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Experimental Investigation on Traditional Fan Performance Improvement using Front Mounted Cooling Coil of Vapor Compression Refrigeration System

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ABSTRACT
The temperature of the world is increasing day by day and the effects of this warming are influential in Bangladesh. A record amount of temperature is rising every year. So, in this situation to work and live comfortably in the hot summer season it is necessary to have cooling devices. In Bangladesh, for the cooling purpose, most of the peoples generally use a traditional fan. Only a few of them are capable to buy Air Conditioner because a major portion of its peoples is poor. But only a fan sometimes is not enough to cool. So, the problem remains between cost and comfort. Considering this issue, a solution is proposed in this work which may serve both the problems. The problem could be solved if a cooling coil is placed on the path of air flow. When the incoming air is passed through the cooling coil it gets cool. The cooling coil is activated by the Vapor compression refrigeration Cycle. This system also made portable. That is, one may call this system a portable air cooler. For this cooling coil 50 feet, a copper tube is used. A 320-watt compressor and fin type condenser are used to construct the vapor compression system. This cooling is used for spot cooling for a periodic basis. A 3.5ºC temperature reduction has been found where the inlet and outlet temperature of the air is 25ºC and 21.5ºC respectively.

Keywords: Cooling Coil, Traditional fan, Air conditioner, Cost and Comfort

1. Introduction

In hot summer season the environment become humid and, in this case, we use different traditional fan for cooling purpose. But sometimes this traditional fan is not enough to cool our body since the air is humid enough and the temperature in Bangladesh varies from around 30ºC to 40ºC during summer season. In that case we need to use a device which can serve this problem. Air conditioner can be used for this purpose but sometime it is costly for third world country like Bangladesh. So, keeping in mind that cost is one of the vital issues which can be reduced to affordable price so that people can be benefited. In Bangladesh as a developing country demand of electricity is increasing day by day and the government is working for the development of electricity. Hence the demand of consumers is also increasing as they are installing more electronic devices. Traditional fan is one of them. Bangladesh is a populous country. Majority of its peoples are poor. So, it is really tough for them to buy an air conditioner. But the price of a conventional fan is affordable to them. So, if a little modification can be done then it may be affordable to many of them and thus, they will get the comfort of air conditioner. The modification is simple. Just putting the cooling coil on outside of the frame of conventional fan and this coil is linked to the compressor and the condenser. The circulated air will be passed through over the cooling coil which is mounted on the frame of conventional fan and become cool after condensing some moisture on the cooling coil. Since the air gets dehumidified hence it become cooler and can be used for cooling purpose. The present air conditioner is difficult to install especially in outdoor condition. This product is designed with a wheel which makes it easier to move and install. With simplest procedure, anyone can easily install this cooling fan to wherever they want. Air velocity has greater effect on the cooling. Higher air velocity has a greater effect to cool hot body. The first reason is that the higher velocity tends to scrub away the boundary layer and expose the course of lumber to larger wet bulb depressions. The second reason relates to the temperature drop across the load. Air conditioning system consists of basically four elements such as compressor, condenser, expansion valve and evaporator. Its working principle is simple. For cooling purpose, it draws air from the desired space and passes it over the cooling coil which is known as evaporator consist of enormous fins. Since the air gets dehumidified it becomes cool and by this way it fulfills the desired condition. The cooling effect is accomplished by the Reverse Rankine Cycle. This cycle uses a working fluid to get proper cooling effect. This substance is known as refrigerant. The compressor is used to maintain proper flow and pressure of the refrigerant. When the compressor compresses the refrigerant, it gets heated or superheated and passes through the condenser. The function of the condenser is to cool the refrigerant. After condenser the refrigerant is passed through expansion valve where it is expanded. In the expansion valve the pressure is dropped and hence the temperature also gets low. The refrigerant is now mostly in liquid phase. Finally, the refrigerant is ready to pass though the cooling coil where it sucks heat from the air and gets evaporated and again gets into the compressor. Thus, the Reverse Rankine Cycle is completed. Warm solace

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is the state of psyche that communicates fulfillment with the warm climate and is surveyed by emotional assessment (ANSI/ASHRAE Standard 55) [1]. Keeping up this norm of warm solace for tenants of structures or different fenced in areas is one of the significant objectives of HVAC (warming, ventilation, and cooling) plan engineers. The vast majority will feel good at room temperature, conversationally a scope of temperatures around 20 to 22 °C (68 to 72 °F) [2], yet this may shift enormously among people and relying upon elements, for example, action level, attire, and dampness. The principle factors that impact warm solace are those that decide heat addition and misfortune, specifically metabolic rate, attire protection, air temperature, mean brilliant temperature, velocity and relative stickiness. Mental boundaries, for example, singular desires, likewise influence warm solace [3]. Individuals have distinctive metabolic rates that can vacillate because of movement level and natural conditions [4][5][6]. The measure of warm protection worn by an individual substantially affects warm solace, since it impacts the warmth misfortune and subsequently the warm equilibrium. Layers of protecting attire forestall heat misfortune and can either help keep an individual warm or lead to overheating. For the most part, the thicker the piece of clothing is, the more prominent protecting capacity it has. Contingent upon the kind of material the dress is made out of, air development and relative dampness can diminish the protecting capacity of the material [7][8]. The planner will choose the best possible averaging, particularly including velocities occurrence on unclothed body parts, that have more noteworthy cooling impact and potential for nearby inconvenience [1]. The suggested level of indoor moistness is in the scope of 30-60% in cooled buildings,[9][10] yet new principles, for example, the versatile model permit lower and higher humidifies, contingent upon different variables associated with warm solace.

2. Experimental setup

To accomplish the experiment different types of materials had been used. Since cost is one of the key factors, the study emphasizes using less material so that the cost of the experiment is minimized. At first, the copper tube was wounded on the face casing of the stand fan. The length of the copper tube was 50 feet. The whole coil was wounded on the casing and attached with it by cable tiers. The tubes were spaced equally and tried to maintain minimum spacing so that the air could get more contact with the tubes. The compressor was placed in a position so that it occupies less space. The compressor was placed at the backside of the fan facing on the pedestal of the fan. It was then tied with a wire to the column of the fan. The condenser was small in size. The size of the condenser was 6 inches by 6 inches. Hence it was easy to fix it in a small place. Since the thickness of the condenser was also small as compared to others it was easy to fix it with the column of the fan. It is tied at the top and bottom by wires. Finally, a cooling fan was placed parallel to the condenser. The fan was fixed at the pedestal by glue. To ensure the connection in the experiment, brazing was employed. Compressor outlet to condenser inlet, condenser outlet to the capillary tube, capillary to the inlet to evaporator were jointed. After completing the joining by brazing, all the joints were checked. There are various methods of checking the leak of the joint. The soap bubble method was used to check the leakages. For checking the leakage, a high-pressure compressor was connected to the compressor charging line and applied high pressure. This high pressure is maintained for a few times. And keeping this high pressure the joints were checked by applying soap bubbles to the joints. After completing all the procedures mentioned above refrigerant was charged. The refrigerant which was compatible with the compressor. In this study, the compressor was compatible with R134a. Before charging the refrigerant, the system was evacuated by a vacuum pump. Then the refrigerator tank was connected to the compressor by hose pipe. Due to having vacuum pressure inside the system refrigerant automatically got into the system. Approximately half kg. the refrigerant was charged. Finally, the hose pipe was disconnected from the compressor charging line where a non-returning valve was placed. After doing all the job, the final assembly had been done and a PVC sheet was used to cover the base elements in which condenser, compressor, and condenser fan were installed. The backside was kept open to circulate the air to cool the condenser. Photos of the complete assembly of the cooling fan shown in Fig. 1 is shown.

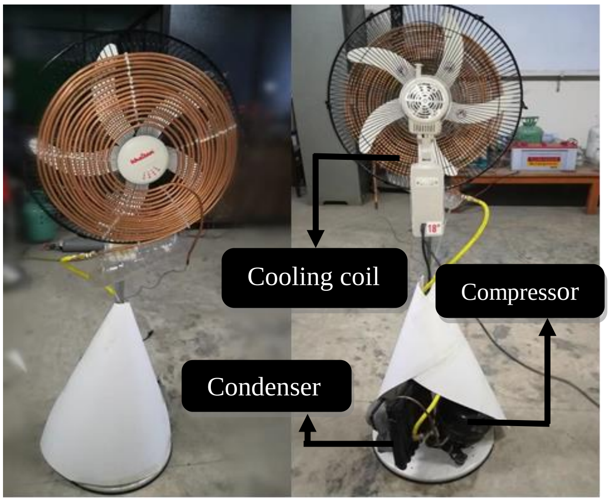

Fig. 1 Photos of complete assembly of the cooling fan

3. Results and Discussion

3.1 Only fan Mood

Only fan mood means that the fan is running without the activation of the cooling coil. During that mood, the temperature of the air was measured. Fig. 2 represents the relation between time, distance and temperature for only fan mood. The temperature was measured against different time and distance. Initially, the temperature is 24℃ when the distance is 0.5 feet and time 1 minute. The maximum temperature drops at 2 feet distance from the fan when the time is 6-7 minutes**.**

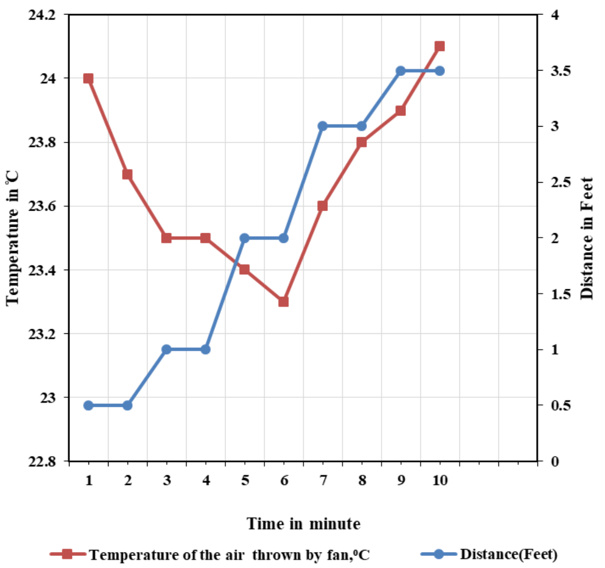

Fig.2 Relation among temperature, time and distance (Before cooling)

In this case, the temperature is 23.3℃. Then the temperature is increased corresponding to increasing the distance from a fan and increasing time. Finally, 24.1℃ temperature is found at 3.5 feet distance from fan and 10 minutes passing.

3.2 Fan in Cooling Mood

Cooling mood means cooling coils are connected with fan. Fig. 3 represents the relationship between time, distance and temperature for the fan in cooling mood.

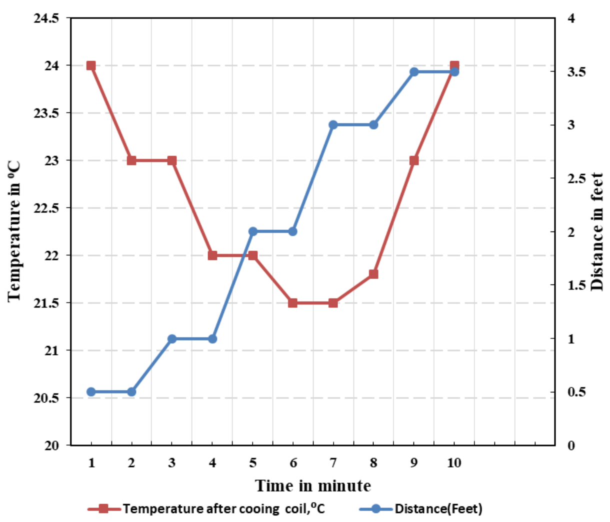

Fig.3 Relation among temperature, time & distance (After cooling)

Initially, the temperature is 24℃ and as the distance increase the temperature decrease at a certain value. The minimum temperature obtains and 2 feet distance from the fan when the time is 6 - 7 minutes. The temperature is 21.5℃. Finally, 24℃ temperature is found at 3.5 feet distance from a fan and 10 minutes passing

3.3 Comparison between Traditional fan and Cooling Fan

Fig. 4 represents the comparison between traditional fan and cooling fan. Initially, the temperature of both fans is the same as 24℃. Fig. 4 clarifies that as distance increasing corresponding to the time the temperature, difference between two fans also appeared. The maximum temperature drop for tradition fan is 1.7℃ (the difference between room temperature, 25° C and minimum temperature of the cooling fan) at 2 feet distance from the fan.

Again, the maximum temperature drop for cooling fan is 3.5℃ at 2-3 feet distance from the cooling fan. So, it is strictly clarifying that by using cooling fan instead of tradition fan more temperature drop are found and numerically it is twice than tradition fan

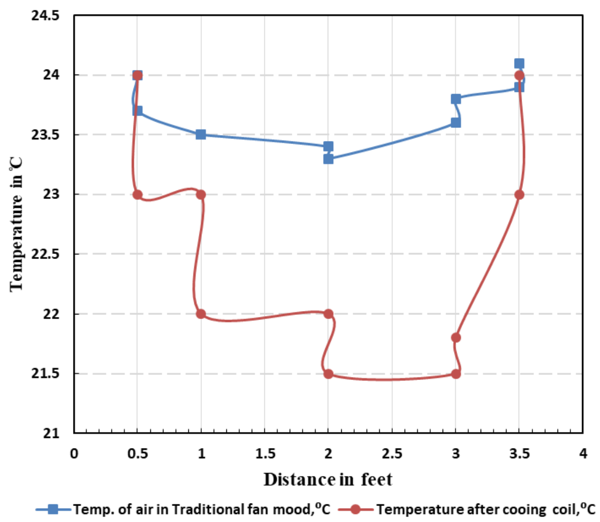

Fig.4 Comparison between Temperature of air in traditional fan and cooling fan, respectfully

3.4 Temperature at various speeds of fan

Air temperature varies with the variation of fan speed. Velocity of air has a great effect on the Reynolds number as it is the ratio of inertia force to viscous force. The inertia force is the multiplication of density of air, velocity of air and length of the object. Hence if the velocity increase, inertia force also increases. This results in generally two profiles of air flow. One is laminar and other is turbulent flow. The higher is the velocity the greater chance to have turbulent flow. As we know heat transfer is higher in turbulent flow hence higher velocity is good for this system. So, a test is carried out to demonstrate this phenomenon which is tabulated below. Fig. 5 represents that the temperature falls much at high speed of fan than that of low speed. The high velocity of the fan also increases the flow rate of air which also useful in evaporative cooling. Because more air means more contact of air with hot body and more evaporation capacity.

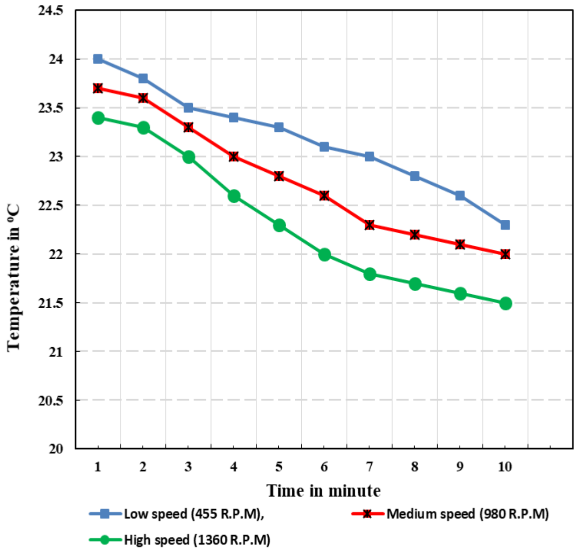

Fig.5 Changes of temperature at various speed with respect to time

4. Conclusion

As a south Asian country like Bangladesh where the majority of its people are poor. Where buying an air conditioner is tough for them. Since the temperature of the country, as well as the world, is increasing day by day it is necessary to have a cooling device for them to work and live comfortably at a low cost comparatively. Keeping this idea in mind this study has been done where a traditional table fan is converted into a cooling fan by a simple modification. This system occupied the same space as it was only a fan before modification. The cost is low as compared to an air conditioner which is about one-fourth of the air conditioner. Since traditional fans can be moved to any place, after modification it has the same condition. That is why we can call it a portable air cooler. A traditional fan can be used as a spot cooler in indoor and outdoor use after a simple modification. In this study, it was possible to reduce inlet air temperature by 3º C. But there was a higher bypass factor which is not desirable at all. This problem may be solved by modification of the cooling coil and by increased fan capacity. The cooling coil was placed in the face of the fan casing and the tubes were fin less. That is why the bypass factor was so high. Due to this, the temperature reduction is not so high. So, if the coil is modified with fins and placed at the back side of the fan casing the bypass factor might be reduced more. Another reason is that only a single tube was used in the path of streamline that's why air got a touch for a single time and had less chance to transfer heat to the refrigerant. So, if multiple tubes could be used in the path of streamline flow the air would cool more. As a fan of medium capacity was used and placed the cooling coil at face casing hence the airflow is restricted. Only a few amounts of air were escaped from the casing and cooling coil. Due to this problem, the air reaches only a few feet away from the cooling coil. If one wants to keep the cooling coil in the face of the casing of the fan, it is necessary to use a stronger traditional fan to create a stronger thrust of air. If the cooling coil is placed at the backside of the fan casing medium-capacity fan could be correct.

References

[1] ANSI/ASHRAE Standard 55-2013, Thermal Environmental Conditions for Human Occupancy

[2] The American Heritage Dictionary of the English Language (5th ed.). (2014)

[3] De Dear, Richard; Brager, Gail, "Developing an adaptive model of thermal comfort and preference". ASHRAE Transactions. 104 (1): 145–67, (1998)

[4] Toftum, J. "Thermal Comfort Indices". Handbook of Human Factors and Ergonomics Methods. Boca Raton, FL, USA: 63.CRC Press, (2005).

[5] Smolander, J. "Effect of Cold Exposure on Older Humans". International Journal of Sports Medicine. 23 (2): 86–92, (2002).

[6] Khodakarami, J. Achieving thermal comfort. VDM Verlag. ISBN 978-3-639-18292-7, (2009).

[7] Havenith, G. "Heat balance when wearing protective clothing". The Annals of Occupational Hygiene. 43 (5): 289–96, (1999).

[8] McCullough, Elizabeth A.; Eckels, Steve; Harms, Craig, "Determining temperature ratings for children's cold weather clothing". Applied Ergonomics. 40 (5), (2009).

[9] Balaras, Constantinos A.; Dascalaki, Elena; Gaglia, Athina "HVAC and indoor thermal conditions in hospital operating rooms". Energy and Buildings,39 (4): 454.doi: 10.1016/j.enbuild.2006.09.004 (2007)

[10] Peder Wolkoff; Søren K. Kjaergaard "The dichotomy of relative humidity on indoor air quality". Environment International. 33 (6): 850–7, (2007).