Comparative Study Between Cross Flow Air To Air Plate Fin Heat Exchanger With Triangular Fins And Triangular Perforated Fins And Optimization Using Taguchi Analysis. , Heat recovery and importance of ventilation.

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Abstract – *Indoor Air Quality (IAQ) is a term which we get to hear a lot after the commencement of the coronavirus pandemic. Heat recovery ventilation (HRV) can play a very important role in this. The fresh air from the ambient is separated from the stale air exhausted from the indoor facilities. Due to this the fresh air is not contaminated by the moisture, dust, pathogens, particulate matters, pollutants, smoke, smell etc. which is exhausted directly from the indoors and only heat transfer takes place further decreasing the load on HVAC systems. Computational fluid dynamics analysis between conventional plate fin heat exchanger model with triangular extended surfaces and proposed perforated model was performed and the comparative characteristics where studied. In order to maximize the parameter such as thermal effectiveness, recovered heat, outlet temperatures, Taguchi analysis was implemented using the L9 orthogonal array. The design variables and levels that would maximize the thermal effectiveness and other factors were plate thickness, velocity of fluid and plate height.*

Keywords-- Plate Fin Heat Exchanger, Taguchi Analysis, Heat Recovery Ventilation, Computational Fluid Dynamics, Thermal Effectiveness, Perforations.

1. INTRODUCTION

HRV also known as the heat recovery air exchangers or Mechanical ventilation heat recovery (MVHR), are equipped with two continuously running fans. The first one expels indoor stale air (consisting of - smell, smoke, pollutants, pathogens etc.), and the second one supplies fresh filtered air from the outside. The fresh new air and expelled stale air never come into contact with each other; the air is not recycled. This technology absorbs heat or cooled energy and recycles it; it does not generate it. It can recover heat during winter or cool during summer from the expelled stale air, and transfers it to the fresh incoming filtered air. In the article the HRV type to be discussed is a Fixed plate type heat exchanger with extended surfaces (fins).Plate heat exchangers are heat exchangers well-known since the 1940's. They can be used as a sensible heat or energy recovery, and are characterized by high effectiveness, compactness, low weight and moderate cost. They are further divided into cross, counter and parallel flow. [1]

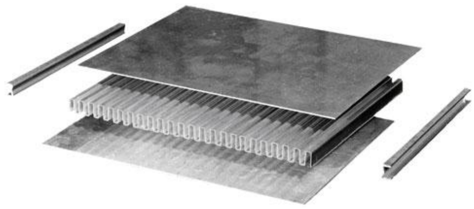


Figure- 1: Plate fin heat exchanger exploded diagram.

1.1 Working principle of PFHE.

The working principle of a plate fin heat exchanger is quite simple. Here is an example of cross flow plate finned heat exchanger. In cross flow the fluids are at an angle of 90°, the two fluids involved in the heat exchange are separated by a parting sheet. Which acts as the primary heat transfer surface. It has side bars which prevents the fluid from spilling. And extended surfaces or fins which are sandwiched between the parting sheets. They act as the secondary heat transfer surfaces.

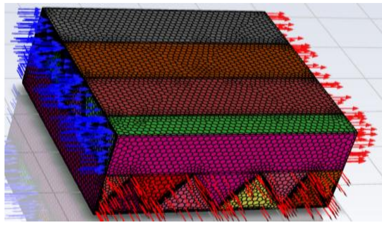


Figure- 2: Cross flow plate fin heat exchanger meshing

As the fluid enters through the channels of the inlet, due to the temperature gradient between the two fluids heat transfer takes place through convection between the fluids and the primary and secondary heat transfer surfaces. This type of fixed plate heat exchangers has superiority to rest of the heat exchangers because of their compactness. Large heat transfer surface area per unit volume (typically 1000 m^2/m^3). It produces a high overall heat transfer coefficient because of the heat transfer associated with the narrow passages and corrugated surfaces.

2.TAGHUCHI ANALYSIS

Table 1: Selected 3-level control parameters and their sub-levels

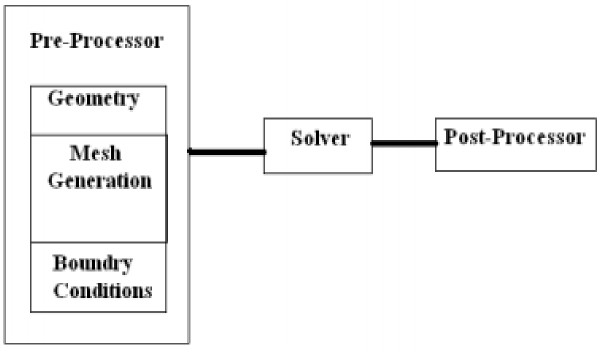
LEVELS	PLATE THICKNESS (mm)	VELOCITY OF FLUID (m/s)	PLATE HEIGHT (mm)
1	0.1	2	3
2	0.2	2.5	4
3	0.5	3	5

The Taguchi method is used to determine the main (important) parameters that have the greatest impact on the response parameter under study. Instead of changing one factor, each time with this method, all factors are changed at once according to the design array and also the change of response values according to the selected performance parameter is observed. It is also possible to evaluate several factors with the minimum number of experiments or numerical solutions by Taguchi method.

Table 2: 9 different designed numerical PHE models according to Taguchi

NUMERICAL RUN NUMBER	PLATE THICKNESS (mm)	VELOCITY OF FLUID (m/s)	PLATE HEIGHT (mm)
1	0.1	2	3
2	0.1	2.5	4
3	0.1	3	5
4	0.25	2	4
5	0.25	2.5	5
6	0.25	3	3
7	0.50	2	5
8	0.50	2.5	3
9	0.50	3	4

3. CFD details and methodology



3.1 Preprocessing:

Step 1: Construction of Geometry. This problem has three geometries namely,

1. Fresh fluid section
2. Intermediate plate section
3. Stale fluid section

The geometries of given problem are created by using Space claim software.
Velocity of the fluid :2 m/s
Fin's type: plain

Step 2: Meshing the Model

1. Volume mesh with Polyhedral and prism layer

Setting physics of the Problem

Since in this problem consists of three phases, we need to select three physics, one for gas, second for liquid and another for SOLID. Physics selected for the fluids

- Three-Dimensional Flow.
- stationary
- Constant density
- Steady Flow.
- Segregated flow model
- TURBULENT FLOW with K-Epsilon model

The Boundary Conditions

In this problem there is inlet one for cool stream and other for hot steam, through the cross section of core. Both streams are separated by each other by an intermediate plate and both are velocity inlet type. Similarly, there are two outlets in which are pressure outlet type the cross section is given as symmetry type and remaining are keep as a wall which are smooth, no slip and adiabatic. The velocity at both the inlet is 2 m/s. the pressure at the outlet is one atmosphere.

- Fresh air temperature =305k
- Stale air temperature = 295k.

4. Results

The results of Taguchi obtained are given below. According to the 9 models made and based on the Taguchi analysis from MINITAB 2019, the model with the cofactors which is 0.10mm plate thickness, 2 m/s velocity of fluid and 3 mm of plate height. And the response table for signal to noise ratio in which larger is better was considered, the rank was given in the follo9wing order; A to plate thickness, B to velocity of the fluid and C to plate height.

Response Table for Signal to Noise Ratios

Larger is better

Level	A	B	C
1	-9.712	-9.998	-10.206
2	-10.317	-10.264	-10.056
3	-10.606	-10.373	-10.373
Delta	0.893	0.375	0.318
Rank	1	2	3

Figure 3: Response table for S/N ratios

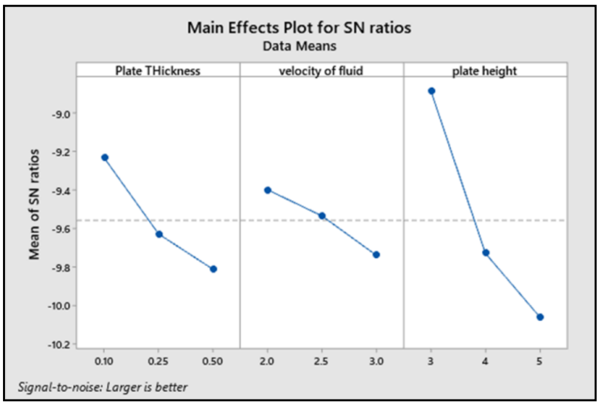


Figure 4: Signal to noise Ratios Plots

The fresh air outlet temperatures obtained for 9 different models are represented below. The maximum decrease in temperature was for the model 1 and the model 7 , 8 ,9 showed similar decrease pattern.

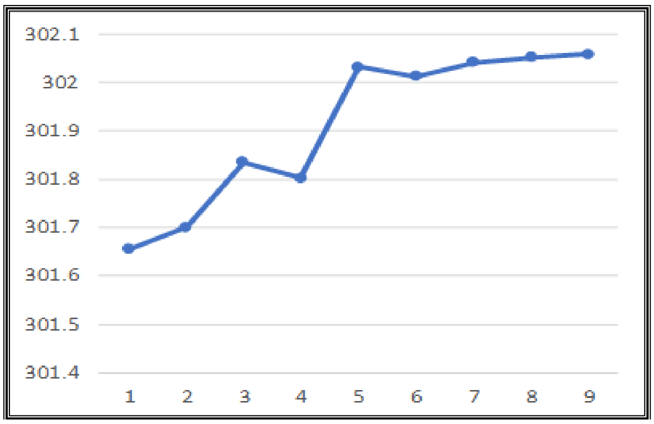


Figure 5: Fresh air outlet temperatures for the 9 Taguchi models.

Therefore, according to the fresh air outlet temperatures obtained, the effectiveness was calculated and again model 1 resulted in the maximum thermal effectiveness.

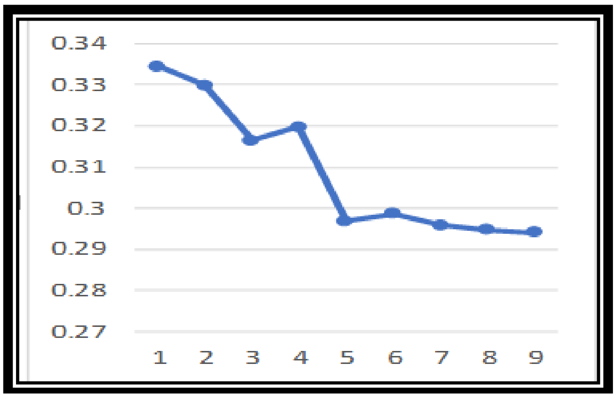


Figure 6: Effectiveness curve for 9 Taguchi models.

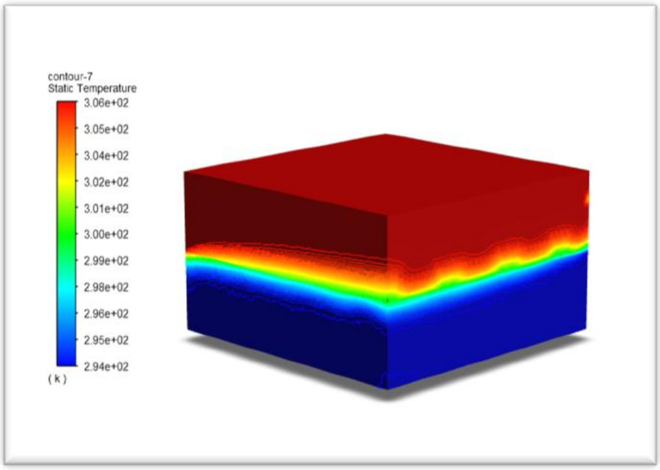


Figure 7: Temperature Contour for the PFHX

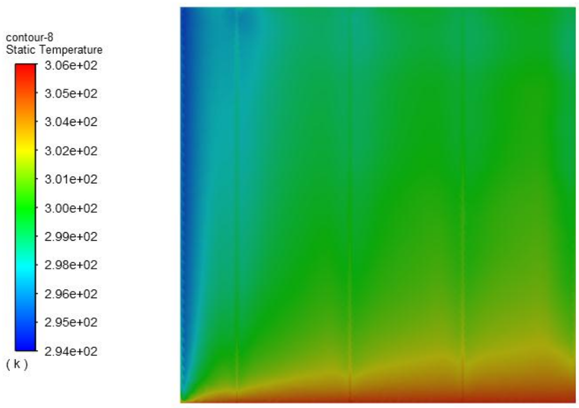


Figure 8:Temperature contour for the intermediate plate

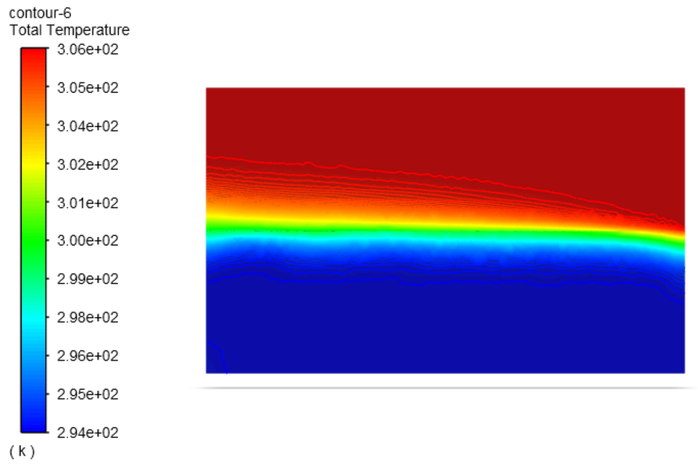


Figure 9: Sectional Plane Temperature Contour

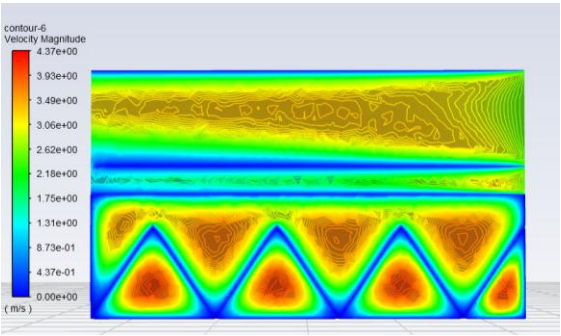


Figure 10: Sectional plane Velocity Contour

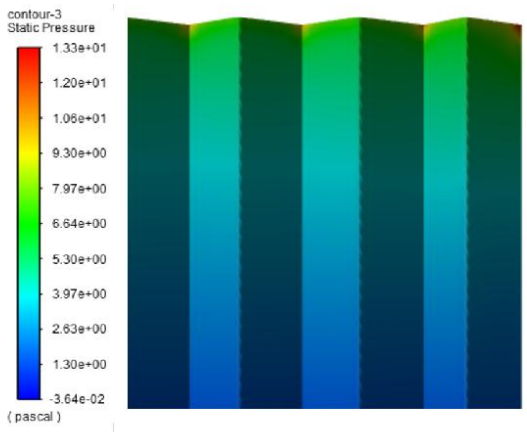


Figure 11: Fresh side fin Pressure Contour

After obtaining results, from Taguchi analysis the model which gave the highest thermal effectiveness was designed and numerically verified. Now in order to further optimize the design and size , a new model with triangular perforations was designed and CFD ANALYSIS was carried on it. The results below were hence obtained.

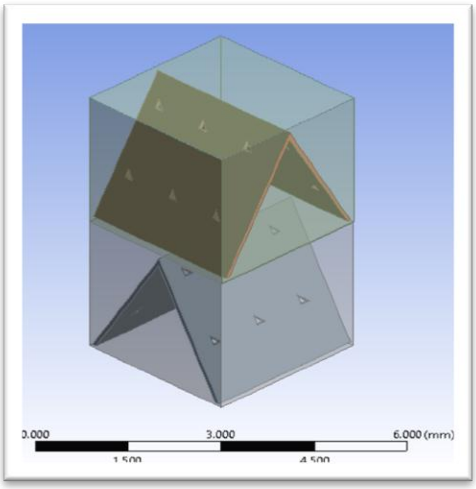


Figure 12: Perforated Fin Model

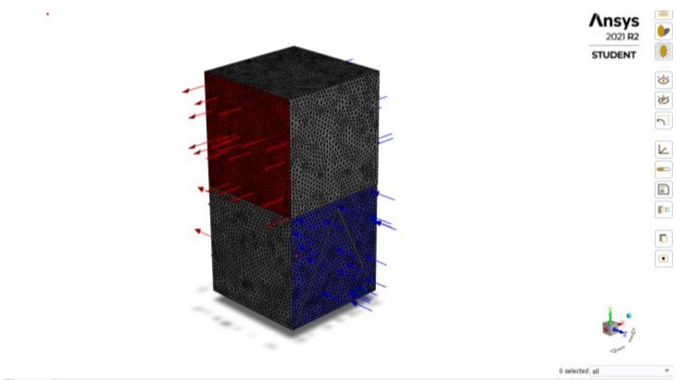


Figure 13: Meshing of the model.

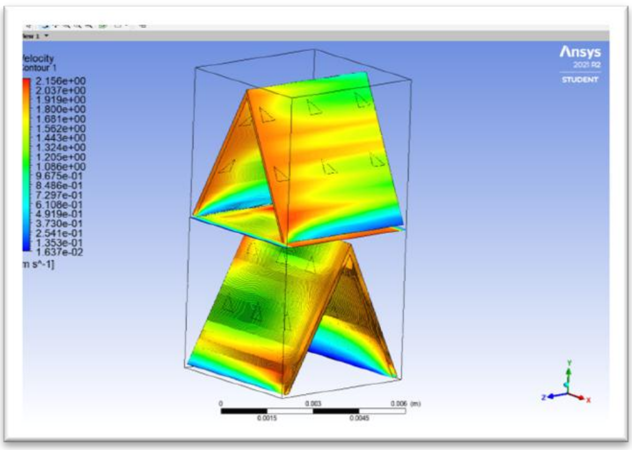


Figure 14: Velocity Contour

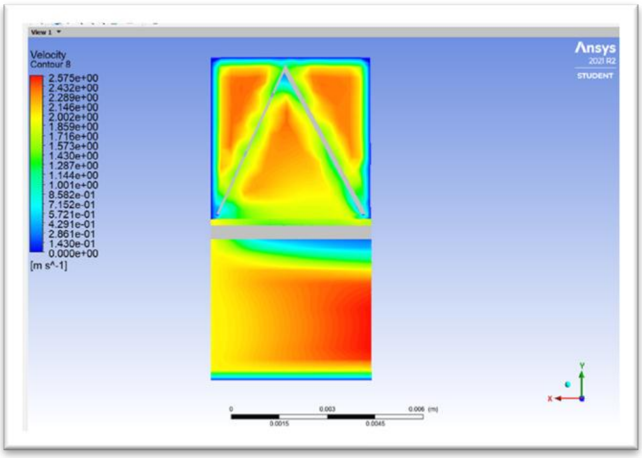


Figure 15: Sectional Plane Velocity Contour Of Perforated Model.

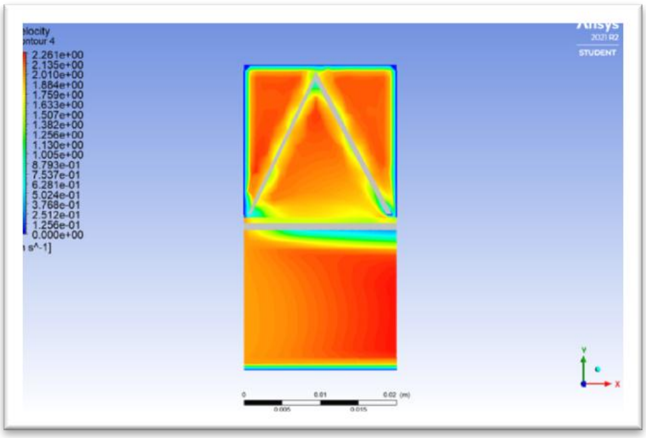


Figure 16: Sectional Plane Velocity Contour Of Perforated Model.

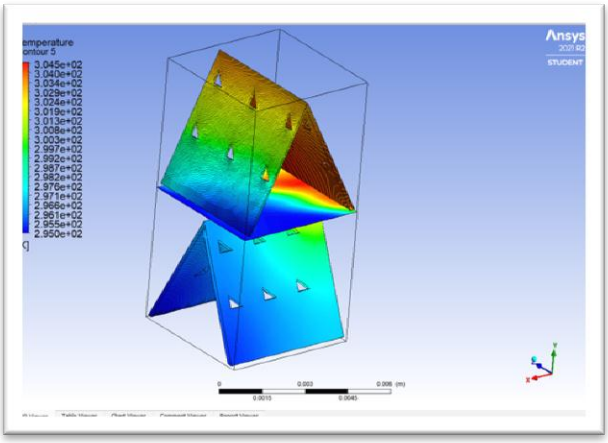


Figure 17: Temperature Contour

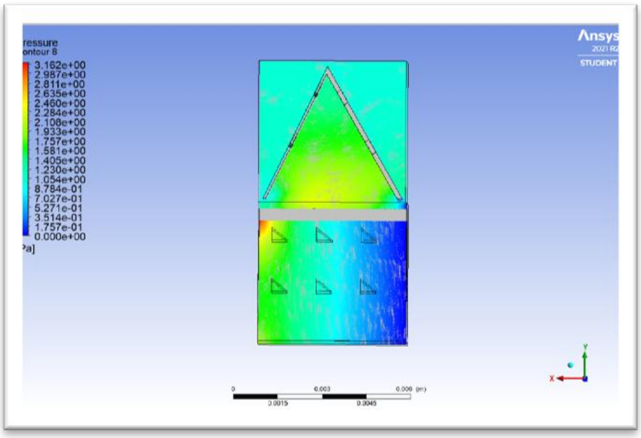


Figure 18: Pressure Contour of the perforated model.

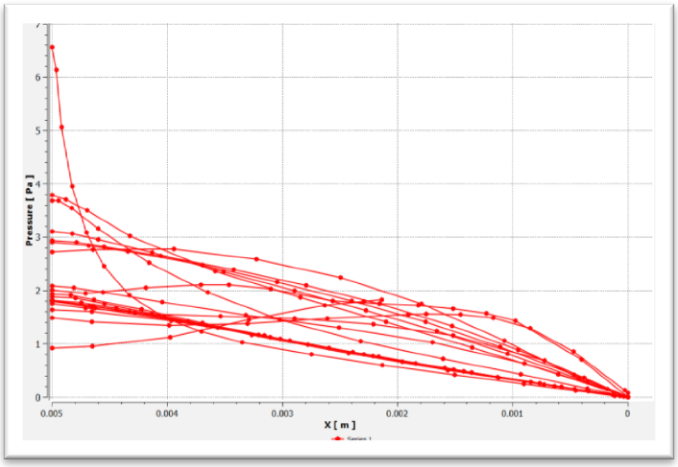


Figure 19: Pressure drop across the Z axis.

	CONVENTIONAL FIN DESIGN	TRIANGULAR PERFORATED DESIGN
FRESH AIR OUTLET TEMP (K)	302.99K	300.48K
STALE AIR OUTLET TEMP (K)	298 K	299.55 K
EFFECTIVENESS (%)	30.0 - 35 %	45.7264 %
Heat Recovered (Qrh) (WATTS)	56.455w	87.927W
KW .H/DAY	1.354	2.110

5.CONCLUSIONS

In this study, a cross-flow plate fin heat exchanger with fixed plate, and triangular fins with triangular perforations was designed by using CFD and Taguchi method for maximum Thermal effectiveness. In Taguchi analysis, 3 control parameters each with 3-levels were selected and numerical analysis were derived for designed 9 different 3-dimesional CFD models

-When optimal levels of the cofactors were used to create design for maximum thermal effectiveness, thermal effectiveness was obtained as 45.73% which is greater than the conventional model thermal effectiveness by 8 to 10%.

-By using the optimal levels of factors for the maximum thermal effectiveness, the difference between thermal effectiveness predicted by the Taguchi method (45.7264%) and that obtained from the solution of the new optimum PHE numerical model (53.289%) .the difference obtained was less than 10%.

-the total heat recovered was which was 56.46w(1.354 KW .H/DAY) in the conventional model was increased to 87.93w (2.110 KW .H/DAY) in the proposed model.
-Considering the average air flow rate is 19 to to 25 m^3/H per person. the PFHE can easily serve 4 – 5 people comfortably.

6. FUTURE SCOPE

- Experimental model could be made tested analyzed and compared with the CFD and numerical results.
- Perforations for porous media can be used and analyzed
- Usage of different material such as cellulose, paper that can retain moisture in the applications of ERV could be studied.
- Circular perforations could be design for the fins and its effect could be studied.

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