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Review on Heat Wheel and it's Application in HVAC System

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Abstract—In HVAC systems, heat recovery system is required for increasing overall performance. The heat wheelis a heat recovery system composed of a mechanically rotating cylinder. The cylinder area is the medium for the heat transfer. As the wheel rotates between the supply air and exhaust air streams it picks up heat energy and releases it into the colder air stream. The driving force behind the exchange is the difference in temperatures between the opposing air streams. In particular, interest in heat wheels is increasing due to its high effectiveness. The aim of this paper is to design a heat wheels which perform in maximum effectiveness. The objective is to design the heat wheel and evaluation of the same using ANSYS Fluent. The device analysis is perform through the variation of operating conditions, namely the air velocity and the revolution speed of wheel.

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I. INTRODUCTION

In the present scenario as fossil fuel resources are depleted, the cost of energy continuous to rise. But in the limited amount of energy resources be world energy consumption has been increasing in a few last decades. According to the world energy consumption studies about 45% of the total energy is consumed by industrial and commercial buildings here the fact that 50% of these energy is used by HVAC systems itself. Increased the ventilation rates, which are required to satisfy the ventilation standard ASHRAE 62.1-2010, [6] mean a given this greater expenditure of energy to condition outside air. Thus, many governmental agencies put regulations on energy consumed by HAVC systems and equipment so. So energy recovery in HVAC system has important role inpresent days.it can be realized by exhaust heat recovery systems like rotary heat exchangers, heat-pipes, plate heat exchangers, etc. here Heat (sensible) wheels are one of the most effective energy recovery system due to its relatively high effectiveness and low manufacturing costs.it is widely used in a broad range of industrial applications, from low temperature air conditioning systems to large power plant energy recovery systems. Energy recovery involves a transfer of energy between an exhaust airstream and a supply airstream. An air permeable rotating disk or wheel is located in a duct-work system consisting of a pair of rectangular ducts. Usually, the disk consists of a large number of parallel flow passages in the axial direction. In most cases, the wall of the flow passages are obtained stacking sinusoidal or wavy metallic (aluminum) bands [12]. The upper half of the disk is fed by hot air moving from right to left through the upper duct, while the lower half of the disk is fed by cooler air flowing from left to right through the other duct. Since the wheel is rotating, it is periodically exposed to both cold and hot streams. As the two airstreams pass through the energy recovery wheel, the rotation of the wheel facility at transfer of energy from the higher energy airstream to the lower energy airstream. This means that the exhaust air preheats the supply air in the winter and precools the supply air in the summer. Most recently, heat wheels have been updated to a heat and moisture exchanger so-called energy wheels. Buildings are exposed to a wide range of weather conditions; however, two weather conditions are of major importance in heating, ventilating and air conditioning (HVAC) applications (hot and humid and cold and dry) because they imply a large rate of energy use to keep a building comfortable for the occupants. Large variations in the ambient air conditions over the year often occur in man climatic regions. This is why HVAC engineers are always concerned with optimization of their design to improve indoor air quality, productivity and at the same time reduce HVAC capital and operating costs.The aim of this workis to provide a detailed analysis and optimization of heatwheel design, maximizing sensible effectiveness. In particularthe effects of revolution speed, air velocity on component performance are evaluated.

II. DesignGeometry and Mesh Generation

2.1 geometry:

The heat wheel, which is characterized by a diameter *D* and a length *L*, is divided into two sections: the first for supply air and the second for exhaust air in a counter current flow arrangement. The wheel rotates at constant speed *N* and each channel is periodically exposed to the two streams. In this model the purge section is not considered A computational model was created to accurately analyse the effect of rotation speed of a rotary thermal wheel and air velocity on the heat transfer rate through a heat wheel

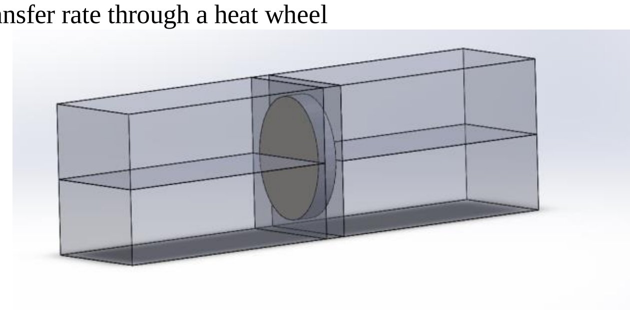

Fig 1. The geometry created in solid works 2014

The geometry was created in solid works 2014 as per the dimensions from design. Dimensions for the geometry can

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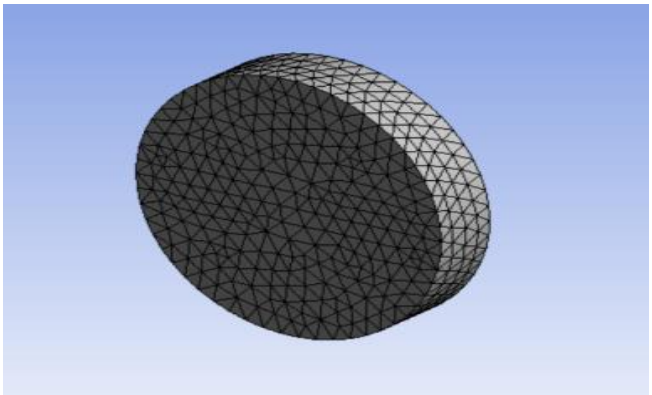
beseen in Figure 1. For the experimental investigation purposeshere considering a small scale geometry and its analysis.

2.2 Mesh

The software used for meshing was ANSYS ICEM CFD. The whole geometry was discretised into 2.4 million cells. The tetragonal mesh having orthogonal quality of 0.5 (range from 0 to 1, near to 1 is good)is used. Also aspect ratio 6.7 (up to 40 aspect table) [6]. The mesh arrangement consisted of 329727 nodes. Grid sensitivity analysis method was used to verify themesh.



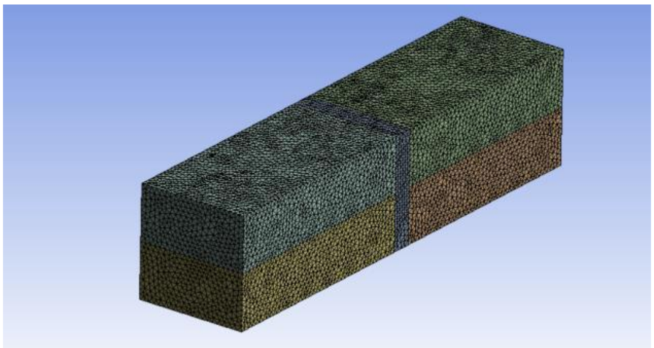


Fig 2. Mesh

The rotation speed and air velocity of the heat wheel were modeled using mesh motion a porous media conditions in ANSYS FLUENT. The mesh motion of the heat wheel was orientated at centre point and vertical axis of the wheel; this ensured that the volume rotated around centre point at the required speeds. Porous media setting applied to the surfaces of the volume. Inertia resistance values were assigned to each direction axis.Value inertial resistance in the X and Y axis direction several orders of magnitude greater than the values in the Z axis directionThis was to prevent any fluid flow through the heat wheel in a radial direction. The porosity is commonly 89%, this value was assigned to the porous media settings, along with inertial resistance C2 value of 89.6 [12].

III DESIGN OF VARIOUS PARTS

3.1 General

Design part consist Design of Heat Wheel, Design of Ordinary/conventional plate type Heat Exchanger. Before going to design we must have to determine maximum flow rate of steam for which heat wheel is to be design. It can be determine by considering standard part specifications and charts available.

3.1.1 Design Data

Pressure of steam in pressure cooker= 1 bar to 1.5 bar. Assume pressure of steam to be atmospheric. P=1.01325bar. At this pressure hf= 419.7kj/kg hg= 2676kj/kg vg=1.651m3/kg from steam tables Heater capacity= 2KW. The spacing between heating coil and cooker bottom is 1cm. Heating coil radius= 100mm From chart of shape factor between two circular surfaces is given by, F1-2=0.9 (appr.) ….from Heat Transfer book of D.S. Pawaskar. Rate of heat given to cooker= F1-2 × 2KW = 0.9 × 2000 = 1800W

3.1.2 Calculation to determine maximum steam flow rate:

This heat is used to convert water into steam

$\therefore 1800 = ms \times hg$

assuming steam to be dried and saturated

$\therefore 1800 = ms \times 2676 \times 10^3$

$\therefore ms = 6.726 \times 10^{-4}$ kg/sec.

Volume flow rate = ms × vg …..

$= 6.725 \times 10^{-4} \times 1.651$
$= 1.11 \times 10^{-3}$ m3/sec.
Q = 1.11 lit/sec.

This is the maximum flow rate of steam for which we have to design the heat wheel setup.

IV DESIGN OF SUPPORTING MEMBERS OF HEAT WHEEL

The shaft and Bearings have been selected as available in standard dimensions. The axle of bike as shaft and suitable bearing is used. Shaft diameter = 12mm, Bearing selected is 6201, because shaft diameter and core diameter are same as 12mm. Now our aim is to check safety of shaft and bearing under loading and operating condition

4.1Wheel Construction:

Your McQuay enthalpy wheel is delivered completely assembled and ready to run. The wheel is built to provide many years of trouble free service following proper installation and performance of the minimal maintenance requirement.

4.2 Definitions

The following are descriptions of various components related to the enthalpy wheel construction (see Figure 4):

4.3 Bearing, external- The wheel and bearing rotate on theshaft, no field lubrication is required.

4.4 Brush seal- The seal used for both the circumferential seal and the inner seal in the cassettes. They are constructed of

nylon brush and configured to seal against the enthalpy wheel band in the case of the circumferential seal, and against the wheel face in the case of the inner seal. These
seals are full contact seals, have an integral clip, and they are clipped to the cassette face panel cutout (circumferential) or to the (inner) post.

4.5 Cassette- The steel structure that houses the rotor. Cassetteshare of punched sheet metal panelized construction.

4.6 Enthalpy wheel- A generic name for an energy conservation wheel. The term "enthalpy" refers to an airstream's total energy (temperature and humidity level).

4.7 Exhaust air- The air stream that is exhausted to the outside.Exhaust air is building return air that has been run throughthe enthalpy wheel.

4.8 Heat wheel- Synonymous with an enthalpy wheel, energyconservation wheel, or total energy recovery wheel. Someheat wheels are sensible only wheels and should not beconfused with McQuay total energy recovery wheels.

4.9 Hub- The center support of an enthalpy wheel.

4.10 Latent energy- Latent energy, in the context of enthalpywheel discussions, is the work done by the wheel to transfermoisture from one air stream to another. Latent work isaccompanied by humidity changes in the air streams.

4.11 Media- The chemical composite part of the enthalpy wheelwhich actually performs the latent and sensible exchange.

4.12 Outdoor air- The air stream that is brought in from theoutside. Outdoor air becomes supply air after going throughthe enthalpy wheel.

4.13 Purge- A small segment of supply air defined by the gapbetween the inner seal on the outdoor air edge of the centerpost and the supply air edge of the center post. The purgeangle is adjustable. The purge captures the small amount ofsupply air captive in the enthalpy wheel when the wheelmoves from return to supply and routes it to return tominimize cross contamination.

4.14 Return air- The air stream that is returned from thebuilding. Return air becomes exhaust air after going throughthe enthalpy wheel.

4.15 Rotor- The part of an enthalpy wheel that performs theenergy exchange and consists of the wheel media, hub,spokes and band.

4.16Sensible heat- Sensible energy, in the context of enthalpywheel discussion, is the work done by the enthalpy wheel totransfer heat from one air stream to another. Sensible work isaccompanied by temperature changes in the air stream.

4.17 Spoke- Flat metal member used to support the enthalpywheel radially.

4.18 Supply air- The air stream that is supplied to the buildingspace. Supply air is outdoor air that has been run through theenthalpy wheel.

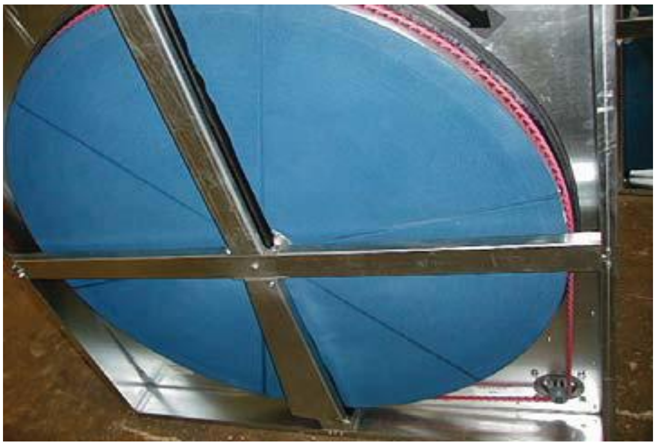


Figure 3: Wheel Construction (Side Side)

V MAINTENANCE

5.1Troubleshooting

The following table may be used as a quick-reference for identifying common symptoms and possible causes related to the recovery wheel.

SYMPTOM	CAUSE
Inadequate Wheel Performance	Check wheel rotation speed (see "Variable Speed Frequency Control" on page 4).
	Check for wheel integrity and adjust seals or replace worn seals (see "Prestart up Checks" on page 5 and "Seals" on page 6).
	Check entering air conditions and compare to design (see "Prestart up Checks" on page 5).
	Check ducting for leakage and fix any leaks.
	Check media for dirt and clean per cleaning instructions (see" Wheel" on page 6 and "Enthalpy Wheel Removal" on page 6).
Improper Wheel Rotation	Check drive belts for engagement with sheave
	Check drive motor.
	Check VFD programming (provided with optional frost protection).

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VI PERFORMANCE OPTIMIZATION

Here the effect of revolution speed, and face velocity oncomponent effectiveness shown in following graphs . It ispossible to state that if inlet temperature of air streams varies within the range of HVAC applications, the rotary heat exchanger performance does Changesignificantly.

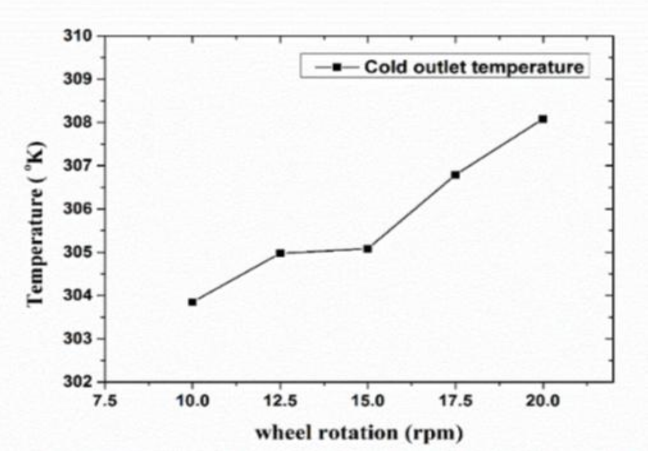

Fig 4. Effect of revolution speed, outlet temperature and cons face velocity in cold inlet

If the heat wheel rotates too slowly, the matrix materialaverage temperature becomes close to the air stream therefore,heat transfer decreases due to limited temperature difference

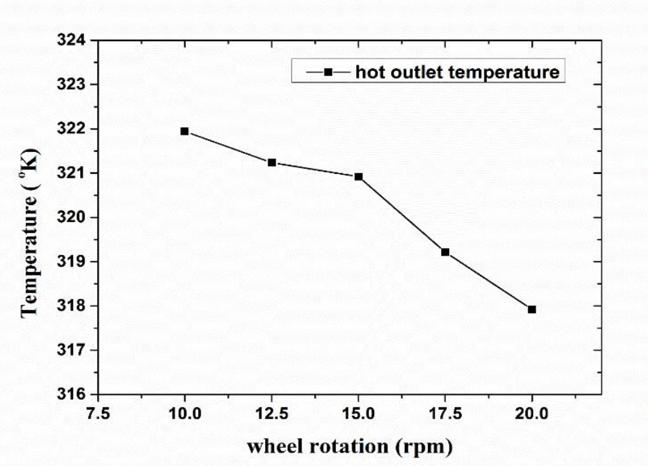

Fig 5. Effect of revolution speed, outlet temperature and constant face of velocity in case of hot inlet

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On the other side, if the wheel rotates too fast, the effect ofcarryover, *i.e.*, the cross contamination between the twostreams due to the amount of air trapped in the wheel channel,becomes relevant. Therefore an optimal revolution speedexists: It is typically around 20 rpm, depending on air flow rates and heat exchanger geometry.

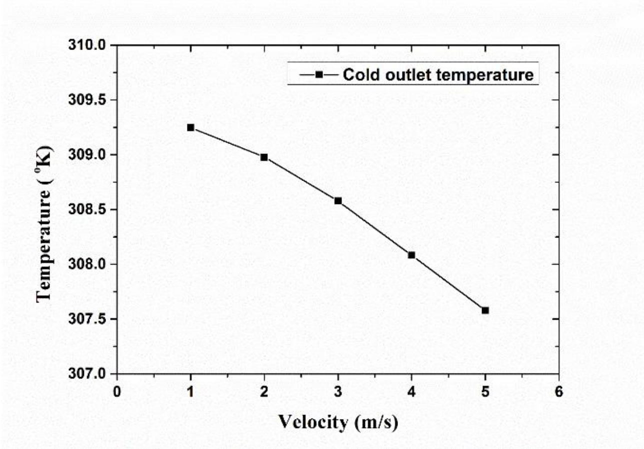

Fig 6. Effect of face velocity, outlet temperature and constant

Revolution of wheel in case of cold inlet

If the face air velocityof both streams increases the sensibleeffectiveness decreases because air heat capacity rate is biggerat constant heat transfer area. Here the maximum velocity
Obtained in this case is 1m/s.

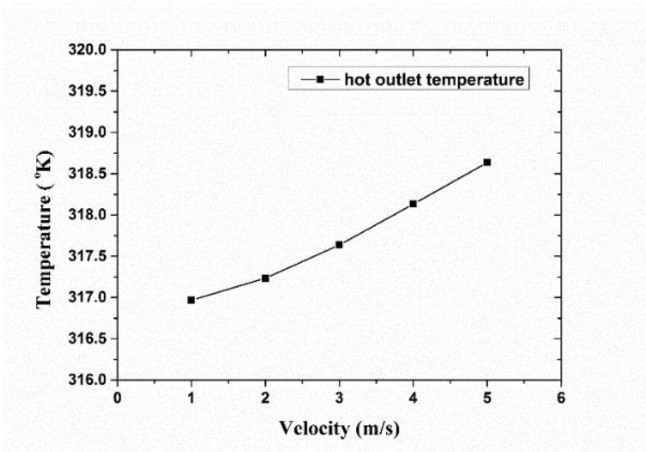

Fig 7. Effect of face velocity, outlet temperature and constantrevolution of wheel in case of hot inlet

All the before mentioned considerations are in agreement with previous research works, such as [12, 13].

VII. PROBLEM FORMULATION

Often in engineering, physical problems are described and deduced from general mathematical equations of physical principles, which are solved analytically or numerically. The act of formulating these equations from physical principles for a specific engineering problem and specifying their boundary and initial conditions is
referred to as modeling.
The effectiveness of the energy recovery wheel gives us a scale of how well the wheel is conserving building energy. This quantity is technically defined as the amount of energy recovered divided by the maximum energy that could theoretically be recovered. While effectiveness can be calculated for both sides of the wheel, the return air effectiveness is typically the determinate of efficiency. The effectiveness is calculated as:

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$$\varepsilon = \frac{v_r \cdot (X_4 - X_3)}{v_{min} \cdot (X_4 - X_3)}$$

where: *v*r is the return air volume rate; *v*min is the lesser of the air flow rates; and *X* is the temperature.This are above formula for to create a effectiveness.

VIII.LITERATURE REVIEW

The concept of Heat Wheel generally comes from Waste heat recovery. Many scientist and engineers have been worked over waste heat recovery.

In 1979 the scientist D.A. Reay and F.N. Span from London worked for adapting various devices of Recovery of waste heat in industries. They introduced the Devices like Recuperator, Air preheater, Thermo compressor etc.

Heat Wheel was firstly invented in order to recover waste heat of exhaust air in air conditioning system. In the mid 1970s, two Enthalpy Wheel products were introduced to industries. One was the oxidized Aluminium Wheel made up of corrugated Aluminium foil and second used silica gel as desiccant.

Enthalpy wheel generally many scientist to create a design for ANSYS fluent and more effective and Dr.penslyVania to optimize the heat wheel design parameter.

IX.CONCLUSIONS

In this paper we can conclude that, global shortage of energy sources can be overcome by using heat wheel torecover wastage of heat in industries. As Heat wheel is more effective it is more suitable to use as rotary heat exchanger. From the results we can say at least 15% of heat can be saved. In future it has wide scope only more feasible design will have to be adapted.

Revolution speed is an important factor to affect the wheel performance. In this analysis we get the maximum revolution for design heat wheel is 20 rpm.

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