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Performance analysis of domestic refrigerator with forced and natural convection

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ABSTRACT

The system is not present in use due to arrangement of its various parts which are using additionally in it. In present, domestic refrigerators work on vapor compression cycle. In this cycle the heat is rejected through condenser or heat exchanger. In this way the rejection of heat occurs as a natural convection, due to this, refrigerating effect will obtain. Our modification in this system is that, if we perform through an arrangement of heat exchanger and exhaust fan the flow rate of heat should increase. Thus, in this way at same energy input the refrigerating effect may improve. Our future plan is to modify the domestic refrigerator that it could work on both natural convection and forced convection. In this way we can compare the Coefficient of performance for both processes and may do comparative study about both systems at different-different conditions.

Key words: COP, Refrigerator, Compressor, Condenser, Refrigerating Effect

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INTRODUCTION

As refrigeration is basic needs people of this era. The permanent demand of refrigerator is increasing continuously in India and also in the whole world. The energy consumption in the refrigeration is also increases. In the kitchen appliances, only the refrigerator consumes power continuously throughout a day (1). In refrigerators compressor consume more power than any other device. In this study use advanced condenser design to improve condensation of refrigerant and modification done by adding extra heat exchanger(condenser) with a cooling fan and it reduces the load on compressor and simultaneously achieve cooling effect and reduces the net power consumption during period of cycle and improves the net COP of the refrigerator. The compressor compartment is the heart of refrigerator (2,3). Domestic refrigerators are the major energy consuming domestic appliances in every household. The function of the compressor is to take the refrigerant vapor from evaporator at low pressure and low temperature and compress it to a high pressure and high temperature. In vapour compression system the main operating cost is the energy input to the system in the form of mechanical work (4-6). The Compressor is the largest power consumer in a vapour compression system. Hence the efficiency of the compressor is very essential for efficient vapour compression system used for refrigeration and air conditioning purpose (7, 8). It is known that the condenser releases heat at high temperatures (first law of thermodynamics) as well as the compressor. This heat is rejected to the environment in almost all practical situations in some degree by natural air convection. However, part of it is due to thermal radiation that causes an overheating of the refrigerator surfaces adjacent to that equipment. As a consequence there are more heat gains to the refrigerator through these surfaces and hence higher air temperatures inside it (9). In refrigerated space various parts are placed inside in an order based on the principle that the inside air temperature is constant through the space. This is because there is difference in temperature due to air circulation from the evaporator (natural or forced convection) (10-13).

Figure 1: Different cooling principles and their typical efficiency. COP is a quality number defined as the ratio between the useful cooling energy and the supplied work

The Coefficient of Performance (COP) is higher than other available techniques. It should be noted, however, that the absorption technique can also be operated by heat instead of electricity which in certain uses is a benefit for this technique (14). By combining a compressor with an expansion device to separate a high pressure side condenser (from which heat is rejected while refrigerant is condensing) and a low pressure side evaporator (into which heat is absorbed while refrigerant is evaporating) a heat pump has been formed (15). At the price of mechanical work, thermal energy is transferred from a lower to a higher temperature. The cooling system, used in domestic refrigeration, is essentially a heat pump that absorbs thermal energy from the cabinets inside and rejects it to the environment to maintain a climate at reduced temperature (16-19).

Refrigerators and freezers are available in several styles. All-freezers could be found as upright freezer or as chest freezer (20). Combination of refrigerators and freezers can be found as top-freezers, bottom- freezers, side-by-side or as a separate freezer compartment located within the larger refrigerator compartment (21, 22). The configurations vary considerably by region, but at a universal level, top freezers are the most common (nearly 40 %), bottom freezers are next at about 33 % and side-by-side combinations are about 13 %. The remaining types are mostly all-refrigerators or other configurations including separate freezer compartments (Harrington, 2009). Good Features which are desirable in a good compartment 1. Maximum food-storage volume for the floor area occupied by the compartment. 2. The best in usefulness, the performance, the convenience, and reliability. 3. Minimum heat gain. 4. Minimum cost to the consumer. Other ways to classify the household refrigeration units is how heat is transferred at the heat exchangers (23-26). The difference between the natural convection and forced convection is that no fan is used in the first case. Every so often natural convection heat exchangers are referred to as “static” or “passive”. Opposite, forced convection heat exchangers, are every so often referred to as “dynamic” or “active”. The way to defrost is either automatic or manual. In the automatic defrosting one can separate cycle defrost (where defrosting occurs in the off-cycle) from the heater defrost (where a heater is activated during defrost). The cycle of defrost is only possible in an on-off cycling refrigerator where the compartment air temperature is higher than 0 °C. In manual defrosting the defrosting must actively be started, for instance by switching on an electrical heater or by turning off the cooling system. The latter is typically used for natural convection freezers. One can also separate the way to control the capacity. In on and off cycling the compressor is switched on and off with the relative on-cycle being longer with increasing capacities. This is the dominating technique to control capacity in household refrigeration. In variable speed capacity control the compressor is varying its capacity through speed-modulation. However, normally in combination with on-off cycling since it is difficult to achieve a sufficient reduction of the compressor speed to perfectly match the heat load (27, 28).

MATERIALS AND METHODS

The materials which are generally used during the experiment are a domestic refrigerator, some copper pipes for installing the arrangement, a cover for the additional heat exchanger, a fan to cool the heat exchanger, some T-valves to regulate the refrigerant in both heat exchangers. Also there are some temperature sensors to measure the temperature at different points, and a temperature display.

The basic method which is use in this is the vapor compression cycle. In this experiment we have done a special arrangement so that the refrigerant can travel through the conventional condenser as well as the newly installed by us for the calculation. The whole process runs on the vapor compression cycle.

RESULTS AND DISCUSSION

The result is in the form of coefficient of performance. The formula for coefficient of performance is given as

COP = (h1-h4)/ (h2-h1)

Where
h1 = enthalpy of the refrigerant at inlet of compressor
h2= enthalpy of the refrigerant at outlet after compressor
h4= enthalpy of the refrigerant after expansion
NOTE-: Temperature is in K and Enthalpy is in KJ/Kg.

Table 1

With fan	**Without fan**
Date- 01/04/2015, Time- 10-10:30 am	Date- 01/04/2015, Time- 10:45-11:15am
Evaporator Temp.-17	Evaporator Temp.-15
Evaporator output Temp.-23	Evaporator output Temp. 24
Compressor output Temp.-33	Compressor output Temp. 38
Condenser Temp.30	Condenser temp. 35
h_1=398.3, h_2=428.58, h_4=236.6	h_1=399.2,h_2=432.1,h_4=243.1
COP=5.34	**COP=4.74**

The different temperatures are finding by the display and their corresponding enthalpies from the T-H diagram. The COP is calculated by the given formula, there is slight improvement in the COP comparatively.

Table 2

With fan	**Without fan**
Date- 01/04/2015, Time- 11:30-12:00 pm	Date- 01/04/2015, Time- 12:15-12:45pm
Evaporator Temp.-15	Evaporator Temp.-16
Evaporator output Temp.-24	Evaporator output Temp. 23
Compressor output Temp.-34	Compressor output Temp. 37
Condenser Temp. 31	Condenser temp. 36
h_1=399, h_2=432.54, h_4=237.9	h_1=399.7,h_2=432.8,h_4=244.4
COP=4.84	**COP=4.52**

Table 3

With fan	**Without fan**
Date- 01/04/2015, Time- 1:00-1:30 pm	Date- 01/04/2015, Time- 1:45-2:15pm
Evaporator Temp.-14	Evaporator Temp.-14
Evaporator output Temp.-24	Evaporator output Temp. 24
Compressor output Temp.-34	Compressor output Temp. 40
Condenser Temp.32	Condenser temp. 39
h_1=399.6, h_2=429.98, h_4=239.2	h_1=399.6,h_2=433.72,h_4=248.3
COP=5.27	**COP=4.49**

Table 4

With fan	**Without fan**
Date- 01/04/2015, Time- 2:30-3:00 pm	Date- 01/04/2015, Time- 3:15-3:45pm
Evaporator Temp.-24	Evaporator Temp.-13
Evaporator output Temp.-36	Evaporator output Temp. 25
Compressor output Temp.-33	Compressor output Temp. 41
Condenser Temp.14	Condenser temp. 40
h_1=399.2, h_2=430.6, h_4=240.5	h_1=400,h_2=434.09,h_4=249.6
COP=5.03	**COP=4.41**

After the taking different reading measurements of average value are following; the day one reading gives the following result.

Average COP with fan= 5.12
Average COP without= 4.54
Average percentage change= 12.77%

Table 5

With fan	**Without fan**
Date- 04/04/2015, Time- 10:00-10:30 am	Date- 04/04/2015, Time- 10:45-11:15am
Evaporator Temp.-17	Evaporator Temp.-15
Evaporator output Temp.-23	Evaporator output Temp. 24
Compressor output Temp.-34	Compressor output Temp. 38
Condenser Temp.31	Condenser temp. 35
h_1=398.3, h_2=430.74, h_4=237.9	h_1=399.2,h_2=432.1,h_4=243.1
COP=4.94	**COP=4.74**

Table 6

With fan	**Without fan**
Date- 04/04/2015, Time- 11:30-12:00 pm	Date- 04/04/2015, Time- 12:15-12:45pm
Evaporator Temp.-17	Evaporator Temp.-16
Evaporator output Temp.-23	Evaporator output Temp. 23
Compressor output Temp.-34	Compressor output Temp. 37
Condenser Temp.32	Condenser temp. 36
h_1=398.3, h_2=431.2, h_4=239.2	h_1=398.7,h_2=432.8,h_4=244.4
COP=4.83	**COP=4.52**

Table 7

With fan	Without fan
Date- 04/04/2015, Time- 1:00-1:30 pm	Date- 04/04/2015, Time- 1:45-2:15pm
Evaporator Temp.-17	Evaporator Temp.-14
Evaporator output Temp.-22	Evaporator output Temp. 24
Compressor output Temp.-34	Compressor output Temp. 40
Condenser Temp.31	Condenser temp. 39
h_1=398.3, h_2=431.15, h_4=237.9	h_1=399.6,h_2=433.72,h_4=248.3
COP=4.88	**COP=4.49**

Table 8

With fan	**Without fan**
Date- 04/04/2015, Time- 2:30-3:00 pm	Date- 04/04/2015, Time- 3:15-3:45pm
Evaporator Temp.-17	Evaporator Temp.-13
Evaporator output Temp.-22	Evaporator output Temp. 25
Compressor output Temp.-33	Compressor output Temp. 41
Condenser Temp.31	Condenser temp. 40
h_1=398.3, h_2=430.74, h_4=237.9	h_1=400,h_2=434.09,h_4=249.6
COP=4.94	**COP=4.41**

The second reading had the slight different result from the previous one. Hopefully , will improve in the next couple of readings.

Average COP with fan= 4.88
Average COP without= 4.54
Average percentage change= 7.6%

Table 9

With fan	**Without fan**
Date- 08/04/2015, Time- 10:00-10:30 pm	Date- 08/04/2015, Time- 10:45-11:15am
Evaporator Temp.-16	Evaporator Temp.-15
Evaporator output Temp.-23	Evaporator output Temp. 24
Compressor output Temp.-35	Compressor output Temp. 38
Condenser Temp.32	Condenser temp. 35
h_1=398.7, h_2=430.95, h_4=239.2	h_1=399.2,h_2=432.1,h_4=243.1
COP=4.94	**COP=4.74**

Table 10

With fan	**Without fan**
Date- 08/04/2015, Time- 11:30-12:00 pm	Date- 08/04/2015, Time- 12:15-12:45pm
Evaporator Temp.-16	Evaporator Temp.-16
Evaporator output Temp.-23	Evaporator output Temp. 23
Compressor output Temp.-34	Compressor output Temp. 37
Condenser Temp.32	Condenser temp. 36
h_1=398.7, h_2=430.95, h_4=239.2	h_1=398.7,h_2=432.8,h_4=244.4
COP=4.94	**COP=4.52**

Table 11

With fan	**Without fan**
Date- 08/04/2015, Time- 1:00-1:30 pm	Date- 08/04/2015, Time- 1:45-2:15pm
Evaporator Temp.-16	Evaporator Temp.-14
Evaporator output Temp.-21	Evaporator output Temp. 24
Compressor output Temp.-35	Compressor output Temp. 40
Condenser Temp.33	Condenser temp. 39
h_1=398.7, h_2=431.67.58, h_4=240.5	h_1=399.6,h_2=433.72,h_4=248.3
COP=4.80	**COP=4.49**

Table 12

With fan	**Without fan**
Date- 08/04/2015, Time- 2:30-3:00 pm	Date- 08/04/2015, Time- 3:15-3:45pm
Evaporator Temp.-16	Evaporator Temp.-13
Evaporator output Temp.-22	Evaporator output Temp. 25
Compressor output Temp.- 35	Compressor output Temp. 41
Condenser Temp.31	Condenser temp. 40
h_1=398.7, h_2=430.49, h_4=237.9	h_1=400,h_2=434.09,h_4=249.6
COP=5.05	**COP=4.41**

The third measurement of temperature gives the improvement in the COP of the refrigerator.

Average COP with fan= 4.93
Average COP without= 4.54

Average percentage change= 8.6%

Table 13

With fan	**Without fan**
Date- 10/04/2015, Time- 10:00-10:30 am	Date- 10/04/2015, Time- 10:45-11:15am
Evaporator Temp.-16	Evaporator Temp.-15
Evaporator output Temp.-23	Evaporator output Temp. 24
Compressor output Temp.-34	Compressor output Temp. 38
Condenser Temp.32	Condenser temp. 35
h_1=398.7, h_2=430.95, h_4=239.2	h_1=399.2,h_2=432.1,h_4=243.1
COP=4.94	**COP=4.74**

Table 14

With fan	**Without fan**
Date- 10/04/2015, Time- 11:30-12:00 pm	Date- 10/04/2015, Time- 12:15-12:45pm
Evaporator Temp.-16	Evaporator Temp.-14
Evaporator output Temp.-23	Evaporator output Temp. 24
Compressor output Temp.-34	Compressor output Temp. 40
Condenser Temp.31	Condenser temp. 39
h_1=398.7, h_2=430.49, h_4=237.9	h_1=399.6,h_2=433.72,h_4=248.3
COP=5.05	**COP=4.49**

Table 15

With fan	**Without fan**
Date- 10/04/2015, Time- 1:00-1:30 pm	Date- 10/04/2015, Time- 1:45-2:15pm
Evaporator Temp.-16	Evaporator Temp. -13
Evaporator output Temp.-23	Evaporator output Temp. 25
Compressor output Temp.-34	Compressor output Temp. 41
Condenser Temp.32	Condenser temp. 40
h_1=398.7, h_2=430.95, h_4=239.2	h_1=400,h_2=434.09,h_4=249.6
COP=4.94	**COP=4.41**

Table 16

With fan	**Without fan**
Date- 10/04/2015, Time- 2:30-3:00 pm	Date- 10/04/2015, Time- 3:15-3:45pm
Evaporator Temp.-15	Evaporator Temp. -16
Evaporator output Temp.-24	Evaporator output Temp. 23
Compressor output Temp.-35	Compressor output Temp. 37
Condenser Temp.32	Condenser temp. 36
h_1=399.2, h_2=430.47, h_4=239.2	h_1=398.7,h_2=432.8,h_4=244.4
COP=5.11	**COP=4.52**

After all the measurements we come to the final result and that was quite satisfactory to us. The following details deals with the final result.

Average COP with fan= 5.01
Average COP without= 4.54
Average percentage change= 10.33%

When we have started this experiment, we were not sure of results. But now we have got a good result regarding our experiment. We think that there should be some more attention would have given and while performing the experiment some more carefulness should have attained. By doing this we can improve our results. If we talk of carefulness it could have been in the experiment timing that is the ambient temperature should had been same for the all days.

OVERALL COP WITH FAN = 5.006
OVERALL COP WITHOUT FAN = 4.54
OVERALL CHANGE IN COP = 10.25%

CONCLUSION

On the starting of this project our purpose was to improve the performance of the domestic refrigerator. The coefficient of performance of refrigerator is to be increased by the improving its coefficient of performance. Initially we were sure about the improvement in coefficient of performance. We make an attempt to improve coefficient of performance by reducing the temperature of heat exchanger (condenser) by means of forced convection to the heat exchanger and results are calculated,and finally it actually works according to our idea. It results in increase in coefficient if performance of the domestic refrigerator. Our idea work as it was desirable and our concept get success and the project gets its desirable result. The project is successful.

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