PERFORMANCE ANALYSIS OF THERMAL WHEEL BY EXPERIMENTAL METHOD

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ABSTRACT

A heat exchanger is a device built for efficient heat transfer from one medium to another. The medium may be separated by a solid wall, so that they never mix, or they may be in direct contact. In particular, interest in heat wheels is increasing due to its high effectiveness The aim of this project is to analyze a heat wheels for its Thermal efficiency. The objective is to analyze the heat wheel and evaluation of the same using Experimental methods.

Keyword : - *Heat wheel optimization, Heat wheel effectiveness, ANSYS Fluent., Relative temperature efficiency.*

1. INTRODUCTION

The rotor with its axial, smooth air channels serves as a storage mass, half of which is heated by the warm air stream and half of which is cooled by the cold air stream, in a counter-flow arrangement.

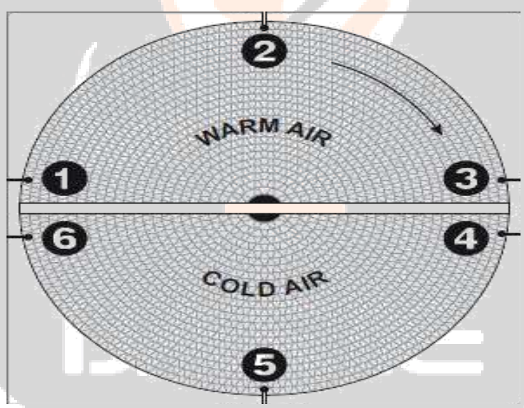

Fig 1 Concept of Heat Transfer Through Wheel [12]

1.1 Warm Air Entry

The portion of thermal wheel is enter into warm air stream at point 1 in fig. Due low rotational speed of thermal wheel the temperature of thermal wheel is increase.

1.2 Mid Air Entry

This wheel has already passed half of its time in the warm air. The storage mass has become warmer due to the air flow; consequently the thermal wheel is no longer cooled as severely as in the entry zone. The channel temperature is about the same on the inlet side and on the outlet side. Condensation occurs only if the humidity differential is great

1.3 Warm Air Exit

The Wheel is on the verge of leaving the warm air. On this point it has nearly reached the temperature of extract air.

The heat transfer rate is now low. The duration of stay in the warm air as well as in the cold air, i.e. the speed of rotation, is decisive for the performance of the rotary heat exchanger. Also, the performance depends on the storage mass (thickness, geometry), the heat transfer and the air velocity.

1.4 Cold Air Entry

After pass over from the warm air side to the cold air side, cold air now flows through the channel (in counter-flow direction). Due to the large temperature difference the heat transfer rate is very high, i.e. the cold air is strongly heated; in turn, the storage mass is severely cooled. Possible condensate on the exchanger surface is (partly) taken up by the heated cold air.

1.5 Mid Cold Air

Half of the time in the cold air is over. The storage mass has become colder. Temperatures difference is decrease.

1.6 Cold Air Exit

The air channel has gone through the cold air zone. The storage mass has been severely cooled; near the inlet the temperature has almost reached the temperature of cold air. After cross-over to the warm air side the cycle starts a new.

2 IMPORTANT TERMS

2.1 Effectiveness

The heat exchanger effectiveness, ε, is defined as the ratio of the rate of heat transfer in the exchanger, Q, to the maximum theoretical rate of heat transfer i.e. Q max

$$E = Q / Q_{max}$$

2.2 NTU

The number of transfer units (NTU) is an indicator of the actual heat transfer area or physical size of the heat exchanger. The larger the value of NTU, the closer the unit is to its thermodynamic limit. It is defined as

$$NTU = UA / (m\,C_P)_{min}$$

2.3 Capacity Ratio

The capacity ratio, Cr, is representative of the operational condition of a given heat exchanger and will vary depending on the geometry and flow configuration (parallel flow, counter-flow, cross flow etc.) of the exchanger. This value is defined as the minimum heat capacity rate divided by the maximum capacity rate i.e.

$$C_r = (m\,C_P)_{min} / (m\,C_P)_{max}$$

2.4 Temperature efficiency

Temperature efficiency

$$= (T_1 - T_2)/(T_3 - T_4)$$

T_1= Fresh air outlet temperature
T_2= Fresh air inlet temperature
T_3 = Hot air (Exhaust air) inlet temperature
T_4 = hot air (Exhaust air) outlet temperature

2.5 Peripheral velocity (V):

V= $\pi \times D1 \times N$
= 4.71cm/sec to 9.42cm/sec

D1 = outer diameter =60cm
D2 = inner diameter = 5cm
Rotational speed = 0 to 30 revolution/min

2.6 Mass flow rate (M) :

Mass flow rate (M) in kg/s = ρ *v

ρ = Air density (kg/m^3)

= 1.1839kg/m^3 at 25°C

v = Air flow rate (m^3/s)

2.7 Air velocity (V_1) :

Air velocity (V_1) = v/A

v = Air flow rate (m^3 / s)

A = cross section area of air flow (m^2)

3 PROBLEM DESCRIPTIONS

The rotor is assembled from alternate layers of flat and thin sheet of mild steel. Having thermal conductivity about 50W/m-c and density about 7801kg/m^3 Specific heat capacity of thermal wheel material is 510 J/kg-K The smooth channels formed by this construction ensure that the flow is laminar, thereby ensuring that the drop is low and minimizing the risk of fouling by dirt or dust.. The rotor media can be cleaned with low temperature steam
The depth of the rotor is 75 mm. The wheel is strengthened by means of double spokes, which are bolted (and welded) in the hub and welded in the rotor shell ensuring a long life span. At the perimeter the rotor is enclosed by a welded steel shell, ensuring true running and allowing maximum use of the wheel face area.
Outer Diameter D2= 600mm
Inner diameter D1= 50mm
Depth of wheel W= 300mm

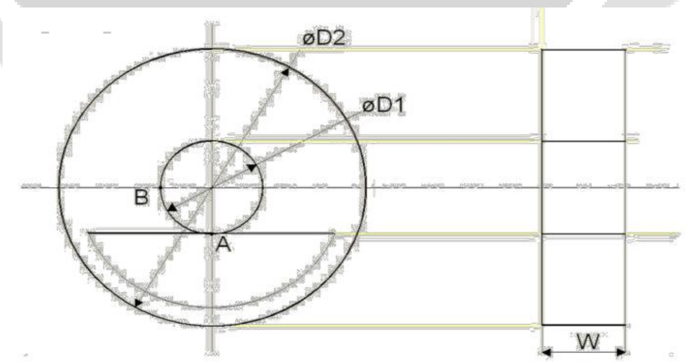

Fig 2 thermal wheel [13]

3.1 Casing

Construction of casing depends on the size of the rotor. Casings are fabricated by using metal sheets. Casing may be single unit or partitioned. Casing supports rotor bearing with the help of the cross members and struts. It also encloses the motor unit.

3.2 Drive

The wheel is driven by means of an electric motor and a drive belt. The motor is usually fixed on a hinged plate in the casing. Drive provided can be constant or variable. Performance control is not possible in constant drive. In variable drive system, the rotor speed is varied as per exhaust temperature. This is achieved by means of cascaded controllers which use rotary heat exchanger as energy resource in heating as well as cooling operation.
Shaft supports the heat wheel, which is rotated by motor having
Power – 90W/220V/3PH/50Hz

3.3 Peripheral slide seal

High tightness seal In rotary heat exchangers with sheet-metal casing automatically adjustable constant-force springs are mounted on the wheel mantle; they press the abrasion-resistant slide seal against the casing .

3.4 Rotational speed monitoring

The speed of rotation of the wheel can be monitored with an inductive sensor. Stoppages, e.g. caused by a broken v-belt, can be detected quickly and the cause can be corrected.

3.5 Air Blower

Low-pressure air blower (LPACs), which have a discharge pressure of 150 psi or less is use for this experiment The air compressor is supplied by ac power and its air discharge rate is adjustable as per requirement.

3.6 Air heater

Electrically powered air heaters may use either single-phase or three-phase power. Typically, these devices use alternating current (AC) instead of direct current (DC) and differ in terms of watt density. When listed as a range or maximum amount, watt density provides a good measure of how quickly the industrial heater can transfer heat .In our experiment we use air heater to replicate the hot air (exhaust air) supply from furnace.

3.7 Temperature measuring device

For this experiment we use thermocouple for measurement of temperature . we use K - type thermocouple which has specification as followings
Temperature Range:
Thermocouple grade wire, −454° to 2,300°F (−270 to 1,260°C)
Accuracy (whichever is greater):
Standard: ± 2.2C% or ±.75%
Special Limits of Error: ± 1.1C or 0.4%

4 EXPERIMENT SETUP

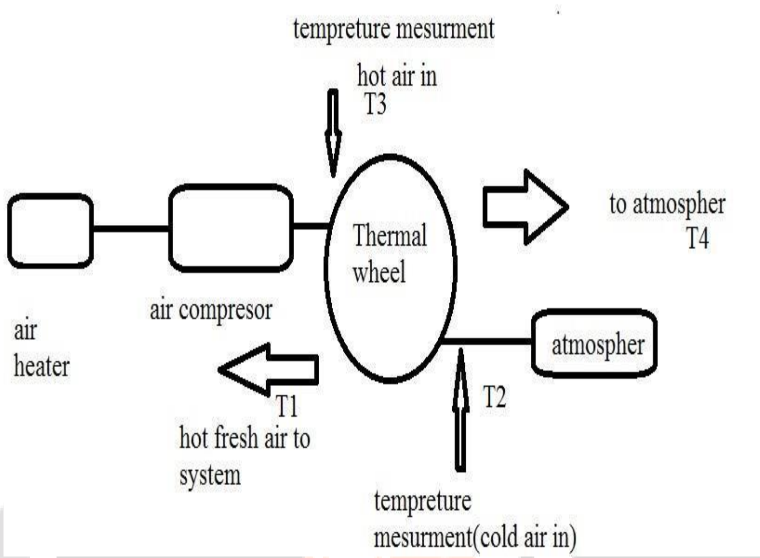

Fig 2 Experiment setup

EXPERIMENT PROCEDURE :

1. First check all connection with air heater, air compressor, thermal wheel, motor, drive, thermocouple, tachometer.
2. Turn on air compressor, air heater, motor.
3. Measure atmospheric temperature(T2). Keep measuring the exhaust hot air temperature for while, until it become steady.
4. When the steady temperature(T3) of exhaust hot air from compressor obtained at that point the temperature of fresh air outlet (T1) and outlet temperature exhaust hot air T4 IS measured.

5 Calculate the temperature efficiency as,
Temperature efficiency= ($T_1 - T_2$)/($T_3 - T_4$)
T_1= Fresh air outlet temperature
T_2 = Fresh air inlet temperature
T_3 = Hot air (Exhaust air) inlet temperature
T_4 = hot air (exhaust air) outlet temperature

6. Change the rotational speed of thermal wheel from 5 rev/min to 25 rev/min and evaluate the temperature efficiency for different revolution speed.

7 .Plot the Graph of Temperature efficiency Vs. revolution speed of thermal wheel.

8 From graphical presentation we can find optimum thermal efficiency for given temperature condition of air coming out of air compressor. Simulate the experiment using the simulation software by applying the appropriate initial and boundary conditions.

4.1 Assumption :

- Atmospheric condition remain unchanged during experiment (atmospheric temperature and pressure remain constant).
- The temperature distribution is uniform across the cross section of thermal wheel
- For convenience we conduct experiment for 60° -90°c temperature of hot exhaust air.
- We assume that experiment data is taken at nearly steady state condition, because absolute steady state condition is impossible to attain.

- Mixing of two fluid is negligible during flow through different part of duct and thermal wheel.

4.2 Precautions :

- All electric connection should proper. The electric connection in this experiment the electric connection with air pre heater, air compressor, and motor should be done properly.
- Both air and exhaust gas (hot air) carrying duct should have leak proof joint.
- Attachment of Thermocouple for both stream and also for both side of thermal wheel should be done properly.
- The reading is taken when the temperatures on both side become steady

5 EXPERIMENTAL DATA :

Consideration,

1.Hot air inlet temperature = 80°C

2. Cold air inlet temperature = 25°C

3.Rotational speed of thermal wheel =20 rpm

4.thermal conductivity of aluminum = 237 w/m k

5. Heat capacity of water is constant = 4.2 kJ/kg

No.	Velocity (m/s)	Air flow rate (CMH)	Pressure drop (Pa)	Hot air outlet temp. (°c)	Cold air outlet temp. (°c)	Efficiency (%)
1	1.0	273	74	55.7	45.7	85.18
2	1.5	409	85	59.1	42.6	84.21
3	2.0	546	102	60.2	41.0	80.80
4	2.5	682	122	61.8	38.6	74.72
5	3.0	765	143	63.4	37.2	73.49
6	3.5	955	165	63.8	35.2	62.96
7	4.0	1092	189	65.5	33	55.17
8	4.5	1228	214	70.1	30.44	54.94

Table1 Efficiency-Air flow Velocity

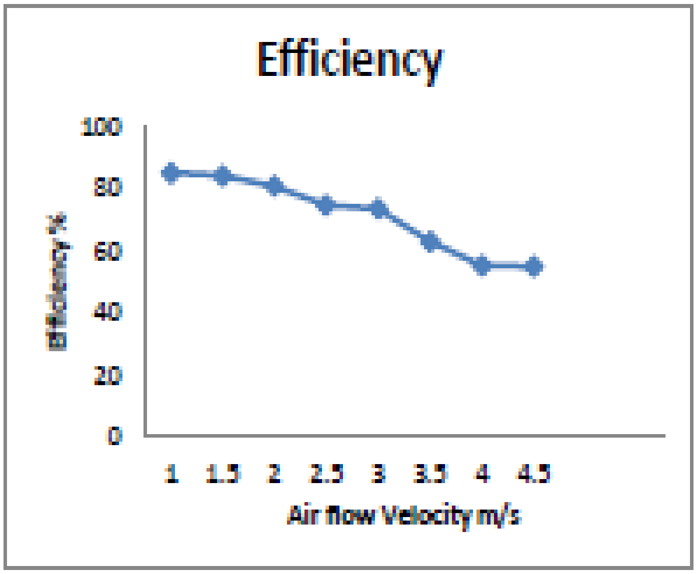

Chart 1 Efficiency –air Flow velocity Diagram

SR NO.	Hot Air inlet Temp. T_3°C	Cold Air inlet Temp. T_2°C	Rotational Speed,N (RPM)	Cold Air out T_1°C	Hot Air Out T_4°C	Efficiency .
1		25	5	35.1	65.2	0.6824
2		25	8	36.1	64	0.6937
3		25	10	37.6	63.6	0.7682
4		25	12	39	61.8	0.7692
5	80	25	15	40.5	59.8	0.7673
6		25	18	42.3	57.6	0.7772
7		25	20	45.4	55.7	0.8395
8		25	22	44.2	57.9	0.8687
9		25	25	40.5	58.6	0.7242
1		25	5	30.8	60.5	0.6102
2	70	25	8	31.5	60.0	0.6500
3		25	10	32.4	59.3	0.6615
4		25	12	33.3	56.4	0.6602

5		25	15	35.8	54.6	0.7012
6		25	18	37.3	53.4	0.7409
7		25	20	39.6	52.3	0.8248
8		25	22	38.4	53.2	0.7976
9		25	25	36.7	53.6	0.7134
1		25	5	28.1	55.0	0.6200
2		25	8	29	54.0	0.6666
3		25	10	31.2	53.9	0.3850
4		25	12	31.9	52.6	0.4000
5	60	25	15	35	51.1	0.5291
6		25	18	36.5	50.6	0.5927
7		25	20	38.4	50.8	0.6979
8		25	22	38	50.2	0.6565
9		25	25	36	50.3	0.5583

Table 2 Rotational Speed –Efficiency

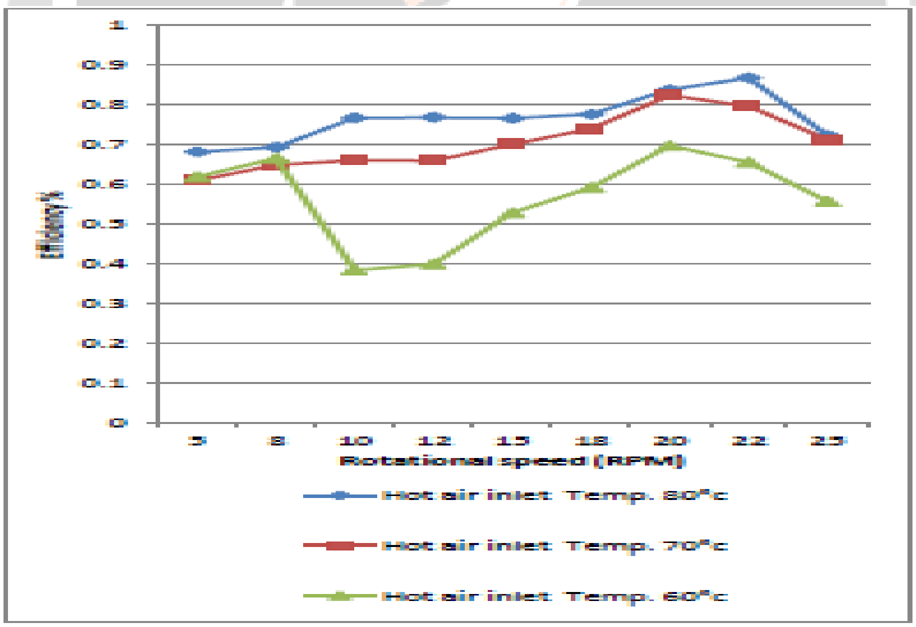

Chart 2 Diagram for Efficiency -Rotational Speed

6 CONCLUSION :

With experiment data we can find the relation between the temperature of hot inlet air and rotational speed for maintain the effectiveness of thermal wheel for given flow rate.

We found from the experiment that air velocity and rotational speed of thermal wheel are two major operational

parameter that affect the thermal wheel performance a most along with geometry, temperature conditions, and material property of thermal wheel.
With increase in air velocity the efficiency of thermal wheel is decrease so it is Favourable to use low air velocity in our experiment we have maximum efficiency when air velocity is minimum1.0m/s then further increase in velocity decrease the thermal efficiency.
Rotational speed is to be maintained with in 15 to 25 rpm to get maximum heat transfer. For temperature of 60°c to 80°c for hot air inlet, it is found that the maximum heat transfer is possible near 20 rpm speed further increment or decrement in rotational speed will decrease the temperature efficiency.
By adjusting the speed of thermal wheel same thermal wheel can use for cooling and heating both.

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