Performance of R-600a Refrigerant with 0.2g/ L of TiO_2- MO Nano Lubricant in Domestic Refrigerator

[1]Bhavana Kaluvagadda, [2]K. Kalyani Radha

[1]PG Scholar, [2]Assistant Professor, [1,2]Department of Mechanical Engineering, JNTUA College of Engineering, Anantapuramu, India, [1]bhavanakaluvagadda@gmail.com, [2]kalyaniradha@gmail.com

***Abstract* - The effect of Hydro Fluoro Carbon and Hydro Chloro Fluoro Carbon refrigerants lead to increase in the rise of temperature of environment and also there is an adverse effect which leads to global warming and green house effect. To overcome this, HYDRO FLURO CARBON refrigerants i.e., R-600a (isobutane) is being used in a single stage reciprocating hermetic compressor of domestic refrigerator with TiO_2 (Titanium Dioxide) – MO (Mineral Oil). In this work a mass charge (40g) of R-600a refrigerant with a concentration of 0.2 g/L of TiO_2- MO based nano lubricant within the compressor of domestic refrigerator and the performance has to be investigated. The main objective of this work is to optimize the performance of R-600a refrigerant based domestic refrigerator with 0.2g/L TiO_2 – MO nano lubricant.**

Keywords: ***Domestic refrigerator, Mineral Oil (MO), Nano lubricant, Refrigerant, R-134a, R-600a, Titanium Dioxide (TiO_2).***

I. INTRODUCTION

The working fluids like Chloro Fluoro Carbons [CFCs] and Hydro Fluoro Carbons [HFCs] are having Ozone Depletion Potential [ODP] and high Global Warming Potential [GWP]. The dead line to phase out and to restrict the usage of these harmful working fluids in the application of refrigeration and air conditioning systems. In developing and developed nations, many researches are going on to replace CFCs and HFCs by natural refrigerants (mainly hydro carbon based type refrigerants) in refrigeration industry [1]. Several literatures have been reported as an excellent replacement for conventional working fluids are hydro carbon refrigerants due to their (i) Close thermodynamic properties (ii)Similarity with existing refrigeration system aided with or without modification (iii) No or low ozone depletion characteristics(iv) Having neutral global warming potential, but their utilization is limited because of flammability constraint. The fear of flammability [2] with the usage of hydro carbon based refrigerators for domestic usage with charges below 150g is disregarded because (i) the usage of refrigerant is limited (ii) the operating temperatures and pressures are high (iii) used in vapour compression refrigeration system with minimum number of connections and properly sealed (iv) accessibility to open flame or source of ignition can be controlled. In the work of Fatouh et al. [3], Mohammad [4] and Medhi et al. [5], the following were observed experimentally and theoretically when hydro carbon refrigerants are used in domestic refrigeration (i) discharge temperatures and pressures are high (ii) low coefficient of performance (iii) change of compressor lubricant from POE oil to mineral oil (iv) need to replace hydro carbon compressor in the place of HFC compressor. R-600a (isobutane) is an environmental friendly refrigerant when compared to other natural refrigerants including R-134a and was selected for the work of [6], [7], [8], [9], [10]. Nano particles have been using in many applications and available in different sizes to improve the performance of engineering systems. The study mainly focused on optimization of COP for R-134a, pure R-600a, R-600a with TiO_2 – MO nano lubricant, based refrigerants and experimentally examine the performance of selected refrigerants in a domestic refrigerator.

II. PREPARATION OF NANO LUBRICANT

The nano particles (TiO_2) and Mineral Oil mixture is initially prepared by mixing directly, and stir the mixture with a magnetic stirrer, the blend is then vibrated in an ultrasonic homogenizer, to isolate completely the nano particles in lubricating oil to avoid bunching of nano particles in the blend. To get homogenization, proper agitation is done by using ultrasonic vibrator to ensure uniform stability and dispersion of nano particles in prepared nano lubricant.

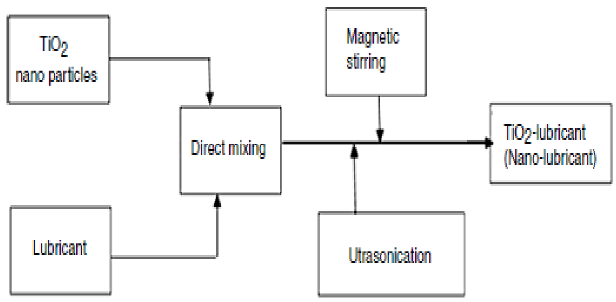

Fig.2. Flow chart for the preparation of nano lubricant

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III. VAPOUR COMPRESSOR REFRIGERATION SYSTEM

The low pressure and low temperature vapour refrigerant from evaporator is drawn into compressor through the suction valve where it is compressed to high pressure and high temperature vapour refrigerant and is discharged to the condenser through discharge valve compressor follows isentropic process. The superheated vapour is cooled to saturation temperature corresponding to the pressure of the refrigerant. The desuperheating occurs in the discharge line, and in the first few coils of condenser. Now the saturated vapour refrigerant condenses by giving its latent heat to saturated liquid refrigerant. This process is called as condensation. This condensation process follows constant pressure heat rejection process. Therefore the high pressure and high temperature vapour refrigerant from the compressor is passed through the condenser and is condensed completely at constant pressure and temperature so that the vapour refrigerant is converted to liquid refrigerant. The liquid refrigerant at high pressure (P_2=P_3) and temperature is expanded by throttle process through the expansion valve to low pressure. It is also called as vaporization process. The liquid vapour (mixture) refrigerant at constant pressure (P_4=P_1) is evaporated and converted its phase to vapour refrigerant. P – h, T - s charts and schematic diagram of vapour compression refrigeration system is as follows

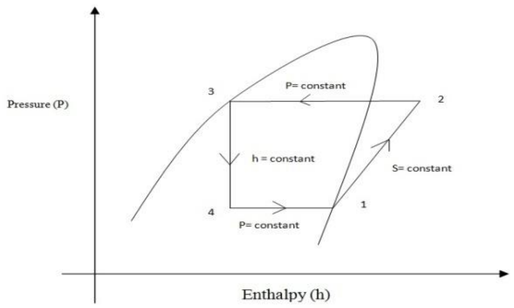

Fig.3.1 P- h diagram of VCRS system

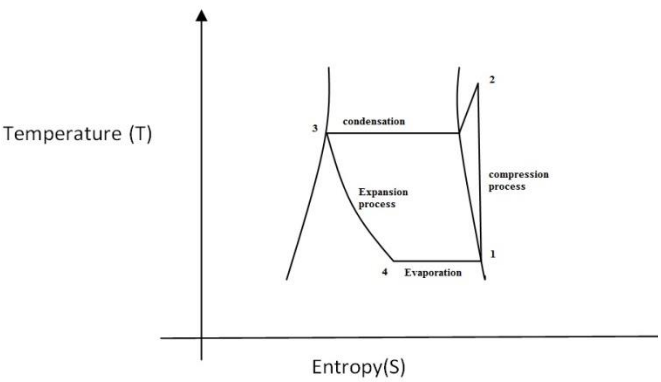

Fig.3.2 T- s diagram of VCRS system

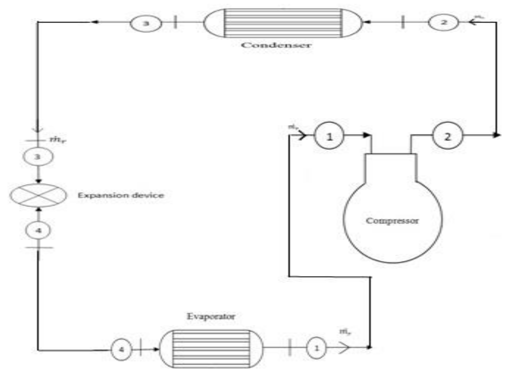

Fig.3.3 Schematic diagram of Vapour Compression Refrigeration System

IV. EXPERIMENTAL PROCEDURE

Inject a mass charge of 40g of R-134a refrigerant into 170 liter capacity domestic refrigerator. Note down the respective readings from ambient temperature to -15°C of evaporator temperature. Now replace R-134a refrigerant with R-600a refrigerant and repeat the same procedure to read the respective readings of temperature and pressure. Evacuate the compressor of the refrigerator, inject a mass charge of 40g of R-600a refrigerant and replace the refrigerant oil with 0.2g/L of TiO_2-MO nano lubricant. Run the system and note down the required readings from ambient temperature to -15°C of evaporator temperature.

The range of the experiment, characteristics of experimental instruments, characteristic of tio_2 nanoparticle, characteristic of lubricating oil are mentioned in the following tables.

Table- 4.1: Range of the experiment

S. No	Parameter	Range of experiment
1	Refrigerant mass charge	40g
2	Refrigerant name	R-134a, R-600a
3	Compressor	R-134a, R-600a
4	Compressor lubricant	POE oil (pure) for R-134a compressor, Pure Mineral Oil and TiO_2 based Mineral oil nano lubricant for R-600a compressor
5	Capacity of refrigerator	170 liters
6	Freezer capacity	18 liters
7	Temperature	Digital thermometer
8	Pressure	Compound gauge
9	Nano particles	Titanium dioxide
10	Cooling type	Direct cooling
11	Quantity of nano lubricant	0.2g/L

Table-4.2: Characteristics of experimental instruments

S. No	Instrument	Measured property	Range	No. required
1	Digital thermometer	Temperature	-50°C to 750°C	5
2	Compound gauge	Pressure	-30 psi to 800 psi	2

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Table-4.3: Characteristic of TiO_2 nanoparticle

S. No	Property	Unit	Value
1	Molecular weight	g/mole	79.87
2	Average molecular diameter	nm	15 -20
3	Purity	%	99.7
4	Density	g/cm^3	0.26

Table-4.4: Characteristic of lubricating oil

S. No	Lubricating oil characteristics	Units
1	Oil type	Capella Mineral Oil
2	ISO viscosity grade	68
3	Flash point	-36°C
4	Density at 15°C	0.91 kg/L
5	Viscosity index	22

V. RESULTS AND DISCUSSION

Following results are obtained when R-134a, R-600a and R-600a with TiO_2-MO nano lubricant, are used as refrigerants in an experimental domestic refrigerator:

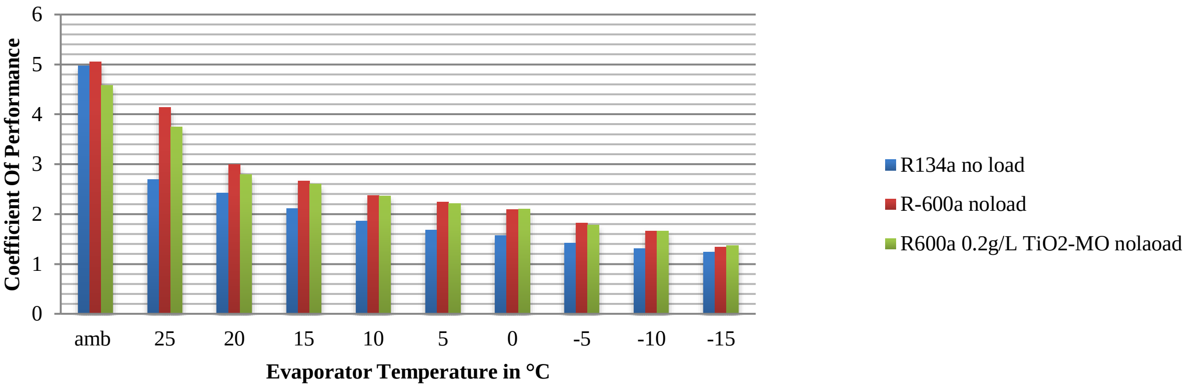

Fig.4.1. Comparison of COP with Evaporator Temperature at no load condition

From fig.4.1, at no load condition, when R-600a is compared withR-134a, there is an increase of 8.51% in COP. There is an increment of 1.74% in COP, when comparing R-600a with TiO_2-MO nano lubricant with R-600a refrigerant in an experimental domestic refrigerator. Therefore, there is an overall increment in COP by 9.42% in comparison with R134a refrigerant.

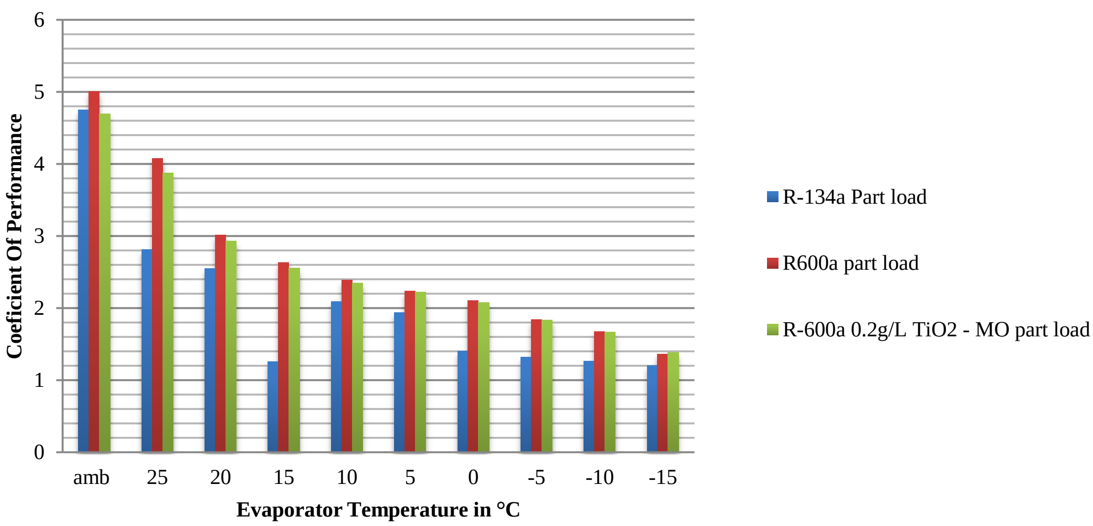

Fig.4.2. Comparison of COP with Evaporator Temperature at part load condition

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From fig.4.2, at part load condition, when R-600a is compared withR-134a, there is an increase of 13.21% in COP. There is an increment of 1.29% in COP, when comparing R-600a with TiO_2-MO nano lubricant with R-600a refrigerant in an experimental domestic refrigerator. Therefore, there is an overall increment in COP by 12.8% in comparison with R134a refrigerant.

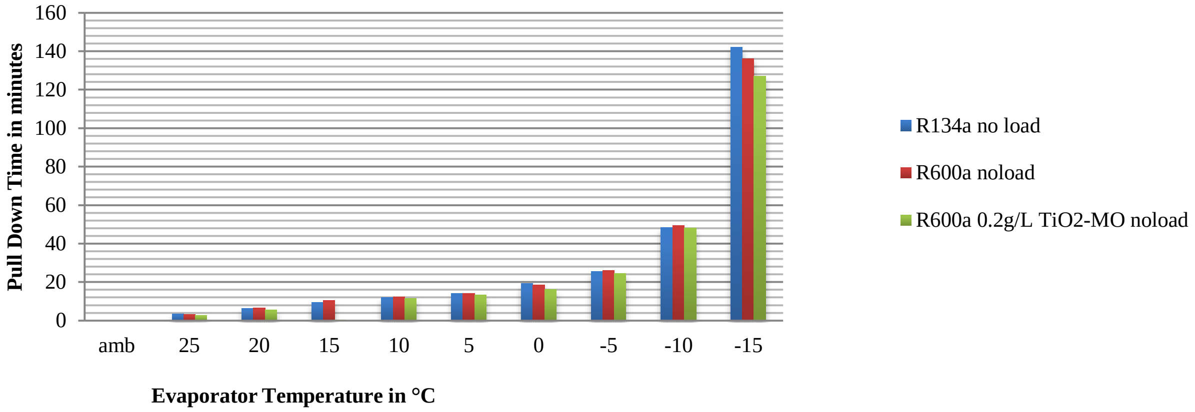

Fig.4.3 Comparison of Pull Down Time with Evaporator Temperature at no load condition

From fig.4.3, at no load condition, when R-600a is compared with R-134a, there is a decrease of 4.26% in pull down time. There is a decrement of 8.32% in pull down time when comparing R-600a with TiO_2-MO nano lubricant with R-600a refrigerant in an experimental domestic refrigerator. Therefore, there is an overall decrement in pull down time by 10.6% in comparison with R134a refrigerant.

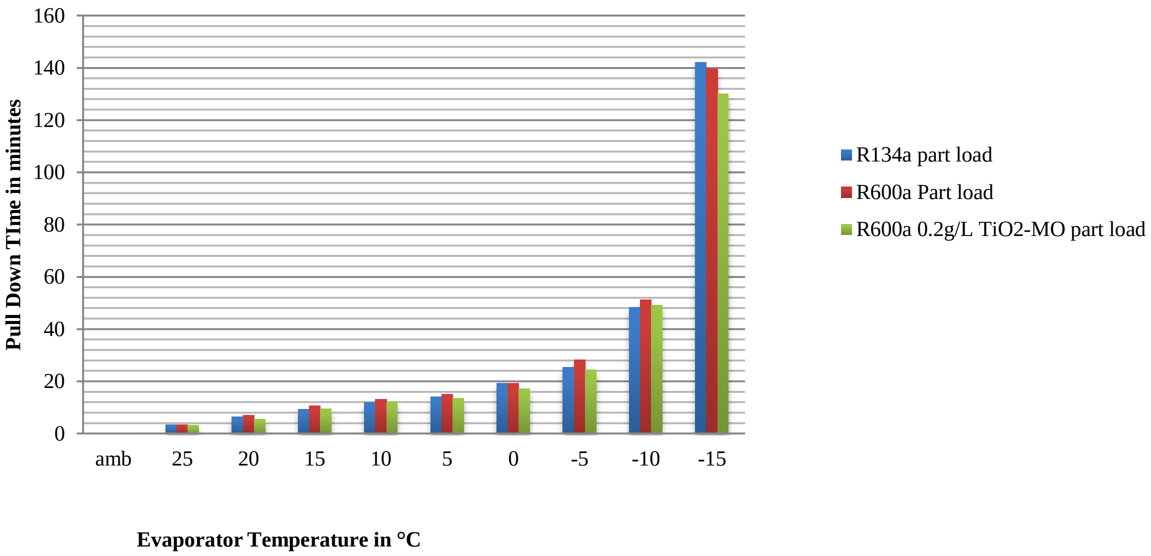

Fig.4.4. Comparison of Pull Down Time with Evaporator Temperature at part load condition

From fig.4.4, at part load condition, when R-600a is compared withR-134a, there is a decrease of 2.83% in pull down time. There is a decrement of 6.7% in pull down time, when comparing R-600a with TiO_2-MO nano lubricant with R-600a refrigerant in an experimental domestic refrigerator. Therefore, there is an overall decrement in pull down time by 9.1% in comparison with R134a refrigerant.

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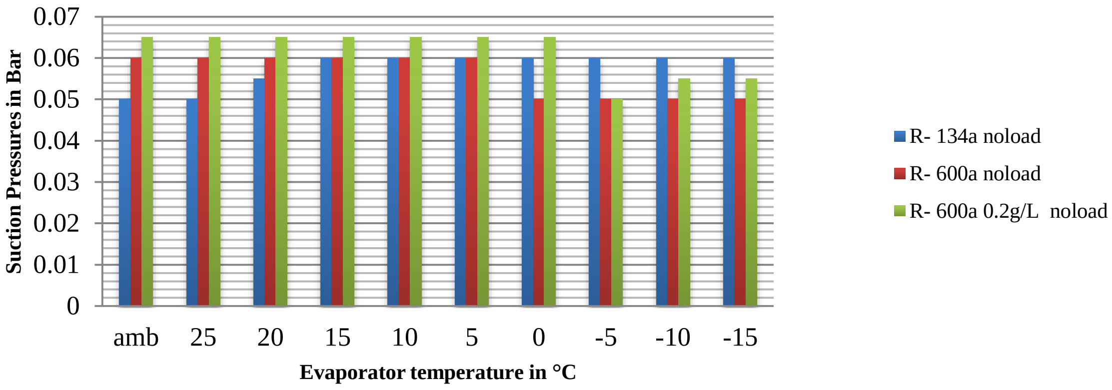

Fig.4.5. Comparison of Suction Pressure with Evaporator Temperature at No load condition

From fig.4.5, at no load condition, when R-600a is compared withR-134a, there is an increase of 2.6% in suction pressure. There is an increment of 8.9% in suction pressure, when comparing R-600a with TiO_2-MO nano lubricant with R-600a refrigerant in an experimental domestic refrigerator. Therefore, there is an overall increase in suction pressure by 6.9% in comparison with R134a refrigerant.

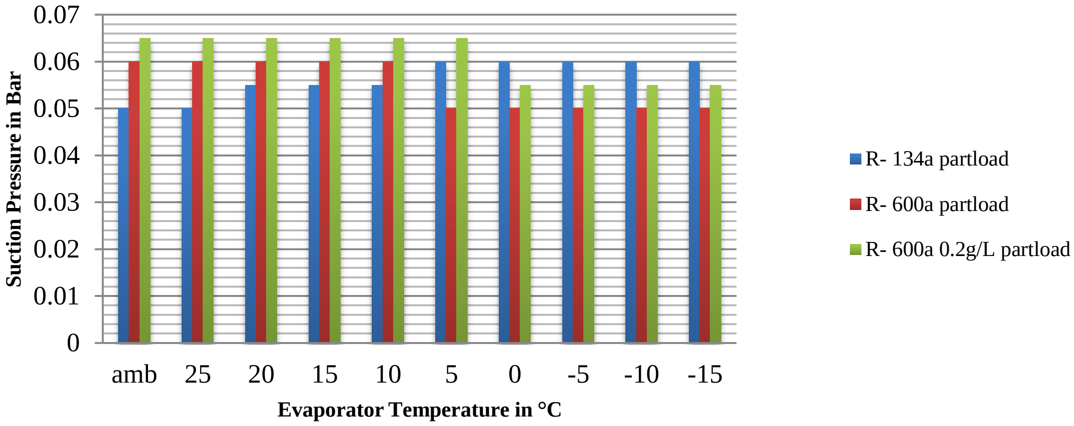

Fig.4.6. Comparison of Suction Pressure with Evaporator Temperature at Part load condition

From fig.4.6, at part load condition, when R-600a is compared withR-134a, there is an increase of 1.76% in suction pressure. There is an increment of 10.9% in suction pressure, when comparing R-600a with TiO_2-MO nano lubricant with R-600a refrigerant in an experimental domestic refrigerator. Therefore, there is an overall increase in suction pressure by 7.9% in comparison with R134a refrigerant.

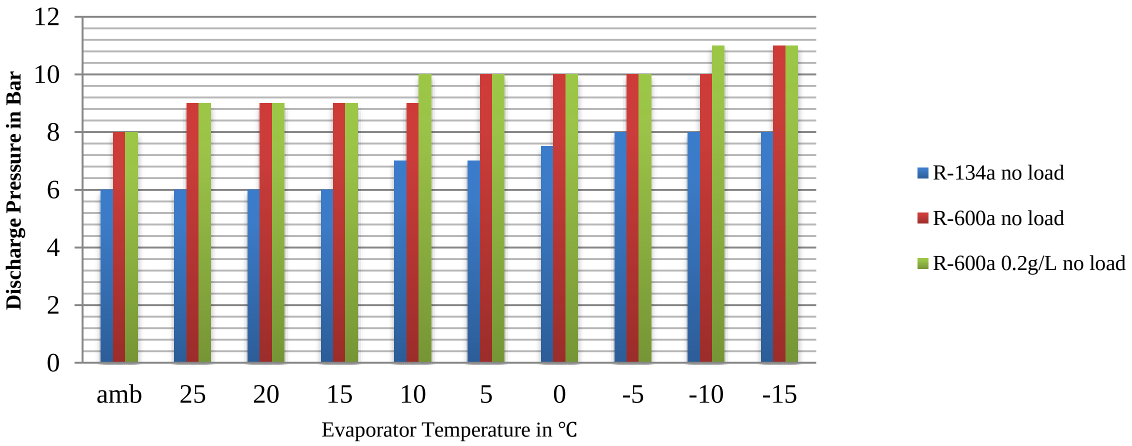

Fig.4.7. Comparison of Discharge Pressure with Evaporator Temperature at Part load condition

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From fig.4.7, at no load condition, when R-600a is compared withR-134a, there is an increase of 26.8% in discharge pressure. There is an increment of 2.1% in discharge pressure, when comparing R-600a with TiO_2-MO nano lubricant with R-600a refrigerant in an experimental domestic refrigerator. Therefore, there is an overall increase in discharge pressure by 28.3% in comparison with R134a refrigerant.

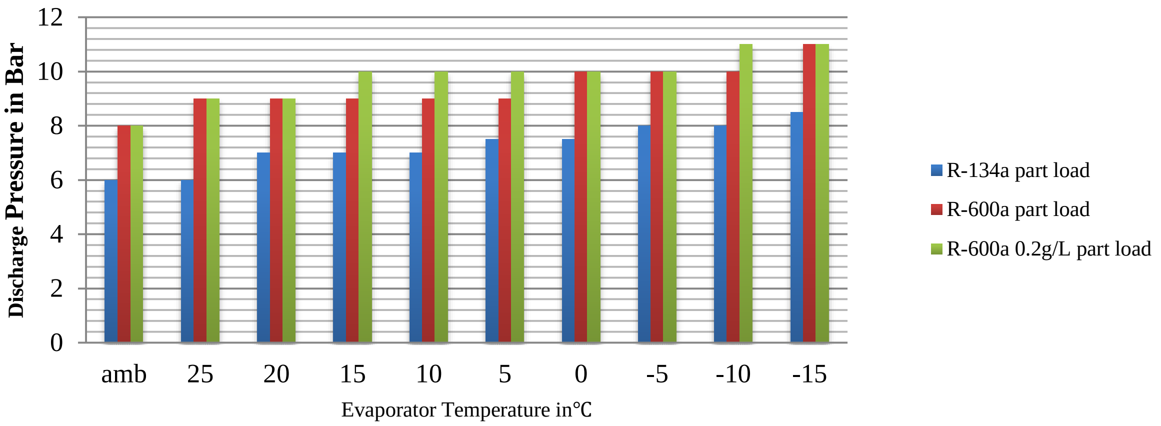

Fig.4.8. Comparison of Discharge Pressure with Evaporator Temperature at Part load condition

From fig.4.8, at part load condition, when R-600a is compared withR-134a, there is an increase of 22.9% in discharge pressure. There is an increment of 4.25% in discharge pressure, when comparing R-600a with TiO_2-MO nano lubricant with R-600a refrigerant in an experimental domestic refrigerator. Therefore, there is an overall increase in discharge pressure by 26% in comparison with R134a refrigerant.

VI. CONCLUSION

From the above results, the following have been concluded, while performing the experiment in domestic refrigerator, when R-134a, R-600a and R-600a with TiO_2-MO nano lubricant are used as refrigerants:

- When compared to R-134a, R-600a refrigerants, there is an increase in coefficient of performance at no load and part load conditions of R-600a and 0.2g/L TiO_2-MO nano lubricant based domestic refrigerator.
- Efficient power saving with the addition of nano lubricant to R-600a compressor, for an overall decrement of 10.6% in pull down time at no load condition, there is a reduction in overall power consumption by 32.61% at no load condition. Similarly at part load condition, there is an overall decrease in power consumption of 20.82%, for an overall decrement of 9.1% of overall pull down time.
- Effective cooling of evaporator is attained for R-600a with TiO_2-MO nano lubricant refrigerant in comparison of R-134a, R-600a refrigerants.
- When no load condition is compared with part load condition, there is an increment in discharge pressure by 7.1% and suction pressure by 1.9%.

Therefore, in an experimental domestic refrigerator, the concentrated 0.2g/L of TiO_2-MO nano lubricant based R-600a refrigerant is effective with pull down time and Coefficient of performance at no load and part load conditions in comparison with R-134a, R-600a refrigerants.

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