Experimental Investigation To Enhance The Performance Of Heat Exchanger By Varying The Geometry Of Fin And Cooling Media

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Abstract: Performance of the IC engines in most of the automobiles is predominantly influenced by the efficiency of the cooling system i.e. Radiator. The challenge in most of the modern automobiles is to increase the effectiveness of cooling system without increasing of its size as it has an impact on the over chassis design. To address this, optimization of the compactness of cooling system i.e. Radiator is needed. This paper presents the experimental investigations carried for improving performance of the radiator by varying the fin geometry orientation. The main focus of the work is confined to reduce the resistance on air side intended to enhance the efficiency of the system. Computer-aided engineering (CAE) and computational fluid dynamics (CFD) tools are used for simulating the different possible working conditions by changing the fin geometry, flow pattern. The possible flow patterns are achieved by varying the louver pitch, louver angle and fin pitch. Total 60 different combinations are studied in the investigations by varying the louvered fin configurations and in each case numerical simulations are done for the air flow pattern. With an experimental setup fabricated in the lab the simulated results are validated. The results have shown that the performance of the heat exchanger using the louvered fins has improved by 35.4 % when compared with that having plain fins. Goodness factor which is used to optimize the possible configurations of the louvered fins. The investigation construed that using of the louvered fin radiators will contribute to the reduction of the size leading to the reduction in the cost with a better and effective performance of the heat exchangers.

Index Terms: Heat exchanger, louvered fin, CFD, heat transfer coefficient, pressure drop, goodness factor.

1. INTRODUCTION

Heat exchangers are widely used in various fields throughout the world. Among that cooling systems are used in automobile industries, chemical eng, etc. Zhang, et al. [1], able to increase the performance of any system in small range also it affects the lot in an economic point of view. Similarly, way cooling systems can also affect the view. Similarly, way cooling systems can also affect the overall performance of systems by its improvement of effectiveness. The possibilities to improve the effectiveness.It can be possible by 2 ways is to improve by the convective methods using the nano particles In cooling fluid. Samira, et al. [2] And Leong KY, et al. [3]. The secondary method was to improve the heat transfer rate by optimum design methods. To improve the heat transfer rate can be possible by the common method is enlarging the surface area and temperature difference. Out of this to increase the temperature difference is having its own limitation of the effected by the flow operation conditions and material properties. For increasing the surface area within the specified volume only way to go for the compactness of designing extended surface. But the main limitation to improve the heat transfer rate is air side thermal resistance Achaichia [4] studied so many years onwards the research work is going on this area. To overcome this lot of experimental study has been done with different variety of fins plain fin, sin way fin louvered fin etc. Eid, et al. [5]and Cuevas et.al. [6]. Out of all the louvered fin is gives a better performance from several studies. Wen, et al. [7] and Yan, et.al.[8].Čarija, et.al. [9] Studied experimentally by keeping the constant fan power and tested at plain, louvered, wavy out all he noticed that louvered fin obtaining the more heat transfer rate. Vaisi, et al.[10]Experimental investigation enhancement of the heat transfer coefficient by changing the fin pitch, louvered pitch, louvered angle, etc. without a changing the main structure also. Beauvais, F. N [11] first person shown that how the flow affected by louvered fin surface being studied. Karthik et.al. [12] indicated that fin pitch, louver angle, louver pitch, etc. of geometry parameters are affected on the flow efficiency clearly from their investigation. Hsieh et.al [13] he concluded from his studies that area can be reduced up to 48-55% by optimization the louver angles. Z. High et.al. [14] Studied how the factors are affecting while increasing the louver angle such broad range of information was given. Aoki, et. Al. (15) studied, particularly at low velocities convective heat transfer coefficient are can be improved by increasing the fin pitch. Webb, et al. [16] studied the 3d simulation very closer to the experimental values, particularly at when we are studying. From the above survey it's very clear that louver fin geometry, great influence on the enhancement of the convective heat transfer coefficient by this it's possible to minimize the air side thermal résistance. The present investigation using the CFD by Simulating at different configuration. This study analysis to find the optimum louvered fin parameters for the corresponding operating condition. That lead to reduction in size, weight and cost. After optimization by the simulation model heat exchanger of louvered fin parameters tested experimentally in the wind tunnel for validation of that simulated results.

1.1 Governing equations

Three-dimensional mass momentum, energy equations are used for the analysis purpose (1-3) equations respectively.

$$\nabla \cdot \rho u = 0 \qquad (1)$$

$$\rho(u \cdot \nabla u) = -\nabla P + \mu \nabla^2 u \qquad (2)$$

$$\rho c_P (u \cdot \nabla T) = k \nabla^2 T \qquad (3)$$

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Assuming the all fluid properties are taking constant, considering the air as incompressible and at walls no slip condition.

1.2 Boundary condition
For a heat exchanger periodicity boundary condition was applied on top and bottom surfaces. Constant Heat source applied on tube side as 350 Kelvin. Front side the air inlet, taking the pressure as zero-gauge pressure, at outlet considering the atmospheric pressure.

2. EXPERIMENTATION SETUP

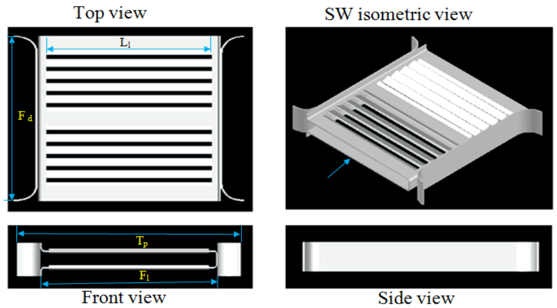

Fig.1 *Louver fin*

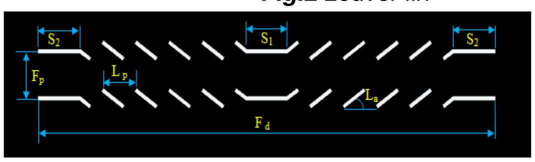

***Fig.** 2*

Nomenclature used in the design of a Louver fin
L l= Louver length
F d= Fin depth
T p= Tube pitch
Fl= Fin length
L p= Louver pitch
F p= Fin pitch
L a= Louver angle
S1= Redirection louver length
S2= Non-louver length at inlet and exit

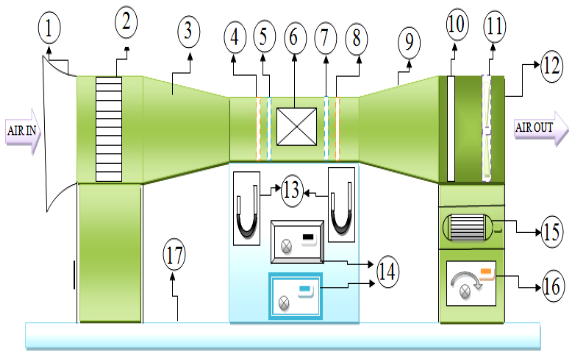

Fig. 3 *Wind tunnel*

1. Air inlet
2. Honey comb and screens
3. Contraction
4. Temperature inlet section
5. Pressure inlet section
6. Testing work piece
7. Pressure out let section
8. Temperature outlet section
9. Diffuser
10. Flow straightened
11. Axial flow fan
12. Multi nozzle plate
13. Manometer reading1,2
14. Temperature indicators
15. Motor
16. Frequency controller
17. Bed

TABLE 1 *Geometry Baseline*

F_P (mm)	L_P (mm)	L_a	F_d (mm)	S_1 (mm)	S_2 (mm)	L_l (mm)	T_p (mm)	F_l (mm)	t (mm)
1.8	1.6	200	22	2	2	17.2	24	19	0.16

TABLE 2 *The ranges of louvered fin are*

S. No	Variable parameters	Ranges
1	Louver angle	$16^0,18^0,20^0,22^0,24^0,28^0$
2	Louver pitch(mm)	1.4,1.6,1.8
3	Fin pitch(mm)	1.2,1.4,1.6,1.8,2
4	S2(mm)	3,2,1

2.1 Description
ALTECH open circuit of AC motor5. 0 KW flow was an axial type as shown in schematic fig. 3 and its construction at the entrance having a bell type mouth inlet suction is connected to the honey cone, then contraction section and diffusion section in between the work piece test section. Test section was made of the plywood and Plexiglas window for the visual observation of flow phenomena. The experimental geometrical configuration was 1:10 to the baseline parameters. That baseline geometry as shown Table I

2.2 Operating procedure
Wind tunnels are used to replicate the air flow environment for the object. It was created by the very high speed axial fans used in this with the help of a motor. The motor was well controlled variable frequency. Rotation of the motor was displayed digitally. Honeycomb and screens will take care of the turbulent air; laminar air was passed through the test piece. Here the air pressure reading was noticed at the passage and departure of the test piece with the help of the pitot tube. Air temperature reading was noticed at passage and departure with the help of temperature indicator with digitizing. In this of k type thermocouple are used to sense the temperature. Mica sheet 450watt was used as heating elements.

3. VALIDATION OF SIMULATED RESULTS WITH EXPERIMENTAL DATA

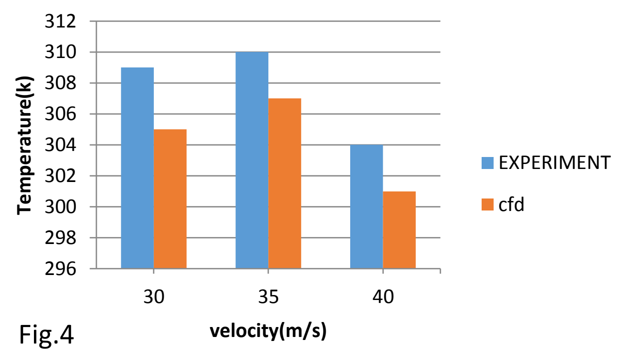

Fig.4

By conducting the experiment on wind tunnel reading are noticed. With same geometry and boundary conditions (pressure, velocity and heat input) conducted on CFD and values are noted down, out of that temperature reading is playing a key role to study the performance. The variation in temperature reading comparison shown in Fig.4 the deviation from the experimental results of the CFD results are 1.3%, 1.1%, 1.03% at a velocity of 30m/s, 35m/s. 40m/s respectively. While measuring the experiment readings deviation is unavoidable errors of so many reasons.

4. OPTIMIZATION AND DISCUSSIONS

4.1. Optimization of fin pitch

All dimension parameters are as per the base line Table.1 heat exchanger. The only variable is the fin pitch. Fin pitch ranges from 1.2mm to 2mm with a scale factor 0.2mm. At all ranges of fin pitch the variation of heat transfer coefficient noticed from fig. 6. heat transfer coefficient was increased by 34.8% from pitch 1.2mm to 1.8 mm at the velocity 5 m/s. Theory behind this while increasing the fin pitch, thermal boundary formation starts reduced that leads to the increment of heat transfer coefficient. Heat transfer coefficient at 1.8mm, 2mm getting higher.

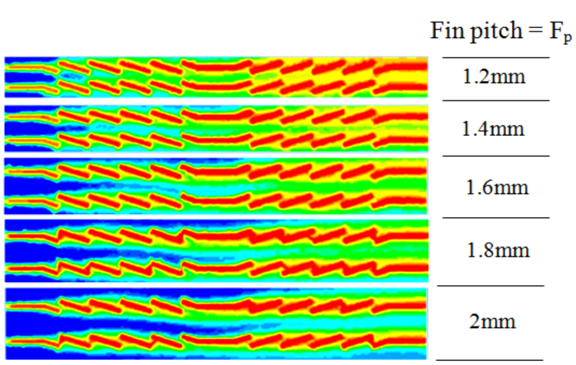

Fig.5

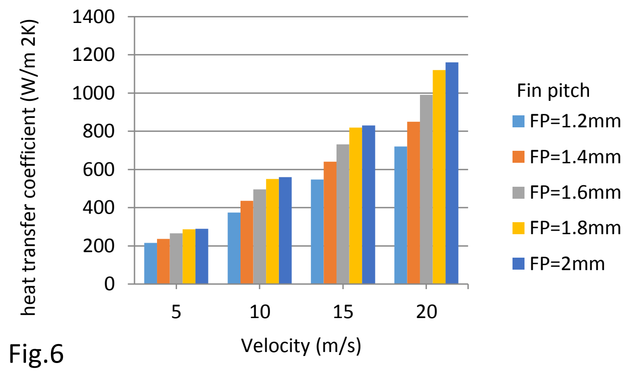

Fig.6

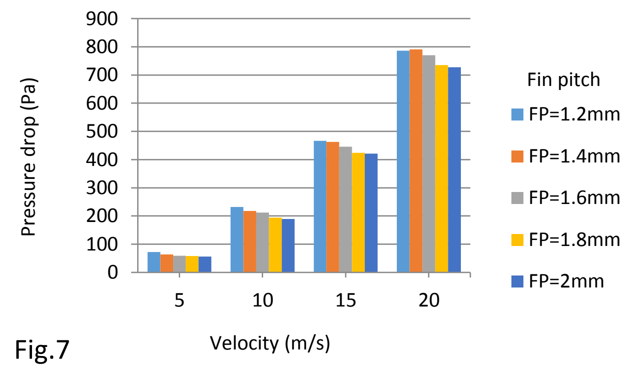

Fig.7

From Fig.7 gives the information that pressure drop decreased when the fin pitch from 1.2mm to 2mm the total pressure drop was 22%, at the velocity 5 m/s. When the fin pitch starts coming closer with each other that leads to increases the resistance to the air side. From the Fig.7 at 1.8mm was the second least pressure drop.

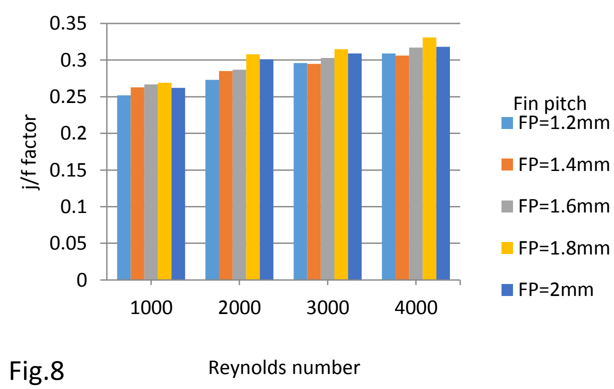

Fig.8

From the Fig.8 it's clear and made easy to pick which one gives the relative the better thermo hydraulic performance of the heat exchanger design. Now from this Fig.8 noticed that highest goodness factor obtained at 1.8mm. Even though fin pitch at 2mm having heat transfer coefficient slightly more than 1.8mm. In design point of view at 1.8mm shows the best goodness factor. Ultimately, choose fin pitch at 1.8mm.

4.2. Optimization of louvered angle

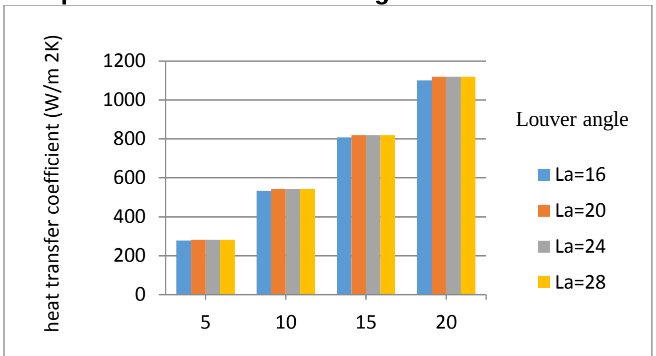

Fig.9

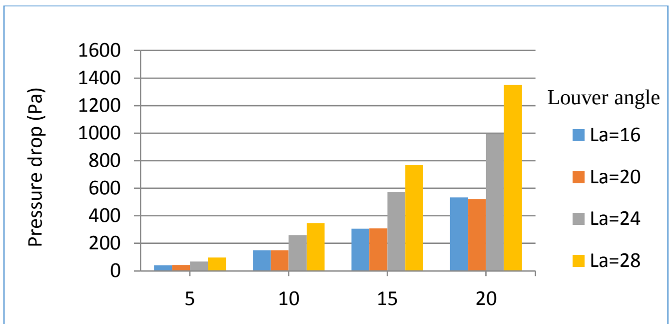

Fig.10

All dimension parameters are as per the base line Table.1 heat exchanger. The only variable is louvered angle. This ranging between the 16^0 to 28^0 with four ranges of a step size is 4^0 are 16^0, 20^0, 24^0, 28^0.

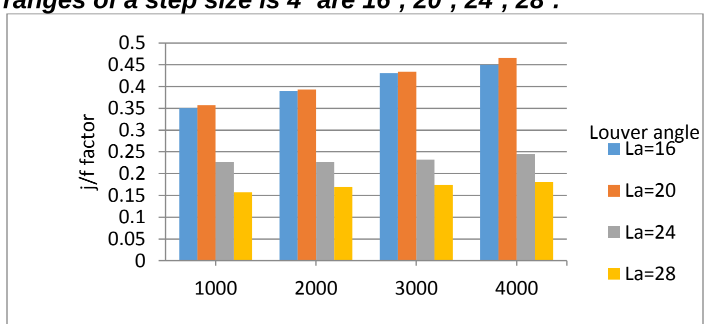

Fig.11

From the Fig.9 the heat transfer coefficient increases from 16^0 to 20^0, then after almost same heat transfer coefficient values noticed. From Fig.10 noticed that the overall pressure drop increased 1.39 times. While increasing the overall louvered angle by the 120at velocity of the air is 5 m/s. When the optimum limit cross increasing the louver angle causes to minimize air duct volume. This will initiate the air stagnation that leads to rise in the pressure drop. Out of this at 16^0, 20^0 noticed less in pressure drop compared to other louvered angles. For deciding the better louvered angle from Fig.11 shows the at 16^0, 20^0 having highest goodness factor value. Mostly, at 20^0 louver angle.

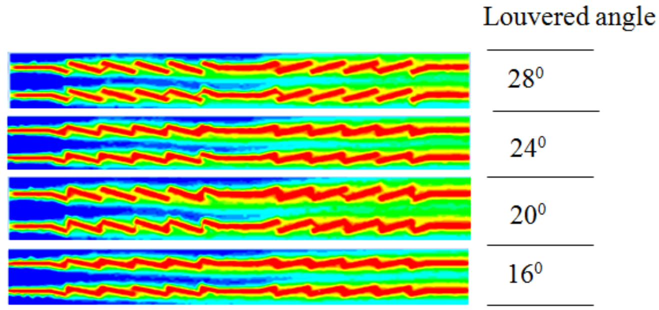

Fig.12

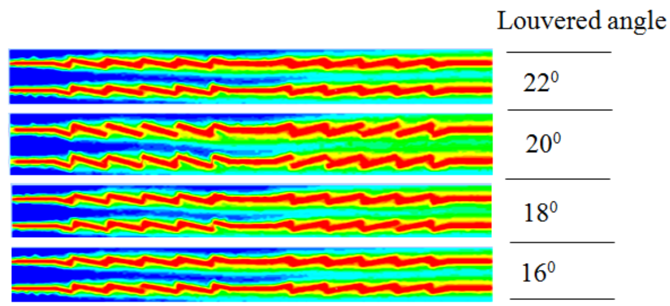

Fig. 13

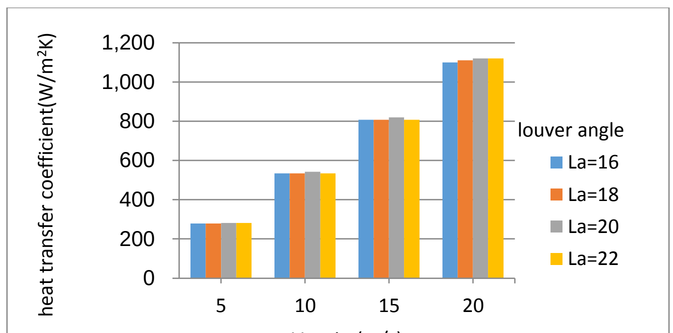

Fig.14

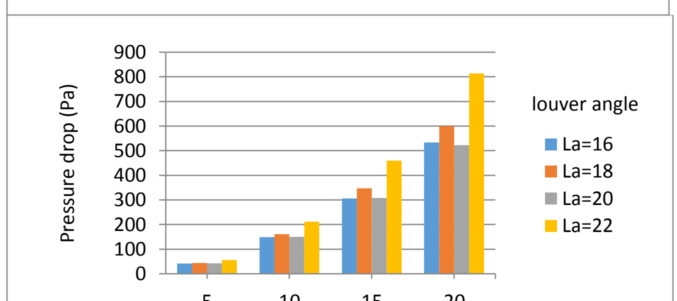

Fig.15

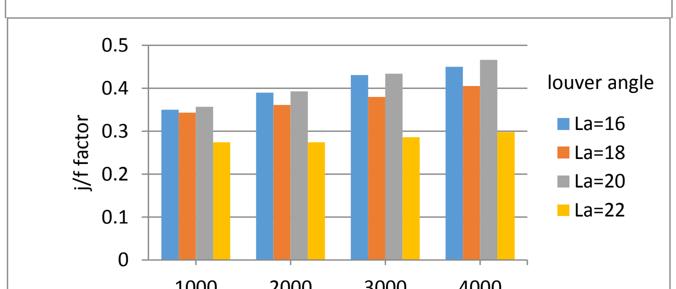

Fig.16

Similarly analysis been carried in narrow range of louvered angle 160 to 220 with the step size of 20 .From the Fig.14 noticed same heat transfer coefficient values at 180,200,220 ,for selecting the optimization of louvered angle from the Fig.15 shows that overall 36.58% rise of pressure drop was noticed with increasing the overall louver angle of 60 , at 200 louvered angle only 4.8 % which was a least pressure drop at same time with good heat transfer coefficient also. at 200 louvered angle shows the best performance can be achieved . From this analysis we optimized the louvered angle at 200 at given baseline heat exchanger.

4.3. Optimization of the louvered pitch

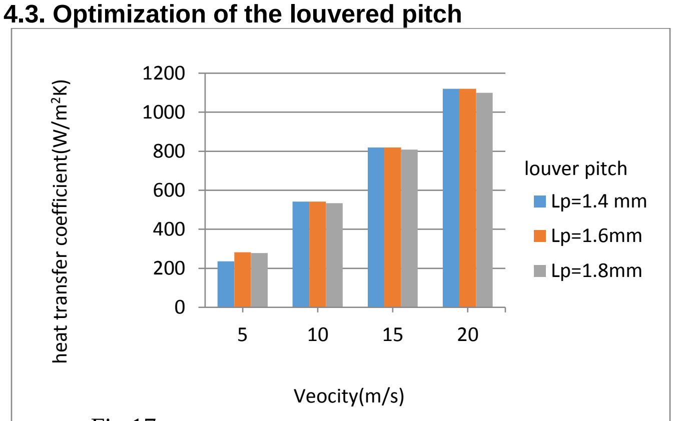

Fig.17

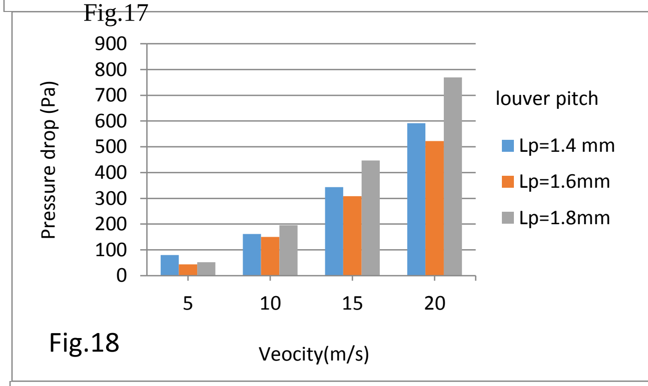

Fig.18

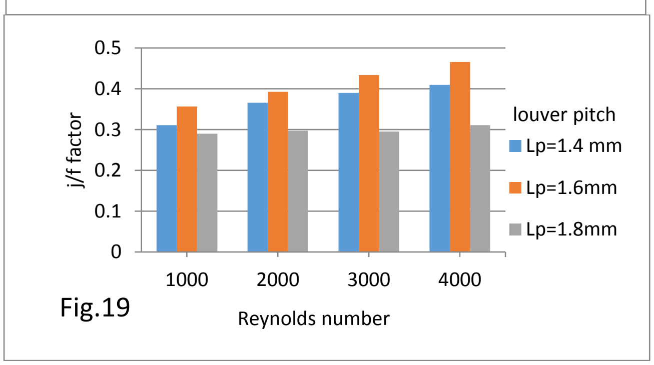

Fig.19

Similarly, All dimension parameters are as per the base line Table.1 heat exchanger. The only variable is louvered pitch value. The variables in the louvered pitch range from 1.4mm to 1.6mm of step size of 0.2 mm are taken total three step size taken. Indication of each louvered pitch effect on the heat transfer coefficient is shown Fig.17, from this noticed that while increasing the louvered pitch from 1.4mm to 1.6mm heat transfer coefficient increased by the 19.49% that was a maximum noticed at the front velocity of 5 m/s. At the same inlet air velocity louvered pitch of 1.4mm to 1.8 we noticed that heat transfer coefficient increment was 17.7% only. From this it is very clear that at louvered pitch 1.6mm getting higher heat transfer coefficient comparatively other cases. From Fig.18 noticed the pressure drop starts reducing to 46.3% at 1.2 mm to 1.6mm louvered pitch. Pressure drop reduced by the 35.16% at 1.2mm to 1.8mm.The desired louvered pitch getting the less pressure drop because of the less stagnation among the all louvered pitches. From the Fig.19 it's very clear that at 1.6mm getting the highest goodness factor from this all above, we can conclude that optimum louvered pitch can be achieved the at 1.6mm.

5. COMPARE THE LOUVERED FIN WITH PLAIN TYPE FIN

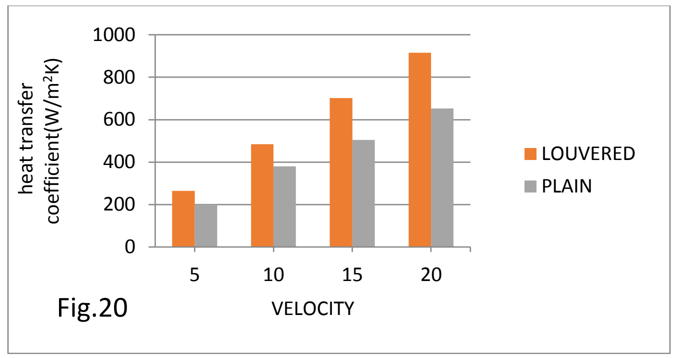

Fig.20

Habibian, et al. [17] studies louver fin heat exchanger can enhance by the 24.6% of heat transfer coefficient by comparing the plain fin. By keeping the constant surface area optimized baseline louvered fin heat exchanger heat transfer coefficient is enhanced by 31.34% to 40.125% comparing the plain fin. At the same time, we can reduce the 1/3 rd of volume and cost also when compared to plain type.

6. CONCLUSIONS

To maximize performance of,60 different configurations of the louvered fins are considered to numerically simulated the performance of the heat exchanger using the CFX and ANSYS tools. The enhancement of heat transfer coefficient has found been influenced with the increasing Fin pitch, while increasing the frontal velocity of air. While at the same time drop in pressure is also found to be decreased with increasing the fin pitch this makes to the selection of the desired fin pitch based on the goodness factor. Increasing the fin louver angle had a little influence on the heat transfer coefficient while had a greater influence in drop in pressure. So, the louver angle is further optimized using the goodness factor. If continue increasing the louver pitch initially reduced the pressure drop, then started increasing. Hence the louver pitch corresponding to the low-pressure drop is considered as desired louver pitch enhances the effectiveness of the heat exchanger. The optimized louvered fin has resulted in improvement of the heat transfer rate at an average of 35.73 % when it compared to the heat exchanger using plain fin.

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