Design of M-cycle Cross Flow Heat Exchanger for Indirect Evaporative Cooling

Prof. R.S.Patil[1] , Kumbhar Jaiprakash[2] , Rakesh Pardeshi[3] , Amul Prajapati[4] , Pratik Gouli[5]

Abstract—This project is mainly focused on analysis of m-cycle cross flow heat exchanger which reduces the temperature of the air without affecting the humidity and without using any type of harmful refrigerant. The software used in this work were Catia v5 and Ansys Workbench . So, by application of theoretical knowledge and guidance of experts in the particular field, we will get the result in terms of reduction in temperature.

Index Terms— Catia V5, Ansys, M-Cycle , Heat Exchanger , CFD , IEC , Analysis.

1 Introduction

The urban sector is main reason for around 25–35% of glob- al carbon emission. Heating, Ventilation and Air Condi- tioning (HVAC) is the major energy user in a building and consumes around 45% of the total supplied energy. Air conditioning, representing an important function of the HVAC system, is increasingly crucial for many buildings, particularly those public types e.g., airports, Cinema hall, Shopping Complex etc., owing to recent frequent warm spells, improved building insulation and growth of in-house heat generating appliances. Over the past decades, evapora- tive cooling, utilizing the principle of water evaporation for heat absorbing, has gained growing popularity for use in air conditioning, owing to its simplicity in structure and good use of natural energy (i.e., latent heat of water) existing in am- bient.The continuous rise in the environmental temperature due to a global warming affects the future air conditioning requirements. The conventional air conditioner consumes the
large amount of electrical energy.

Evaporative cooling is environment friendly and more effi- cient air cooling method. The efficiency of evaporative cooling system increases with and increase with temperature and de- crease in temperature therefore in hot and dry climates it can save large amount of energy used for conventional air condi- tioning system. The evaporative refrigerator is based on Mai- sotsenko-cycle. It consists of two channels 'Dry channel' and 'Wet channel' respectively. There are two types of assemblies based on Channels Direct Evaporative Cooler (DEC) and Indi- rect Evaporative Cooler (IEC).

DEC uses a wetted pad with large air water
contact surface area through which air is passed at uniform rate to make it saturated. In IEC the air to be cooled is does not come direct contact with water. It is in contact with surface i.e. maintained at lower temperature. In this experiment,

experimental evaluation we are using the combination of two indirect evaporative cooler to improve the performance of whole system.

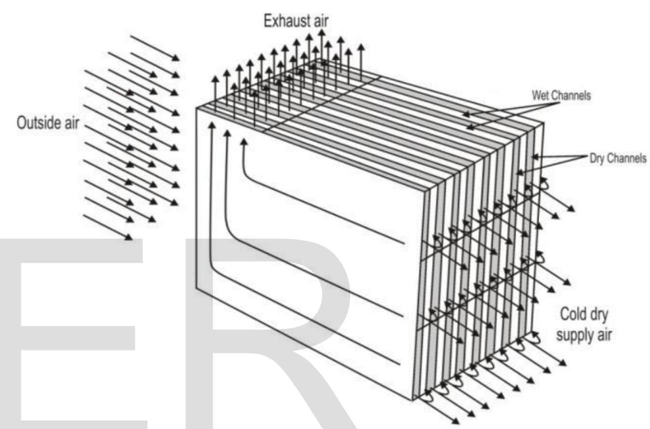

Fig : Indirect Evaporative Cooling

Systems using Maisotsenko Cycle find a multi-climate application like dry and humid. Therefore a multi-climate country like India can be benefitted if the systems proposed in this paper can find certain practical applications. Our pro- posed project is based on evaporative air-conditioner based on Maisotsenko Cycle or M-cycle.

Our setup consists of mainly two heat exchangers based on indirect evaporative cooling separated by a little gap through a passage so as to minimize leakage of product air from 1st heat exchanger an using the product air of the pre- vious heat exchanger as the working air for the latter, which is pre-cooled and would provide better efficiency.

The stale air from the room is recalculated to maintain the moisture level in the room and improve freshness.The product air is cool,fresh and moisture free.

2 WORKING PRINCIPLE:

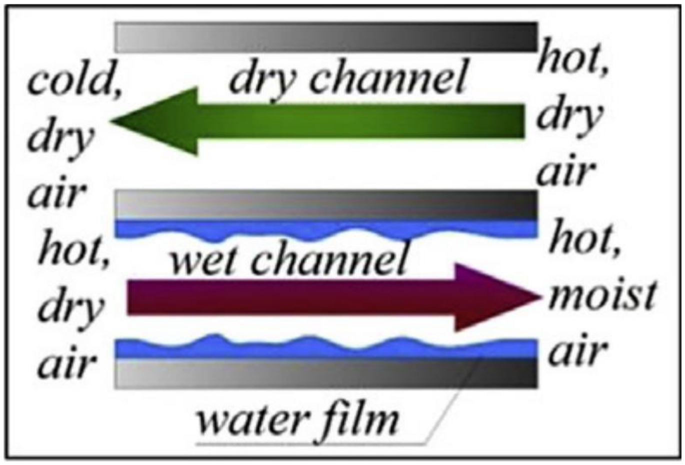

Fig : Working Principle

As shown in figure 2 (above) the indirectly cooled primary air stream is cooled by heat and mass transfer be- tween the secondary wet air stream and wet wall surface. The latent heat transfer and the vaporization process is the key concept in heat transfer process. Indirect evaporative cooling works on cross flow heat exchanger. The main disadvantage of the indirect evaporative cooling is that the temperature drop is only achieved up to wet bulb temperature of the am- bient air. Figure 4 shows the indirect evaporative cooling us- ing psychometric chart.

In order to overcome the disadvantage of the indirect evaporative cooling, in recent years, a new type of heat and mass exchanger (Fig. 4) utilizing the benefits of the Maisotsen- ko cycle has been developed. In this type of heat exchanger, part of the surface on the dry side is designed for the working air to pass through and the rest is allocated to the supply air. Both the supply and working air are guided to flow over the dry side along parallel flow channels. There are numerous holes distributed regularly on the area where the working air is retained and each of these allows a certain percentage of air to pass through and enter the wet side of the sheet.

The air is gradually delivered to the wet side as it flows along the dry side, thus forming an even distribution of airstreams over the wet surface. This arrangement allows the working air to be pre-cooled before entering the wet side of the sheet by losing heat to the opposite wet surface. The pre- cooled air delivered to the wet side flows over the wet surface along channels arranged at right angles to the dry side chan- nels, absorbing heat from the working and product air.

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As a result, the product air is cooled before being de- livered to spaces where cooling is required, and the working air is humidified, heated and discharged to the atmosphere. Ow- ing to effect of pre- cooling, the working air in the wet side (working air wet channel) has a much lower temperature and therefore, is able to absorb more heat from its two adjacent sides, i.e. the dry working air flow side and the dry product air flow side.

3 PROBLEM STATEMENT:

Air conditioning of buildings is currently dominated by conventional compression Refrigeration system, which takes over 95% of market share in this sector. This kinds of system is highly energy intensive due to extensive use of electricity for operation of the compressor, and therefore, is neither sustainable nor environment friendly. Also due to this some health issues might occur. The use of Indirect Evapora- tive Cooling has a High potential for meeting air conditioning needs at low energy costs

4 OBJECTIVE:

The main purposes of this project are listed below:

To develop a cooling with minimum power consump- tion and with no environmental damage

To achieve temperature near to dew point tempera- ture without refrigerant

Modeling and CFD based Analysis of fluid flow in Indirect Evaporative Cooling based on M-Cycle.

5 LITERATURE SURVEY

Zhiyin Duan, et al.,[1] represents an overview of the Indirect Evaporative Cooling (IEC) technology, which was concluded by considering various aspects including background, history, current status, concept, standardization, system configuration, operational mode, research and industrialization, market prospect and barriers, as well as the future focuses on R&D and commercialization. This paper work represents that the IEC technology has potential to be an alternative to the con- ventional mechanical vapour compression refrigeration sys- tems to take up the air conditioning system of building

Chandrakant Wani, et al.,[2] reviews and represents the unde- rutilized applications that the Maisotsenko Cycle could have. The use of Maisotsenko Cycle overcomes the constraints set by the conventional vapour compression system. Direct evapora- tive cooling is associated with the increased humidity though it gives a fair drop in temperature. On the other hand, the in- direct evaporative cooling controls the humidity but the tem- perature drop is insufficient. Both the systems are coupled in Maisotsenko cycle to form a new system.This paper after re- viewing the literature of many authors across the globe re- garding the Maisotsenko Cycle, evaporative cooling, desiccant cooling, cooling pads concludes that M-cycle cools down the product air without any considerable increase in the humidity. This principle of M-cycle can find a very vital role in many applications of cooling.

Hakan Caliskan, et al.,[3] showed the study based on three various novel air coolers based on M-Cycle are evaluated us- ing energy analyses based efficiency assessments along with their impact on environment and sustainability parameters. The M-Cycle systems are considered to cool a building room air while their inlet air parameters are same, but outlet cooled air parameters are different. The energy and energy analyses, and sustainability and environmental impact assessments are applied to the three novel air cooler systems considered to cool a building air. Energy analysis is performed for achieving the wet bulb effectiveness, cooling capacity, COP and PER of the systems.

B. Riangvilaikul, et al.,[4] shows that the dew point evapora- tive cooling system is an alternative to vapour compression air conditioning system for sensible cooling of ventilation air. This paper presents the theoretical performance of a novel dew point evaporative cooling system operating under vari- ous conditions of inlet air (covering dry, moderate and humid climate) and influence of major operating parameters (namely, velocity, system dimension and the ratio of working air to in- take air).A model of the dew point evaporative cooling system has been developed to simulate the heat and mass transfer processes

C. X. Cui, et al.,[5] presented the performance of a novel dew- point evaporative air cooler is theoretically investigated in this paper. The novel dew-point evaporative air cooler, based on a counter-flow closed-loop configuration, is able to cool air be- low the ambient wet bulb temperature and approaching dew-point temperature. A systematic computational model for the cooler has been developed. The novel dew-point evaporative air cooler was able to cool air to the temperature below its in- let wet bulb temperature and approaching dew-point temper- ature efficiently. Operating under variant inlet conditions (air temperature and humidity ratio), simulation results showed that the cooler could achieve wet bulb effectiveness of up to 132%, and dew-point effectiveness of up to 93%.

Sergey Anisimov, et al.,[6] describes numerical modelling of heat and mass transfer in the Maisotsenko cycle heat and mass exchanger (HMX) used for indirect evaporative cooling. For this purpose a numerical model is developed based on the modified e-NTU method to perform thermal calculations of the indirect evaporative cooling process, thus quantifying overall heat exchanger performance. Numerical simulation reveals many unique features of considered HMX, enabling an accurate prediction of its performance. The outcomes of com- puter simulation showed high efficiency gains that are sensi- tive to various inlet conditions, and allow for estimation of optimum operating conditions, including suitable climatic zones for the proposed unit using. This study presents theoret- ical energy analyses of the novel plate-fin heat exchanger based on Maisotsenko cycle and used for indirect evaporative cooling in air conditioning system. The performance of the Maisotsenko HMX was investigated and parametrically eva- luated by transitional simulation under various ambient and working/operating conditions in terms of cooling efficiency.

Ghassem Heidarinejad, et al.,[11] studiedCooling function of two-stage indirect/direct evaporative cooling system is expe- rimentally investigated in the different conditions. For this purpose, a two-stage evaporative Cooling experimental setup consisting of an indirect evaporative cooling stage (IEC) fol- lowed by a direct evaporative cooling stage (DEC) was de- signed, constructed and tested. In different outdoor condi- tions, the effectiveness of IEC stage varies over a range of 55–61% and the effectiveness of IEC/DEC unit varies over a range of 108– 111%. Considering the evaporative comfort zone, this system can provide comfort condition in a huge region in Iran where direct evaporative alone is can't provide summer com- fort condition

6 Material Selection

The materials used in the project setup have been chosen according keeping in mind their viability and availabil- ity. The materials used are listed and explained below:

Aluminum Sheet :

This Sheet serves as the base for the dry as well as wet pads. These sheets are light in weight and have higher strength. The thickness of the sheet is 0.5mm

Cotton Cloth :

The main purpose of Cotton Cloth is to hold the water in the wet channel.

Acrylic Sheet:

This is a very light material and has high load bear- ing capacity. It is also water resistant.

7 EXPERIMENTAL SETUP

In order to predict the approximate cooling require- ment for the room of the given dimension, we must incorpo- rate all the sources of the heat addition to the room and keep- ing in considerations the climatic conditions of Pune, India. The sources of heat addition to the room are sunlight through windows, glass panes, glass conduction. Heat is also added through the heat absorbed by exterior wall, roofs, partition wall, etc. people residing in the room as well as the equipment working in the room e.g. bulb, television, computer etc. also add to the heat. Also the heat due to infiltration and ventila- tion must be accounted for.

A Schematic diagram of green evaporative cooling system, along with various components as shown in below figure

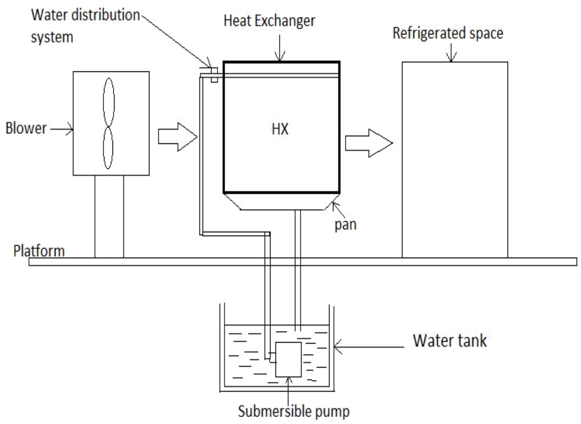

Fig :Experimental Setup

8 CALCULATION:

Let,
Inlet air temperature (T1) = 330C, Relative humidity =67%
T1WBT =180C
As we know the evaporative cooler is having efficien- cy between 0.8 to0.9

So considering efficiency=0.8
Efficiency DEC = (T1-T2)/(T1-T1WBT)
0.8= (30-T2)/(30-18)
T2=20.40C
Heat transfer by convection is given by equation,
Q=h A dT =15*0.22*0.55*(30−20.4) …(assuming convection heat transfer coeff.=15W/m2K)
Q=17.424W
So plate temperature is calculated using equation, Q=K A dT/dX
17.42= 202*0.22*0.55*(X−20.4)
X=20.50C
Now air entering through the holes into wet channel at 20.50C
So T11=20.50C
T11WBT=15.60C
Relative humidity=60%
Now, 0.8=(20.5-X)/(20.5-15,6)
X=16.58=T3
Considering the cooling to be produced is about 1 KW
.
Q=hA(T1-T4)
Calculation of h (convective heat transfer coeff.), h=(Nu*k)/Lc

Nu=0.664(Re)0.5*(Pr)0.33
Now, Re=(1.164*2*0.55)/(1.872*10^−5)
Re=68397.44
And value of Pr=0.72

Nu=156.39W/m2K
So, Nu=(h*Lc)/K
156.39=(h*0.55)/0.02588
h=7.35W/m²k
Finally by using ‘h’ we can calculate area of plate. Hence, Q=h A dT
1000=7.35*A*13
A=11.33m2

We are using total 40 plates alongside which product air is flowing so
Total area (A)= 40*(area of 1 plate) 1000=7.35*40*(area of 1 plate)*13 Area of one plate=0.2627m2

So we taken the plate dimension as B=0.6m, L=0.6m Area of Plate =0.6*0.6 =0.36m2
Surface area of plate = 0.6*0.6=0.36 m2
No. of wet Plate=21
No.of Dry Plate =20

9 CAD MODEL

The CAD Model was made using Catia V5 and the dimensions used for making the model are as follows:

Sr. No	Description		Dimension
1	Channel Height		5mm
2	Dry channel Dimensions		60 cm x 60 cm
3	Wet Channel Dimension		60 cm x 60 cm
4	Wet Channel	Stage 1	16 cm
		Stage 2	13 cm
		Stage 3	13 cm
		Stage 4	13 cm
5	Dry Channel		Divided into 2 parts of 29 cm each
6	Holes		15mm Diameter

TABLE: CAD MODEL DIMENSIONS

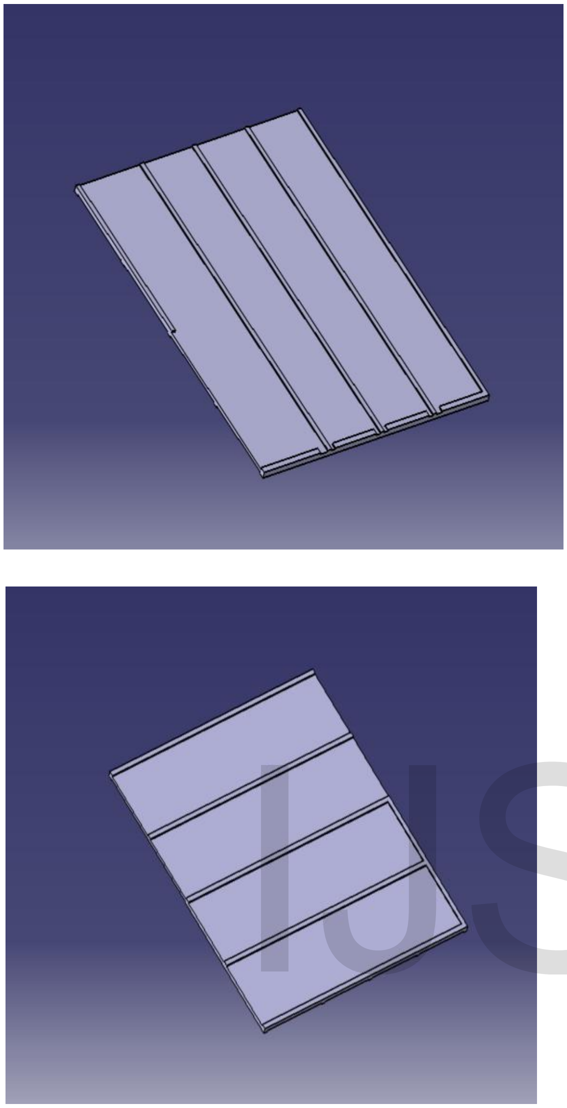

Fig :DRY Channel

The Dry channel and wet channel when assembled

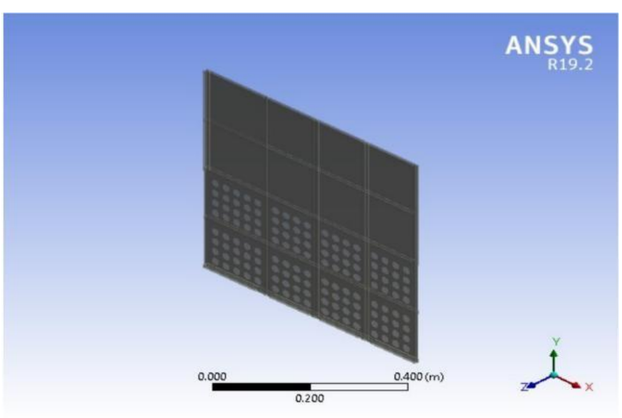

Fig :Assembly of IEC

together alternately make an IEC

10 CONCLUSION

After conducting the literature review on published journals related to Maisotsenko cycle or evaporative cooling, it can be inferred that devices based on the principal of M cycle have higher energy saving capabilities. This uses cooling properties of water rather than use of refrigerants. Channel inlet velocity, inlet air velocity, relative humidity are the major factors in determining efficiency of the evaporative cooling devices

This paper introduces a method of indirect evapora-
tive cooling heat exchanger based on CFD . The temperature drop by analytical method was 14.7 ℃.

11 ACKNOWLEDGMENT

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