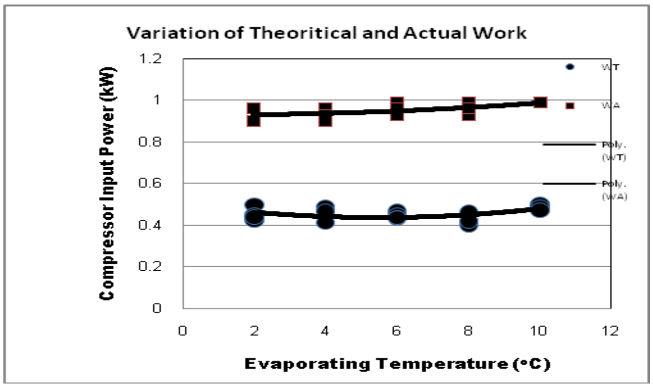

Fig .2 Variation of theoretical and actual work

Fig.2 shows the variation of theoretical and actual work for R-22. It is clearly observed that actual work increaser as the evaporator temperature increases and theoretical work first decreases slightly and then increases.

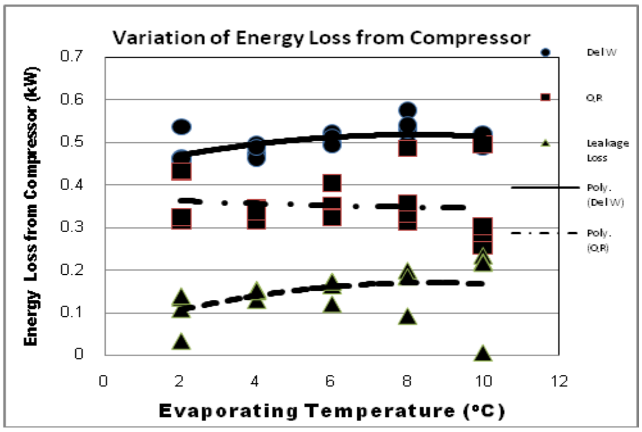

Fig. 3 Variation of Energy loss from compressor

Fig.3 shows the variation of energy loss from compressor. In this graph three different values are included ΔW, Q_R and leakage loss.

ΔW which is overall compressor power loss has increasing nature. Q_R has decreasing trend and leakage loss follows increasing trend.

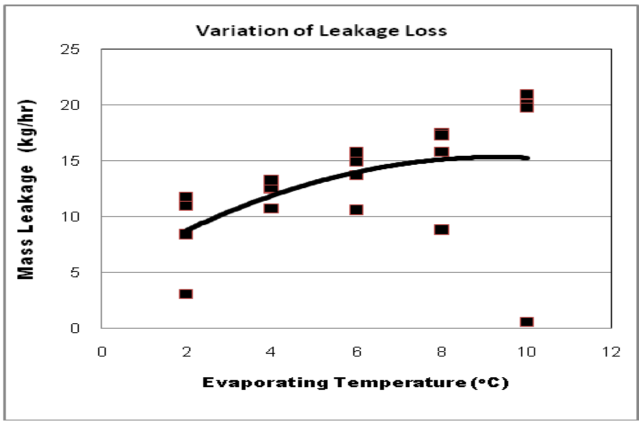

Fig .4 Variation of leakage loss

Fig.4 shows the variation of leakage loss taking inside the compressor. As evaporating temperature increases mass leakage increases.

II. CONCLUSION

Mass leakage through compressor is investigated for R-22, R-404A and R-407C. Mass leakage from each refrigerant is checked for the compressor through experimental investigation. It is found that leakage value increased as the evaporator temperature increases.

Mass leakage correlation can also be developed for current data and can exist as future scope of the same experiment.

III. REFERENCES

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Nomenclature

$\dot{m}_R$ Mass of refrigerant (kg/sec)
Q_L Cooling capacity (W)
W_T Theoretical work (W)
W_A Actual work (W)
Q_R Refrigerating capacity (W)
ΔW Compressor power loss
h_1 Enthalpy at inlet to compressor (KJ/Kg)
h_2 Enthalpy at exit to compressor (KJ/Kg)
h_4 Enthalpy at inlet to evaporator (KJ/Kg)

