Experimental and Numerical Analysis of Heat Transfer on Plate Fin Heat Exchanger at Different Fin Pitches with Ceramic Coating

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***Abstract*:- This Project presents the airside performance of fin and tube heat exchangers for multi-louvered plate fin. This project focuses on heat and fluid flow analysis by various fin pitches and angle patterns. A steady –state three-dimensional numerical model is used to study the heat transfer and pressure drop characteristics of a multi-louvered plate fin heat exchanger with Reynolds number in the range of 1000-1600.A numerical study is performed on compact fin and tube heat exchanger having circular tube with plate fin vortex generator. The performance of heat exchanger in the air side with coating and without coating of the fin will be analyzed for various pitches such as 2, 2.5, 3, 3.5 mm and 4mm. By varying fin pitches, the overall heat transfer rate will increase in the system. In heat exchanger device the heat transfer analysis will be done by increasing number of tubes, rows, passes, and pitches.**

Keywords: Fin Pitch, Pressure drop, Heat Exchanger, Fin Thickness

I . INTRODUCTION

A heat exchanger is a device that is used for transfer of thermal energy (enthalpy) between two or more fluids, between a solid surface and a fluid, or between solid particulates and a fluid, at differing temperatures and in thermal contact, usually without external heat and work interactions.

Currently, the plate fin-and-tube heat exchanger earns its popularity in waste heat recovery system applications. This is because of the easy manufacturing process of the plate fin, which is quite common in industrial services. The conventional plate fin is a simple type of the plate fins. The main difference between the conventional plate fin with several plate fin types is that the feature of fin base. The tube surface at the base of conventional multi-louvered plate fin is not covered by the fin, leading to the risk of tube corrosion.

The experimentally investigated the effects of fin pitch and fin outside diameter on the characteristics of heat transfer and pressure drop for serrated multi-louvered finned- tube heat exchangers having staggered tube layouts. It was indicated that the fin pitch increased with increasing heat transfer coefficient at the same Reynolds number. The fin outside diameter, however, had an insignificant effect on the heat transfer coefficient. The multi-louvered plate finned tube heat exchangers have better air-side heat transfer Performance than the plate-finned tubes , because of high vortex shedding frequency.

Plate and fin heat exchangers are mostly used for low temperature services such as natural gas, helium and oxygen liquefaction plants, air separation plants and transport industries such as motor and aircraft engines.

1.1CORRUGATIONS (FINS)

Corrugations are also made with heat transfer enhancement devices..Plain corrugation is the basic form and is used normally for low pressure drop streams. Perforated corrugation shows a slight increase in performance over plain corrugation, but this is reduced by the loss of area due to perforation. The main use is to permit migration of fluid across fin channels, usually in boiling duties. Serrated corrugation is made by cutting the fins every 3.2 mm and displacing the second fin to a point half way between the preceding fins. This gives a dramatic increase in heat transfer.

Herringbone corrugation is made by displacing the fins sideways every 9.5 mm to give a zig-zag path. Performance is intermediate between the plain and serrated forms. The friction factor continues to fall at high Reynolds 14 numbers, unlike the serrated, showing advantages at higher velocities and pressures. The designer can, therefore, vary fin heights, fin pitch and fin thickness together with four standard fin types giving great versatility of design.

1.2REASON FOR SELECTION

PLATE FINS

High heat transfer coefficient
High mechanical strength of fin
Increase the heat transfer surface area

CERAMIC COATING

TemperatureRanges

For many years, the only coating able to withstand the high temperatures of many motorcycle parts was chrome. As formulation, ceramic can withstand from 600 to 2000 degrees Fahrenheit. Exhaust pipes, manifolds and headers become hot, and the choices for coating are limited. Ceramic coatings withstand the extensive heat generated by these parts and can lower the temperature of the part. Most ceramic coatings are also smooth and reduce friction when used on engineparts

ColorChoices

Ceramic also allows you to add color other than chrome to your engine and exhaust parts. It has become common to "black out" bikes. Although ceramic does not come in a huge variety of colors, there are still many colors from which to choose. Most ceramic colors come only in 3 to 30 percent gloss. NIC Industries has a line of ceramic that comes in bold red, yellow, blue and purple as well as black, silver and various shades of brown and green, which can withstand approximately 1200 to 2000 degrees Fahrenheit.

Durability

In addition to being heat resistant, ceramic is durable once cured. It is resistant to scratches, impacts and corrosion. Some ceramic coatings are more resistant that others. Special "high humidity" Chromex can withstand up to 3,000 hours in a salt spray test. This test is used in the coating industry to determine durability of powder and ceramic coating. Depending on whether a primer is applied, most air dry or oven cure ceramic coatings can withstand from 350 to 1000 hours in a salt spray test.

SPECIFICATION OF PLATE FIN MODEL

The plate fin arrangements are modeled as per the standard specifications.

MULTI-LOUVERED PLATE FIN		TUBE	
Material	Aluminium	Material	Copper
Fin Pitch	3mm	Outer diameter	9.5mm
Fin Thickness	1mm	Inner diameter	6mm
Outer diameter of fin	30mm	Wall Thickness	3.5mm
Inner diameter of fin	9.6mm	No. of row in tube	2
		Longitudinal tube pitch	40mm
		Transverse tube pitch	31mm
		No of Tubes in a row	8

Table 1.Specification of plate fin model

DESIGN OF MULTI-LOUVERED PLATE FIN HEAT EXCHANGERS

The plate-fin heat exchanger is made up of layers of corrugated sheets separated by plate metal plates, typically aluminium, to create series of finned chambers. Separate hot and colt fluid streams flow through alternating layers of the heat exchanger and are enclosed at the edges by side bars. Heat is transferred from one stream through the fin interface to the separator plate and through next set of fins into the adjacent fluid. The fins also serve to increase the structural integrity of the heat exchanger and allow it to withstand high pressures while providing an extended surface area for heat transfer. A high degree of flexibility is present in plate-fin heat exchanger design as they can operate with any combination of gas, liquid, and two-phase fluids. Heat transfer between multiple process streams is also accommodated, with a variety of fin diameters and types as different entry and exit points available for each stream.

The main four types of fins are: plain, which refer to simple straight-finned triangular or rectangular designs; herringbone, where the fins are placed sideways to provide a zig-zag path; and serrated and perforated which refer to cuts and perforations in the fins to augment flow distribution and improve heat transfer.

Fig 1.multi louvered plate fin exchanger

III . EXPERIMENTAL SETUP AND PROCEDURE:

The schematic of the experimental system used in this research is shown in Fig 2. It includes, an electrical heater , a temperature controller ,a digital thermometer. The test section of the heat exchanger tube inlet was connected with electrical heater outlet port and its configuration is the louvered fin-and-tube type. The fins and tubes are made with aluminium and copper tubes. Hot water allow to pass through the exchanger tube inlet. At that same time study the water inlet and outlet temperature of the fin and tube heat exchanger and engine operation timing for numerical analysis. A water inlet and outlet temperatures, engine operation timing shown in Tables 2-5. Experimental readings are taken for different fin pitches with ceramic coating at every 15 min of engine operations upto 60mins.

Fig 2.schematic of experimental setup“alternately” (unless you really mean something that alternates).

3.1 EXPERIMENTAL READING FOR DIFFERENT FIN PITCHES WITH CERAMIC COATING

Different Inlet And Outlet Temperature At Various Timings

SL.NO	Fin Pitch	Water Inlet Temperature	Water outlet Temperature
	(mm)	(°C)	(°C)
1	2	42	39
2	2.5	42	37
3	3	42	33
4	3.5	42	35
5	4	42	38

Table 2. For First 15min of engine operation

SL.NO	Fin Pitch	Water Inlet Temperature	Water outlet Temperature
	(mm)	(°C)	(°C)
1	2	46.55	41
2	2.5	46.55	38
3	3	46.55	35
4	3.5	46.55	39
5	4	46.55	42

Table 3. For 30min of engine operation

SL.NO	Fin Pitch	Water Inlet Temperature	Water outlet Temperature
	(mm)	(°C)	(°C)
1	2	51	49
2	2.5	51	46
3	3	51	39
4	3.5	51	42
5	4	51	46

Table 4 For 45min of engine operation

SL.NO	Fin Pitch	Water Inlet Temperature	Water outlet Temperature
	(mm)	(°C)	(°C)
1	2	56.5	51
2	2.5	56.5	49
3	3	56.5	44
4	3.5	56.5	45
5	4	56.5	46

Table 5 For 60min of engine operation

3.2 GOVERNING EQUATIONS FOR CALCULATING AIR SIDE HEAT TRANSFER OF MULTI-LOUVERED PLATE FIN AND TUBE HEAT EXCHANGER

The method of number of transfer units (e-NTU), based on the concept of heat exchanger effectiveness, was applied to determine the UA product.

The air-side heat transfer rate is given as:

$Q_a = m_a cp_a \Delta T_a$------------ (1)

The water-side heat transfer rate is given as

$Q_w = m_w\, cp_w \Delta T_w$---------- (2)

The total rate of heat transfer used in the calculation is averaged from the air-side and water-side as follows:

$$Q_{ave} = \frac{[Q_a]+[Q_w] \text{---------}}{2} \quad (3)$$

The overall heat transfer coefficient can be written in terms of the total resistance to heat transfer. This total resistance is the sum of the individual resistances, as follows:

$$\frac{1}{UA} = \frac{1}{hiAi} + \frac{\ln({}^{d_0}/{}_{d_{i)}}}{2\pi k_t l} + 1/\eta_0 h_0 A_o \text{--------}(\ 4\ )$$

3.3 EXPERIMENTAL CALCULATION

TOTAL HEAT TRANSFER RATE (At fin pitch of 2mm)

Air inlet Temperature = 31°C ,
Air outlet Temperature=32.5°C
Water Inlet Temperature=46.55 °C ,
Water Outlet Temperature=41°C
Total heat transfer rate $Q = mc_p\, \Delta T,$
Mass flow rate of water (m) = 0.18 kg/s
Specific heat of water (m) = 4186 J/kgk
Total Heat transfer rate (Q)
= 0.18X4186(46.55-41)°C
=4181.8 W
Total no of fins = 15
Heat transfer rate of single fin
= over all heat transfer/15
= 278.7W

$$Q_{max} = mC_p\,(T_{water\ inlet} - T_{air\ inlet})$$

= 11716

$$\epsilon_{fin} = \frac{Q_{fin}}{Q_{max}} = 4181.8/11716.6$$

= 0.356

$\epsilon_{fin} = 0.356$

TOTAL HEAT TRANSFER RATE (At fin pitch of 2.5mm)

ϵ_{fin}=0.549

TOTAL HEAT TRANSFER RATE (At fin pitch of 3mm)

ϵ_{fin}=0.742

TOTAL HEAT TRANSFER RATE (At fin pitch of 3.5mm)

ϵ_{fin}=0.485

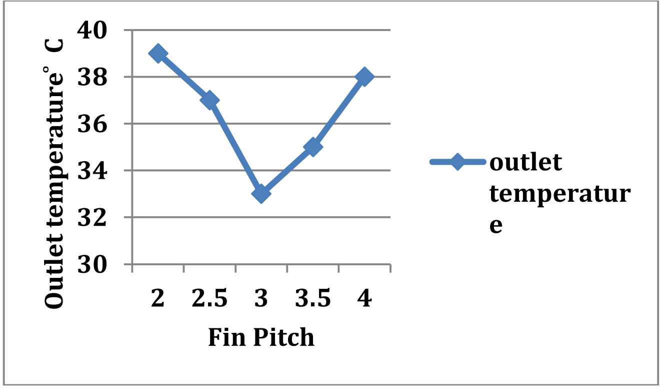
TOTAL HEAT TRANSFER RATE (At fin pitch of 4mm)

ϵ_{fin}=0.29

IV. RESULT AND DISCUSSION

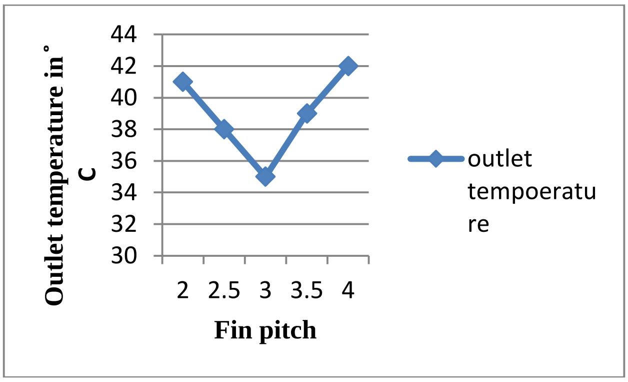
4.1. Effect of fin pitch

The study focuses the effect of fin pitches (2, 2.5,3,3.5 and 4), air side performance of multi-louvered plate fins with ceramic coating on 5 tube pass compact fin and tube heat exchanger, this type of heat exchangers used in wide applications like automobile radiator economizers, refrigeration's.



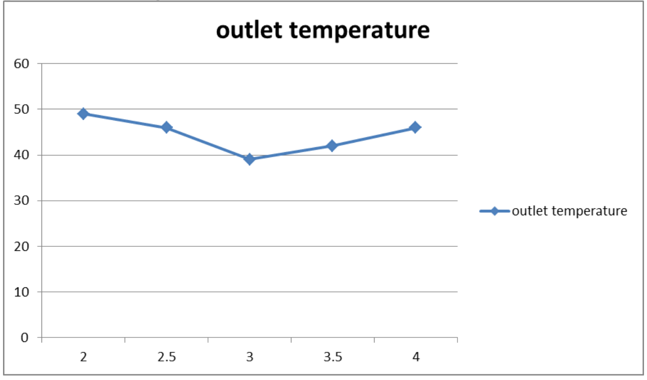
Graph 4.1 Outlet temperature Vs fin pitches

The graphical representation **4.2** is shown b/w fin pitch and outlet temperature of water at first ½ hour operation of engine



Graph 4.2 Outlet temperature Vs fin pitches

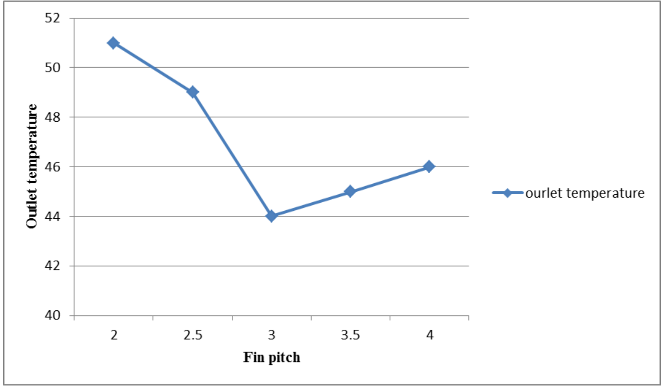
The graphical representation **4.3** is shown between fin pitch and outlet temperature of water at first ¾ hour operation of engine



Graph 4.3 Outlet temperature Vs fin pitches

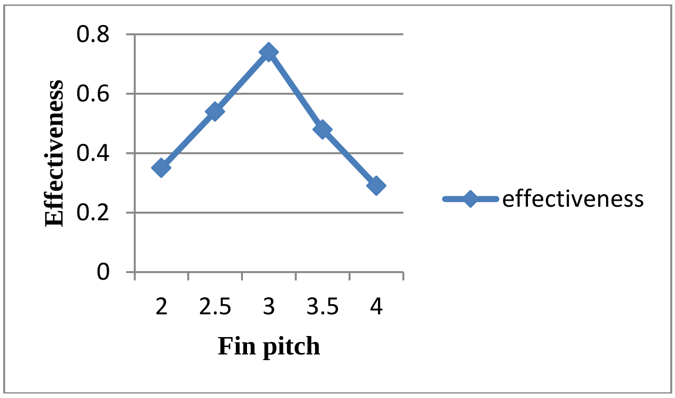
The graphical representation **4.4** between fin pitch and outlet temperature of water at first 1 hour operation of engine

The graphical representation **4.1** is shown between fin pitch and outlet temperature of water from first ¼ hour operation of engine



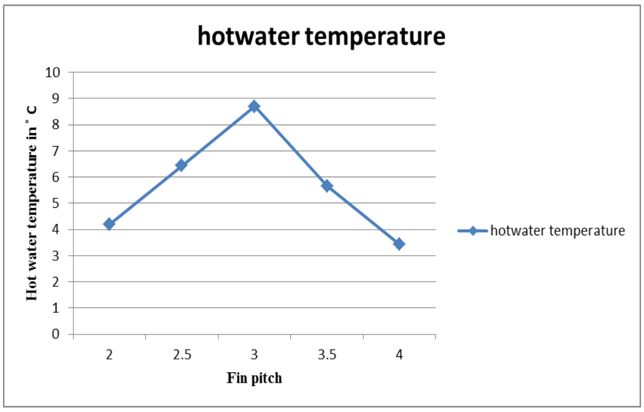
Graph 4.4 Outlet temperature Vs fin pitches

The graphical representation **4.5** is shown between the fin pitches and effectiveness at engine operation of ½ hour



Graph 4.5 Effectiveness Vs fin pitches

The graphical representation **4.6** is shown between heat transfer rate per fin and fin pitch



Graph 4.6 Heat transfer rate Vs fin pitches

The performance plot for the three configurations investigated is depicted for Reynolds numbers 1000, 1200 and 1600, respectively. It is clear that for the same heat transfer area, the case with multi-louvered plate fins delivers better performances than the case with other fins. The configuration with multi-louvered plate fins shows an about 9% better heat transfer rate for the same power input than the configuration with other fins having the same heat transfer area. The graphical represented of heat transfer rate with respect to fin pitches at different operating time, it shows that the heat transfer rate is higher at fin pitches of 2.5 and 3.

The experimental was carried out different fin pitches of 2, 2.5, 3, 3.5,4 from that fin pitches of 2.5,3 gives higher heat transfer rate and fin pitches affect heat transfer rate if fin pitch increases to increase pressure drop. The reduction of fin pitch increase heat transfer if fin pitch reduced more the is restricted to reduce the heat transfer rate.

V. CONCLUSIONS

The numerical investigation was carried out in this study show the advantage of multi-louvered plate fins in improving the performance of finned tubes or compact fin and tube heat exchanger. This is mainly due to the fact that the interruption of fins in these devices improves the re-build of the boundary layer close to heat transfer surfaces and increases the level of fluid mixing in the flow domain. The fin Pitches 2.5 to 3.5 gives better performance and also gives more heat transfer rate .

The fin effectiveness is maximum at a fin pitch of 2.5,3.

The heat transfer rate per fin is maximum at fin pitch of 2.5,3, So using the multi-louvered plate fin and tube heat exchanger in any applications like radiators etc.. At a fin pitches of 2.5,3 gives higher heat transfer and increase performance of heat exchanger. The results obtained show that for the same heat transfer area, the multi-louvered plate fin tubes have better performances than the full fins. The ceramic coating gives better performance in under wet conditions, there no corrosion on the finned tube when used for number of days in practical Application. It is useful for manufacturing industries and power plants to increase performance in future days.

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