A PROJECT REPORT

ON

"ANALYSIS OF HEAT EXCHANGER PERFORMANCE USING WIND TUNNEL TEST RIG FACILITY"

Submitted to

UNIVERSITY OF MUMBAI

In Partial Fulfilment of the Requirement for the Award of

BACHELOR'S DEGREE IN
MECHANICAL ENGINEERING

BY

ALBUQUERQUE FARHAN	**16ME05**
ANSARI REHAN	**16ME12**
CHAURASIA SUNNY	**16ME15**
NADAR VENKATESH	**16ME50**

UNDER THE GUIDANCE OF
PROF.RIZWAN SHAIKH

DEPARTMENT OF MECHANICAL ENGINEERING
Anjuman-I-Islam's Kalsekar Technical Campus
SCHOOL OF ENGINEERING & TECHNOLOGY
Plot No. 2 & 3, Sector - 16, Near Thana Naka,
Khandagaon, New Panvel - 410206

2019-2020

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CERTIFICATE

This is certify that the project entitled

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submitted by

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ANSARI REHAN	**16ME12**
CHAURASIA SUNNY	**16ME15**
NADAR VENKATESH	**16ME50**

is a record of bonafide work carried out by them, in the partial fulfilment of the requirement for the award of Degree of Bachelor of Engineering (Mechanical Engineering) at ***Anjuman-I-Islam's Kalsekar Technical Campus, Navi Mumbai*** under the University of MUMBAI. This work is done during year 2019-2020, under our guidance.

Date: / /

(Prof.RIZWAN SHAIKH)
Project Supervisor

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Acknowledgements

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We must thank NEXA Mumbai for providing us with the opportunity to work on the Defence project, which was designed by NEXA Mumbai for the DRDO-CVRDE and I would like to express my gratitude to all the individuals whose contribution have helped us in undergoing training and successful completion of my project at NEXA MUMBAI, New Panvel, Navi Mumbai-410206.

Without the support, assistance, and motivation provided by those around us. This study would never have been accomplished.

ALBUQUERQUE FARHAN
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Project I Approval for Bachelor of Engineering

This project entitled ***"ANALYSIS OF HEAT EXCHANGER PERFORMANCE USING WIND TUNNEL TEST RIG FACILITY"*** by ***Albuquerque Farhan , Ansari Rehan, Chaurasia Sunny, Nadar Venkatesh*** is approved for the degree of ***Bachelor of Engineering in Department of Mechanical Engineering.***

Examiners

1. ....
2. ....

Supervisors

1. ....
2. ....

Chairman

....

Declaration

I declare that this written submission represents my ideas in my own words and where others ideas or words have been included, I have adequately cited and referenced the original sources. I also declare that I have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in my submission. I understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

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ABSTRACT

In this study performance evaluation and testing of the heat exchanger (radiator) are done using wind tunnel test rig facility because all internal combustion engines produce heat as a byproduct of combustion of fuel and friction of moving parts. This heat can reach temperatures up to 1925°C (3500°F) and can cause catastrophic damage to the engine components. Furthermore, it can have negative effects on the engine such as reduction in engine performance and shortening of engine's service life, therefore cooling systems must be accurately designed, tested, operated and maintained for optimum engine life and smooth operation.

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CHAPTER 1

1.1 GENERAL INTRODUCTION ON HEAT EXCHANGER

A heat exchanger is a system used to transfer heat between two or more fluids. Heat exchangers are used in both cooling and heating processes.[1] The fluids may be separated by a solid wall to prevent mixing or they may be in direct contact.[2] They are widely used in space heating, refrigeration, air conditioning, power stations, chemical plants, petrochemical plants, petroleum refineries, natural-gas processing, and sewage treatment. The classic example of a heat exchanger is found in an internal combustion engine in which a circulating fluid known as engine coolant flows through radiator coils and air flows past the coils, which cools the coolant A heat exchanger is a system used to transfer heat between two or more fluids.

Heat exchangers are used in both cooling and heating processes.[1] The fluids may be separated by a solid wall to prevent mixing or they may be in direct contact.[2] They are widely used in space heating, refrigeration, air conditioning, power stations, chemical plants, petrochemical plants, petroleum refineries, natural-gas processing, and sewage treatment. The classic example of a heat exchanger is found in an internal combustion engine in which a circulating fluid known as engine coolant flows through radiator coils and air flows past the coils, which cools the coolant and heats the incoming air. Another example is the heat sink, which is a passive heat exchanger that transfers the heat generated by an electronic or a mechanical device to a fluid medium, often air or a liquid coolant. The heat exchangers are found to have a wide range of applications ranging from the house-hold purposes to refineries and cryogenic operations.

These heat exchangers had become the essential requirement of the current society as they do not cause any harmful effects to the environments. The cost involved in this energy extraction is also very less and economical. One of the concerns regarding these heat exchangers is to enhance the heat transfer and improve their efficiency. The survey and researches had been carried out in a large manner to improve the heat transfer enhancements. In this context, an objective is set to review the literature related to heat exchangers under the following categories: general study of heat exchangers, various configurations of heat exchangers, the compact heat exchangers and the effects of nanofluid in the heat transfer enhancements.

They are widely used in space heating, refrigeration, air conditioning, power plants, chemical plants, petrochemical plants, petroleum refineries, natural gas processing, cryogenics applications and sewage treatment. One common example of a heat exchanger is the radiator in a car, in which the heat source, being a hot engine-cooling fluid, water, transfers heat to air flowing through the radiator (i.e. the heat transfer medium).

HEAT EXCHANGER TYPES

1) Radiator (Engine Cooling): -

Radiators are heat exchangers used for cooling internal combustion engines, mainly in automobiles but also in piston-engine aircraft, railway locomotives, motorcycles, stationary generating plant or any similar use of such an engine.

Internal combustion engines are often cooled by circulating a liquid called *engine coolant* through the engine block, where it is heated, then through a radiator where it loses heat to the atmosphere, and then returned to the engine. Engine coolant is usually water-based, but may also be oil. It is common to employ a water pump to force the engine coolant to circulate, and also for an axial fan to force air through the radiator.

In automobiles and motorcycles with a liquid-cooled internal combustion engine, a radiator is connected to channels running through the engine and cylinder head, through which a liquid (coolant) is pumped. This liquid may be water (in climates where water is unlikely to freeze), but is more commonly a mixture of water and antifreeze in proportions appropriate to the climate. Antifreeze itself is usually ethylene glycol or propylene glycol (with a small amount of corrosion inhibitor).

A typical automotive cooling system comprises:

- a series of galleries cast into the engine block and cylinder head, surrounding the combustion chambers with circulating liquid to carry away heat;
- a radiator, consisting of many small tubes equipped with a honeycomb of fins to dissipate heat rapidly, that receives and cools hot liquid from the engine;
- a water pump, usually of the centrifugal type, to circulate the coolant through the system;
- a thermostat to control temperature by varying the amount of coolant going to the radiator;
- a fan to draw cool air through the radiator.

The radiator transfers the heat from the fluid inside to the air outside, thereby cooling the fluid, which in turn cools the engine. Radiators are also often used to cool automatic transmission fluids, air conditioner refrigerant, intake air, and sometimes to cool motor oil or power steering fluid. Radiators are typically mounted in a position where they receive airflow from the forward movement of the vehicle, such as behind a front grill. Where engines are mid- or rear-mounted, it is common to mount the radiator behind a front grill to achieve sufficient airflow, even though this requires long coolant pipes. Alternatively, the radiator may draw air from the flow over the top of the vehicle or from a side-mounted grill. For long vehicles, such as buses, side airflow is most common for engine and transmission cooling and top airflow most common for air conditioner cooling.

Fig 1.1 Radiator in general

Fig 1.2 Honey-Comb structure of Radiator

HEAT EXCHANGERS BASED ON FLOW

Heat exchangers are generally categorized by the flow of the two fluids in relation to one another. Three categories consist of ***parallel flow***, ***counter flow*** and ***cross flow***.

1)Cross Flow Heat Exchangers: - In a *cross-flow* heat exchangers fluids pass perpendicular to one another. The most common configuration for the *cross-flow* design consists of fins which evenly distribute the free-flowing fluid across tubular pass-through that contain the second fluid. Often this design utilizes ambient air as the free-flowing fluid to remove heat from the fluid contained within the closed tubes. This configuration is shown in the following figure.

A cross-flow heat exchanger is used in a cooling and ventilation system that requires heat to be transferred from one airstream to another. A cross-flow heat exchanger is made of thin metal panels, normally aluminum. The thermal energy is exchanged via the panels. A traditional cross-flow heat exchanger has a square cross-section. It has a thermal efficiency of 40–65%. A counter-flow or dual cross-flow heat exchanger can be used if greater thermal efficiencies are required – typically up to 75–85 %.

In some types of exchanger, humid air may cool down to freezing point, forming ice. A cross-flow is typically less expensive than other types of heat exchanger. It is normally used where hygienic standards require that both airstreams are kept completely separate from one another. It is often used in heat recovery installations in large canteens, hospitals and in the food industry. Unlike a rotary heat exchanger, a cross-flow heat exchanger does not exchange humidity

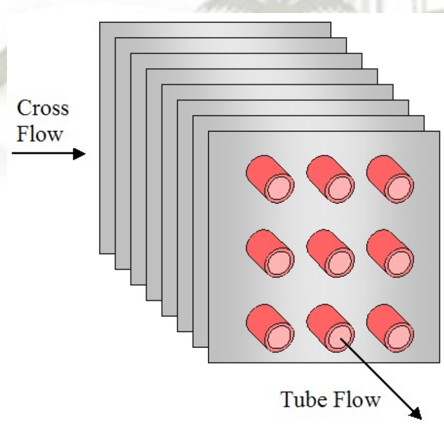

Fig.3.1 Cross Flow Heat Exchangers

1.2 PROBLEM DEFINITION

I. Due to persistent over heating problems of Automobile radiators, Initial testing of these radiators had to be ramped up so as to improve performance specifically cooling.

II. The Radiators originally used in Military Tanks, Armored Vehicles and Automobiles were unable to provide adequate cooling to the engine under harsh summer desert conditions.

III. Therefore, the Radiator in this project was designed by Defence Research and Development Organisation (DRDO) and its laboratory Combat Vehicles Research & Development Establishment (CVRDE) to check the characteristics of engine oil, coolant and special lubricants used in military tanks radiators.

IV. The following could be potential problems that the Heat Exchanger could face: -

a) **Fouling**: It is one of the most common issues in heat exchangers. It occurs when solids, such as sand, algae, dirt or scale are deposited on conducting surfaces, thereby inhibiting the exchanger's ability to transfer heat from one medium to another.

b) **Tube vibrations**: Flow-induced vibration of heat-exchanger tube bundles often serious damage, resulting in reduced efficiency and high maintenance costs.

c) **Leakage**: There are two types of leaks in heat exchangers: internal and external. In most cases, leaks are a result of faulty gaskets and can be easily remedied. Leaks in tubes, on the other hand, are typically more problematic, as they may necessitate the need to plug or weld the leak, or in some cases, replace the tube entirely. Common root causes of tube leaks include corrosion, metal fatigue, and weld defects. These problems are often exacerbated under high pressure.

d) **Dead Zones**: They are regions of slow or stalled fluid flow which can lead to fouling in the heat exchanger.

1.3 OBJECTITVES OF STUDY

I. A primary objective in the Heat Exchanger Design (HED) is the estimation of the minimum heat transfer area required for a given heat duty, as it governs the overall cost of the Heat Exchanger.

II. Increase in Heat Exchangers performance can be accomplished without a dramatic increase in surface area. This constraint directly translates to increasing the overall heat transfer coefficient, U. The overall heat transfer coefficient is related to the surface area, A, Heat flow Q, and the temperature difference, ΔT.

III. To Estimate how much pressure, drop in the wind tunnel across the radiator is available. For single phase heat transfer coefficients, higher fluid velocity increases heat transfer coefficients and pressure drop.

IV. To Determine that the heat exchanger is operating as designed if not then Correcting flaws in construction and piping that may have a detrimental effect on heat transfer and pressure drop may be the solution.

V. To reduce noise produced up to a bare minimum level and to reduce tube vibrations and leakages in the radiator by accurate implementation of baffles.

CHAPTER 2

LITERATURE SURVEY

Saneipoor et al. (2014) [5] had done an analysis of heat transfer with the Manroch heat engine using water/ glycol mixture as the working fluid. Four shell and tube exchangers are used in this experiment. The shell side fluid is the compressed air and the tube side fluid is water/ glycol (propylene glycol) mixture. The transient heat transfer analysis has been done as the hot fluid after passing through one set of heat exchangers become cold fluid and then sent through another set of heat exchangers. This procedure can be used for studying the heat exchangers working under transient conditions

S.M. Peyghambarzadeh, S.H. Hashemabadi, S.M. Hoseini , M. Seifi Jamnani (2011) [6], Traditionally forced convection heat transfer in a car radiator is performed to cool circulating fluid which consisted of water or a mixture of water and anti-freezing materials like ethylene glycol (EG). In this paper the heat transfer performance of pure water and pure EG has been compared with their binary mixtures. Furthermore, different amounts of Al_2O_3 nanoparticle have been added into these base fluids and its effects on the heat transfer performance of the car radiator have been determined experimentally. Liquid flow rate has been changed in the range of 2–6 l per minute and the fluid inlet temperature has been changed for all the experiments. The results demonstrate that Nano fluids clearly enhance heat transfer compared to their own base fluid. In the best conditions, the heat transfer enhancement of about 40% compared to the base fluids has-been recorded.

S.M. Peyghambarzadeh, S.H. Hashemabadi, M. Naraki, Y. Vermahmoudi (2013) [7], the heat transfer performance of the automobile radiator is evaluated experimentally by calculating the overall heat transfer coefficient (U) according to the conventional Ɛ-NTU Technique.

A. Witry, M.H. Al-Hajeri, Ali A. Bondok (2005) [8], the thermal performance of an automotive radiator plays an important role in the performance of an automobile cooling system and all other associated systems. For a number of years, this component has suffered from little attention with very little changing in its manufacturing cost, operation and geometry. As opposed to the old tubular heat exchanger configurations used in automotive radiators, plate heat exchangers currently form the backbone of today's process industry with their advanced performance Reaching levels the designers of tubular heat exchangers can only dream of the aluminums roll-bonding technique widely used in manufacturing the cooling compartments for domestic refrigeration units is one of the cheapest methods for heat exchanger configurations that can help augment heat transfer whilst reducing pressure drops. CFD results obtained for a patterned plate heat exchanger using the CFD code FLUENT show tremendous levels of possible performance improvement on both sides of the heat exchanger. For the internal flow, heat transfer augmentation caused by the repetitive impingement against the dimple obstructions renders such geometries equal to those of aerospace industry pin-fins whilst lowering pressure drops due to the wider cross-sectional areas. For the external flows, the wider and wavy nature of the surface area increases heat transfer leaving the addition of extra surface roughness add-ons as an option.

CHAPTER 3

METHODOLOGY

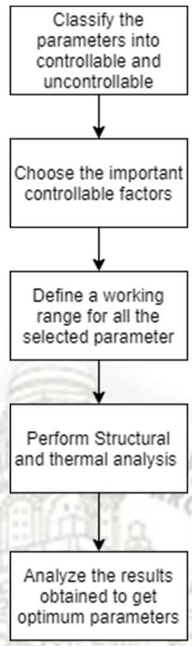

Fig 3.1 Flow chart of Methodology

The methodology that is followed to attain the research objectives is divided into the following work phases:

1.Classify the research parameters into controllable and uncontrollable parameters. The identified controllable parameters are the construction materials, air flow rate , coolant flow rate , pressure drop in the wind tunnel etc.,. While the uncontrollable parameters are material limitations, noise level, unwanted vibration and unaccounted heat losses such as radiation and friction.

2.selecting the controllable factors such as material, flow rate, pressure drop etc., that have a larger influence on the research study as the interest domain.

3.Choosing an appropriate working range for each potential factor. For example, it is found that the working range for flow rate should be between 50 to 500 liters per minute for coolant while mass flow rate for air should strictly vary between 0.5 to 3 Kg per seconds.

4.Perform structural analysis and strength of material-based analysis to determine a which material is best suited and at what factor of safety.

5. Performing the testing and evaluation of heat exchanger performance by using LMTD and ε-NTU techniques by the selecting the experimental levels for each selected factor, i.e. the coolant flow rate to be in two levels (50, 100 LPM) and air flow rate to also be in two levels (1, 2 Kg/S)

6.Analyze the results to get the proposed optimal set of parameters.

CHAPTER 4
EXPERIMENTAL SETUP

The test facility, which comprises primarily of a wind tunnel, radiator, pump for oil and coolant.

1. Wind Tunnel

- A basic wind tunnel used to simulate real life like fluid simulation of air around the heat exchanger.
- The wind tunnel was designed to create the parameters strictly constrained by CVRDE for radiator to check engine oil and coolant performance in radiators of the Military tanks.
- It was used to generate the following parameters;
    - Air flow rate of 1.5 Kg per second
    - Coolant flow rate of between 50 to 200 liters per minute with pressure of up to 8 bar
    - Oil flow rate of between 50 to 2200 liters per minute with pressure of up to 1.5 bar
    - Tank Temperature of 140 C for oil and 120 C for coolant

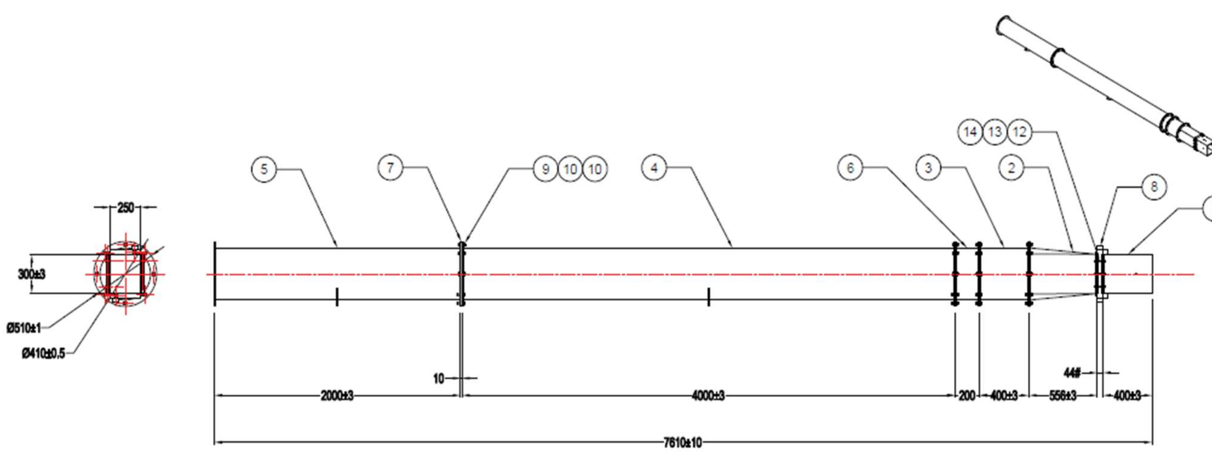

Fig 4.1 Wind Tunnel schematic

2. Pump Station

- Gear pump was used to pump oil from the oil tank to radiator inlet at a pressure of 1.5 bar.
- It was also used to pump coolant from coolant tank to radiator inlet at a pressure of 8 bar.

Fig 4.2 Pump Station consisting of Oil Pump and Coolant pump

3. Coolant and Oil Tank with Heaters

- The capacity of coolant tank is 430 Liters and Oil is 200 Liters.
- Heaters fitted in the tanks can heat coolant up to 120 KW and Oil up to 60 KW.
- Both Tanks are made out of Stainless-Steel SS 316L
- The heaters are controlled by a PID controller and are capable of maintaining the desired temperature in the system.

4. Radiator

- The Radiator have been successfully developed and precision manufactured indigenously using aluminum alloy core, plate and fin type, furnace brazed with multi-pass liquid flow between headers**.**

- Size of core matrix: 927 x 470 x 130 mm

Fig 4.4 Radiator RH

Fig 4.4 Radiator LH

CHAPTER 5
INSTRUMENTS USED TO RECORD DATA

The following instruments were used for data collection during experiment:

1. Temperature Sensors: The following temperature sensors were used for recording temperature at inlets and outlets of air and coolant/oil.

   A. An RTD (Resistance Temperature Detector) is a sensor whose resistance changes as its temperature changes. The resistance increases as the temperature of the sensor increases. The resistance vs temperature relationship is well known and is repeatable over time.

   B. Thermocouple Sensor consists of two dissimilar metal wires, joined at one end, and connected to a thermocouple thermometer or other thermocouple-capable device at the other end. When properly configured, thermocouples can provide temperature measurements over wide range of temperatures.

Fig.RTD Sensor

Fig.Thermocouple

2. Pressure Sensors: a **pressure sensor** is an instrument consisting of a pressure sensitive element to determine the actual pressure applied to the sensor (using different working principles) and some components to convert this information into an output signal.

Fig. Pressure sensor

3. Flow meters: A flow meter is a device used to measure the volume or mass of a gas or liquid. Generally, it measures in units liters per minute.

Fig. Different types of flow meters

CHAPTER 6
COSTING OF PROJECT

A. **Expenditure borne by our project team including all four members during the course of the project are as follows: -**

COMPANY	NEXA MUMBAI		PANVEL, NAVI MUMBAI
PROJECT	ANALYSIS OF HEAT EXCHNAGER PERFORMANCE USING WIND TUNNEL TEST RIG FACILITY		COST
SR NO	PARTICULARS	QTY	PRICE
1	TRAVELLING	4	5,000₹
2	MISC	4	6,000₹
3	JOURNAL	1	2,600₹
4	REPORT	4	1,400₹
TOTAL			15,000₹

CHAPTER 7
HEAT EXCHANGER PERFORMANCE ANALYSIS

7.1 DATA COLLECTION

The data recorded after Wind Tunnel Test Rig operation are as follows: -

A]For Coolant :

Sr.no	Air flow rate (Kg/s)	Coolant flow rate (lpm)	Coolant Inlet Temperature (℃)	Coolant Outlet Temperature (℃)	Air Inlet Temperature (℃)	Air Outlet Temperature (℃)
1	1.06	100	84.8	82.1	34.5	56.4
2	1.06	100	85.3	82.4	34.7	56.5
3	1.06	100	85.7	82.6	34.7	56.5
4	1.06	100	87.1	82.4	34.8	55
5	1.06	50	87.5	83.2	34.7	55.6
6	1.06	50	88.3	83.8	34.4	55.8
7	2.06	100	88.4	83.5	35	50.5
8	2.06	100	88.5	83.4	34.9	50.5
9	2.06	100	88.5	83.4	34.9	50.5

B]For Oil:

Sr.no	Air flow rate($\dot{m}c$) (Kg/s)	Oil flow rate($\dot{m}h$) (lpm)	Oil Inlet Temperature (℃)	Oil Outlet Temperature (℃)	Air Inlet Temperature (℃)	Air Outlet Temperature (℃)
1	1.06	100	86.4	84.1	34.5	42.4
2	1.06	100	87.3	84.4	34.7	42.5
3	1.06	100	87.7	84.6	34.7	42.3
4	1.06	100	89.1	84.4	34.8	41
5	1.06	50	89.5	85.2	34.4	41
6	1.06	50	90.3	85.8	34.1	41.6
7	2.06	100	90.4	85.5	35	41.8
8	2.06	100	90.5	85.4	34.9	41.5
9	2.06	100	90.5	85.4	34.8	41.5

7.2 ANALYSIS

Sample Calculation for Coolant :

Mass flow rate of Hot fluid ($\mathring{m}h$) = Mass of Coolant = (lpm*density*10^{-3})/60
= (100 lpm * 1000)/ (60000)
= 1.67 Kg/s

Temperature of Hot fluid at inlet (Th1) =84.8˚C
Temperature of Hot fluid at outlet (Th2) =82.1˚C
Temperature of Cold fluid at inlet (Tc1) =34.5˚C
Temperature of Cold fluid at outlet (Tc2) =56.4˚C
Specific heat capacity of coolant (Ch)= 4.187 KJ/Kg˚C
Specific heat capacity of air (Cc) = 1.005 KJ/Kg˚C

Heat Transfer on Air Side = $\mathring{m}c$*Cc*(Tc2-Tc1) = 1.06*1.005*(56.4-34.5) =**23.33 KW**

Heat Transfer on Coolant Side = $\mathring{m}h$*Ch*(Th1-Th2) = 1.67*4.187*(84.8-82.1)
=**18.9 KW**

Mean Heat Transfer (Q)= **21.115KW**

Log Mean Temperature Difference (θ)=

$$LMTD = \frac{\Delta T_A - \Delta T_B}{\ln\left(\frac{\Delta T_A}{\Delta T_B}\right)} = \frac{\Delta T_A - \Delta T_B}{\ln \Delta T_A - \ln \Delta T_B}$$

= ((84.8-56.4)-(82.1-34.5))/Ln((84.8-56.4)/(82.1-34.5))= **37.177˚C**

Q=UAFθ
Area of Radiator = 0.26 m^2
Fouling Factor=0.99 (from below graph)

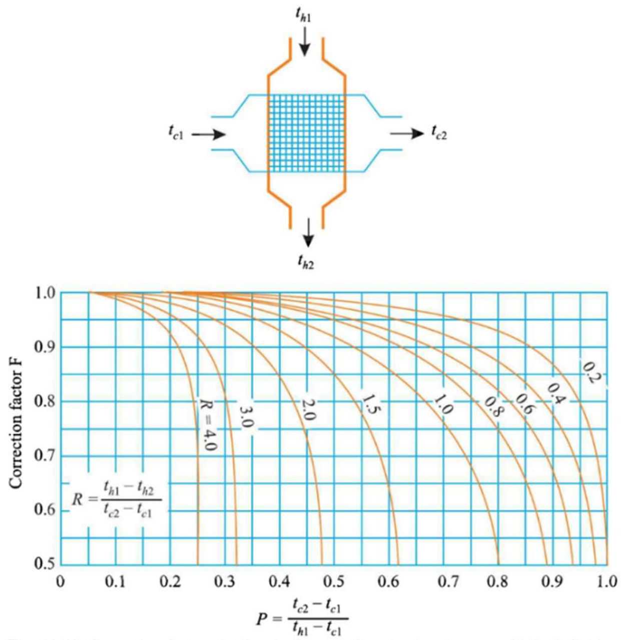

Fig. 10.42. Correction factor plot for single cross-flow heat exchanger with both fluids unmixed.

21.115=U*0.26*0.99*37.177

Overall Heat Transfer Coefficient (U)=2.2 KW/m^2 °C

CMax=1.67*4.2 = 7.014 KJ/K

CMin=1.06*1.005=1.0653 KJ/K

$$NTU = \frac{UA}{C_{\min}}$$

NTU=(2.2*0.26)/1.0653 = 0.536

$$C_r = \frac{C_{\min}}{C_{\max}}$$

Cr=1.0653/7.014 = 0.1518

the effectiveness of a Cross flow heat exchanger is calculated with:

$$\varepsilon = 1 - e^{\left[\mathrm{NTU}^{0.22}\left(e^{-C^{*}\mathrm{NTU}^{0.78}} - 1\right)/C^{*}\right]}$$

Effecitiveness (ε)= 0.401 OR 40.1%

Sample Calculation for Oil :

Mass flow rate of Hot fluid (m̊h) = Mass of Oil = (lpm*density*10^{-3})/60
= (100 lpm * 850)/ (60000)
= 1.4167 Kg/s

Temperature of Hot fluid at inlet (Th1) =86.4˚C
Temperature of Hot fluid at outlet (Th2) =84.1˚C
Temperature of Cold fluid at inlet (Tc1) =34.5˚C
Temperature of Cold fluid at outlet (Tc2) =42.4˚C
Specific heat capacity of Oil (Ch)= 2.08 KJ/Kg˚C
Specific heat capacity of air (Cc) = 1.005 KJ/Kg˚C

Heat Transfer on Air Side = m̊c*Cc*(Tc2-Tc1) = 1.06*1.005*(42.4-34.5) =**8.415 KW**

Heat Transfer on Oil Side = m̊h*Ch*(Th1-Th2) = 1.67*4.187*(86.4-84.1)
=**6.77 KW**

Mean Heat Transfer (Q)= **7.592 KW**

Log Mean Temperature Difference (θ)=

$$LMTD = \frac{\Delta T_A - \Delta T_B}{\ln\left(\frac{\Delta T_A}{\Delta T_B}\right)} = \frac{\Delta T_A - \Delta T_B}{\ln \Delta T_A - \ln \Delta T_B}$$

= ((86.4-42.4)-(84.1-34.5))/Ln((86.4-42.4)/(84.1-34.5))= **46.74˚C**

Q=UAFθ
Area of Radiator = 0.26 m^2
Fouling Factor=0.99 (from below graph)

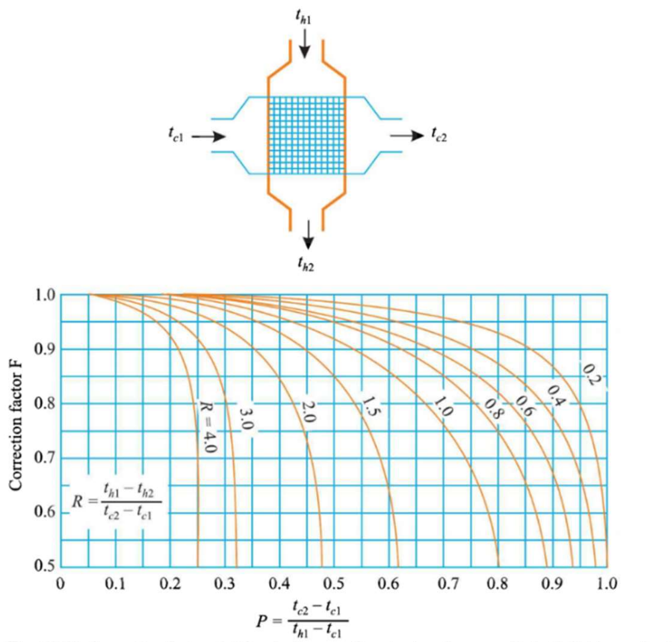

Fig. 10.42. Correction factor plot for single cross-flow heat exchanger with both fluids unmixed.

7.592=U*0.26*0.99*46.74

Overall Heat Transfer Coefficient (U)=0.63 KW/m^2 °C

CMax=1.4167*2.08 = 2.9467 KJ/K

CMin=1.06*1.005=1.0653 KJ/K

$$NTU = \frac{UA}{C_{\min}}$$

NTU=(0.63*0.26)/1.0653 = 0.1536

$$C_r = \frac{C_{\min}}{C_{\max}}$$

Cr=1.0653/2.9467 = 0.361

the effectiveness of a Cross flow heat exchanger is calculated with:

$$\varepsilon = 1 - e^{\left[\mathrm{NTU}^{0.22} \left(e^{-C^* \mathrm{NTU}^{0.78}} - 1 \right) / C^* \right]}$$

Effecitiveness (ε)= 0.1401 OR 14.01%

RESULTS: -

A : For Coolant

sr.no	Qair (kw)	Qcoolant (kw)	Qmean (kw)	LMTD (˚C)	U (kw/m2 C)	NTU	R	ε
1	23.33	18.9	21.115	37.177	2.2	0.5369	0.1518	0.401
2	23.2235	20.3	21.7618	37.4586	2.4	0.6508	0.1518	0.4036
3	23.2235	21.7	22.4618	37.785	2.3093	0.5636	0.1518	0.4033
4	21.519	16.45	18.9845	39.35	1.8788	0.4573	0.1518	0.3403
5	22.2647	15.05	18.6574	39.62	1.8287	0.4463	0.3036	0.3303
6	22.7974	15.75	19.2737	39.8785	1.9875	0.4623	0.3036	0.3385
7	32.0896	34.3	33.1948	42.84	3.01	0.3729	0.2951	0.4101
8	32.02966	35.7	33.8648	42.96	3.189	0.3789	0.2951	0.413
9	32.2966	35.7	33.9983	42.98	3.1945	0.3875	0.2951	0.4136
MEAN					2.45			0.3837

B : For Oil

sr.no	Qair (kw)	Qoil (kw)	Qmean (kw)	LMTD (˚C)	U (kw/m2 C)	NTU	R	ε
1	8.41587	6.77	7.592935	46.74	0.63	0.153	0.361	0.14
2	8.3	8.54	8.42	46.7543	0.86	0.1813	0.361	0.1402
3	8.9	9.13	9.015	46.7896	0.77	0.1645	0.361	0.1465
4	6.71139	13.84	10.2757	47.8152	0.79	0.1745	0.361	0.1521
5	7.3098	6.33	6.8199	47.912	0.58	0.1245	0.723	0.125
6	7.98975	7.51	7.749875	47.9785	0.53	0.1266	0.723	0.1263
7	14.078	14.1443	14.11115	49.84	0.98	0.1189	0.7025	0.1535
8	13.67	15.02	14.345	49.36	1.003	0.1196	0.7025	0.1589
9	13.98	15.02	14.5	49.99	1.015	0.1199	0.7025	0.1579
MEAN					0.8			0.14489

CHAPTER 8

CONCLUSION

I. Effectiveness is Highest that is 0.41 or 41% in case of Coolant with Coolant flow rate 100LPM, Air flow rate of 2.06 Kg/s and Heat Dissipation of 33 KW.

II. Effectiveness is lowest that is 0.31 or 31% in case of Coolant with Coolant flow rate 50LPM, Air flow rate of 1.06 Kg/s and Heat Dissipation of 18.6 KW.

III. As Effectiveness for coolant is better than oil that is over 150% more therefore coolant is a more viable option for Heat Transfer fluid than Oil.

IV. Effectiveness is Highest that is 0.16 or 16% in case of Oil with Oil flow rate 100LPM, Air flow rate of 2.06 Kg/s and Heat Dissipation of 14.4 KW.

V. Effectiveness is lowest that is 0.12 or 12% in case of Oil with Oil flow rate 50LPM, Air flow rate of 1.06 Kg/s and Heat Dissipation of 6.82 KW

VI. As Air Flow rate increase Heat Dissipation increases and Effectiveness also increases.

VII. As Coolant Flow rate decreases Heat Dissipation, Effectiveness and Pressure drop decreases.

CHAPTER 9

VALIDATION

I. Effectiveness is Highest that is 0.41 or 41% in case of Coolant with Coolant flow rate 100LPM, Air flow rate of 2.06 Kg/s and Heat Dissipation of 33 KW while Effectiveness is lowest that is 0.31 or 31% in case of Coolant with Coolant flow rate 50LPM, Air flow rate of 1.06 Kg/s and Heat Dissipation of 18.6 KW as validated by **S.M. Peyghambarzadeh , S.H. Hashemabadi , S.M. Hoseini , M. SeifiJamnani in International Communications in Heat and Mass Transfer Vol 38, Pg 1283–1290, in the year 2011.**

II. Effectiveness is Highest that is 0.16 or 16% in case of Oil with Oil flow rate 100LPM, Air flow rate of 2.06 Kg/s and Heat Dissipation of 14.4 KW, While Effectiveness is lowest that is 0.12 or 12% in case of Oil with Oil flow rate 50LPM, Air flow rate of 1.06 Kg/s and Heat Dissipation of 6.82 KW as validated by **S.M. Peyghambarzadeh, S.H. Hashemabadi, M. Naraki, Y. Vermahmoudi in Applied Thermal Engineering Vol 52 Pg 8-16 in the year 2013**

CHAPTER 10

FUTURE SCOPE

A. Different sizes of heat exchangers can be tested in the same setup by using interchangeable connecting tube between the radiator and the main body of the wind tunnel.

B. Other fluids like pure ethylene glycol, propylene glycol or their mixtures with water can be chosen as base fluids and proper suspensions can be selected to enhance the heat transfer performance.

C. In Future, Al2O3 nanoparticles of approximately 50-100nm sizes can be used. It can be extended to other nanomaterials like SiC and CNTs in various sizes considering the thermal conductivity of particulate.

D. The present work can be extended to analyze the wear aspects of radiator material due to the nanoparticles being added to the base fluid.

E. Insulation can be provided to further reduce noise level below 50 dB as compared to the present 75 dB.

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