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DESIGN AND ANALYSIS OF EXHAUST GAS HEAT EXCHANGER

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ABSTRACT

Ideal heat exchangers recover as much heat as possible from an engine exhaust at the cost of an acceptable pressure drop. They provide primary heat for a thermoelectric generator, engine intake air pre-heating and air-conditioning and their capacity and efficiency is dependent on the material, shape, and type of the heat exchanger. Four different exhaust heat exchangers were designed within the same shell, and their computational fluid dynamics (CFD) models were developed to compare heat transfer and pressure drop in typical driving cycles for a vehicle with a 1.2 L gasoline engine. And two different materials (carbon steel and AISI4140) were applied to shell. Both the materials are best suited for manufacturing of heat exchanger, with reliable properties. These are the engineering materials that are helpful and playing a vital role in extraction of maximum heat from the exhaust of the engine. The result showed that the serial plate structure enhanced heat transfer by 7 baffles and transferred the maximum heat of166.358kw and maximum pressure drop of 9.2712kpa in a suburban driving cycle. Modeling of shell and all the structures were done in PTC-CREO and simulations were done in ansys FLUENT 15.0.

INTRODUCTION

In order to meet the increasing demands of modern automobiles, bigger and bulkier equipments are connected to engines. Bigger and bulkier alternators which operate at an efficiency of 50 to 62% consume around 1 to 5% of the rated engine output. However, due to the expansion of the passenger room and to improve the vehicle aerodynamics, the space for the alternator in engine room is becoming smaller. About 30% of the energy supplied to an IC engine is rejected in the exhaust as waste heat. If approximately 6% heat can be recovered from the engine exhaust, it can meet the electrical requirements of an automobile and it would be possible to reduce the fuel consumption around 10%. Heat is rejected through exhaust gases at high temperature. This shows the possibility of energy conversion using a thermoelectric generator (TEG), turbo charging and automobile cabin cooling to tap the exhaust heat energy. TEG is like a heat engine which converts the heat energy into electric energy and it works on the principle of Seebeck effect. Moreover TEG are highly reliable, operate quietly and are usually environmentally friendly. Semi-conducting materials (in conjunction with copper inter-connecting pads), were found to offer the best combination of See beck coefficient, electrical resistivity, and thermal conductivity. Semi-conducting materials provide another benefit, the ability` to use electrons or “holes” (the absence of an electron in a crystal matrix) to conduct current. Thermoelectric module (TEM) has a cold side and a hot side. At the hot side, heat is absorbed by electrons as they pass from a high energy level in the n-type semiconductor element, to a lower energy level in the p-type semiconductor element. The power supply provides the energy to move the electrons through the system. At the cold side, energy is expelled to a heat sink as electrons move from a high energy level element (n-type) to a lower energy level element (p-type). Bismuth telluride-based TEM are designed primarily for cooling or combined cooling and heating applications where electrical power creates a temperature difference across the TEM. By using the modules in reverse, where a temperature differential is applied across the faces of the module, it is possible to generate electrical power. Although power output and generation efficiency are presently low, useful power often may be obtained where a source of heat is available.

MATERIALS

In the present work, we are applying two different materials AISI4140 and steel for the heat exchanger with same structure differing in internal arrangement of plates. We have worked on four different arrangements (Empty, Parallel, Inclined and Serial) for the same shell, with two different materials.

***Table 1:* Material Properties**

Materials	Density	Specific heat	Thermal conductivity (k)
AISI4140	7850	477.59	42.6
Steel	8030	502.48	16.27

***Table 2:* Operating Conditions**

Driving Cycle	Mass Flow Rate of Exhaust (g/s)	Hot side temperature of generator (k)	Exhaust temperature
Urban	5.7	423.15	573.15
Suburban	14.4	473.15	673.15
Maximum Power output	80.1	423.15	873.15

***Table 3*: Fuel Consumption**

Driving Cycle	Fuel Consumption (L/100 Km)	Time-Averaged Exhaust mass flow rate (g/s)
Urban	6.7	5.7
Suburban	5.1	14.4
Overall	5.7	8.53
Maximum power output	-	80.14

DESIGN AND ANALYSIS

Initially the heat exchanger is designed for four different arrangements as shown in the figures using PTC-CREO

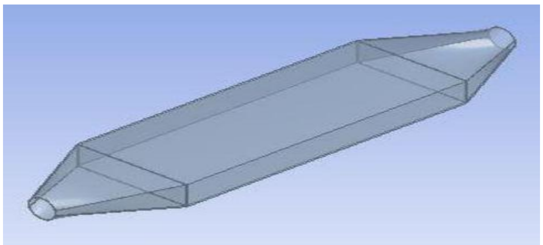

Fig 1: Empty Shell

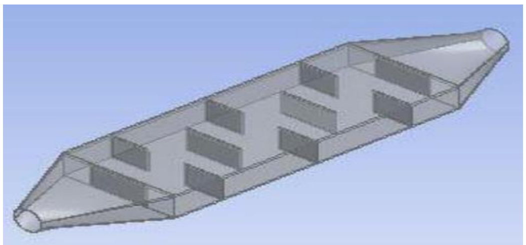

Fig 2: Parallel Plate

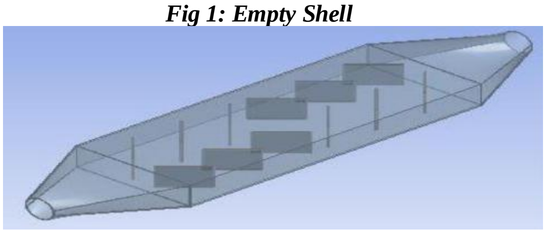

Fig 3: Inclined Plate

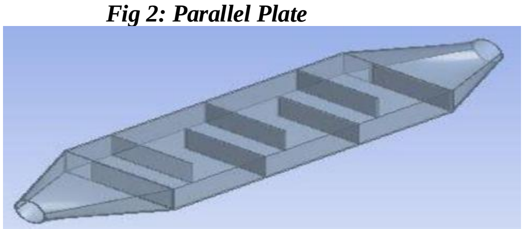

Fig 4: Serial Plate

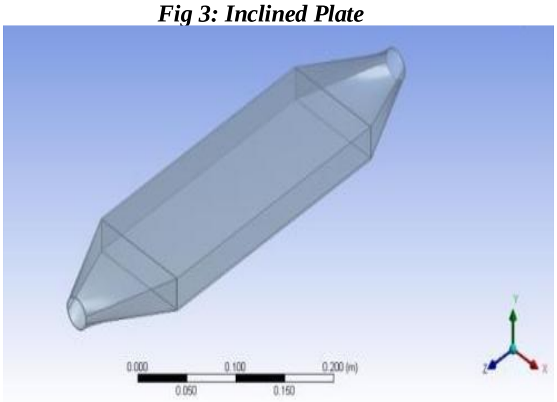

Fig 5:Requiored Assignments

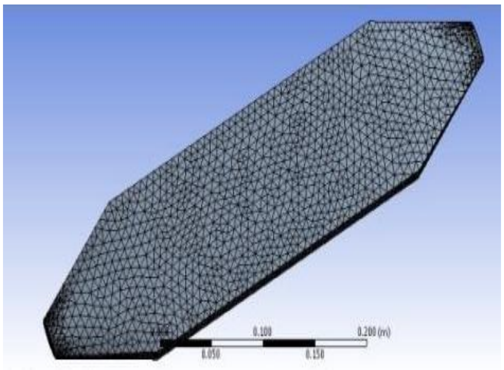

Fig 6:Meshing

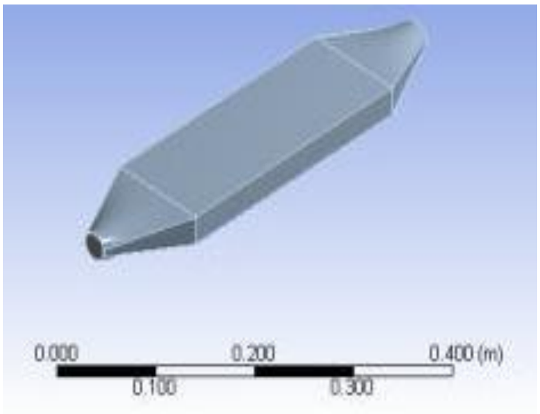

Fig 7: Selection of Faces

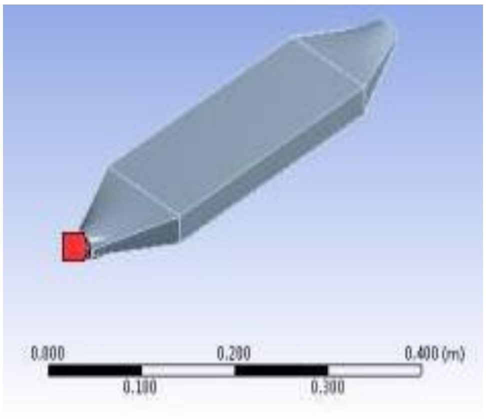

Fig 8: Naming of Selected Geometry

RESULTS AND ANALYSIS

Maximum heat transfer occurs for structure with series of baffles because of the huge amount of pressure drop and the heat transferred is**166.358kw**and the pressure drop occurred is **9.27kpa.**

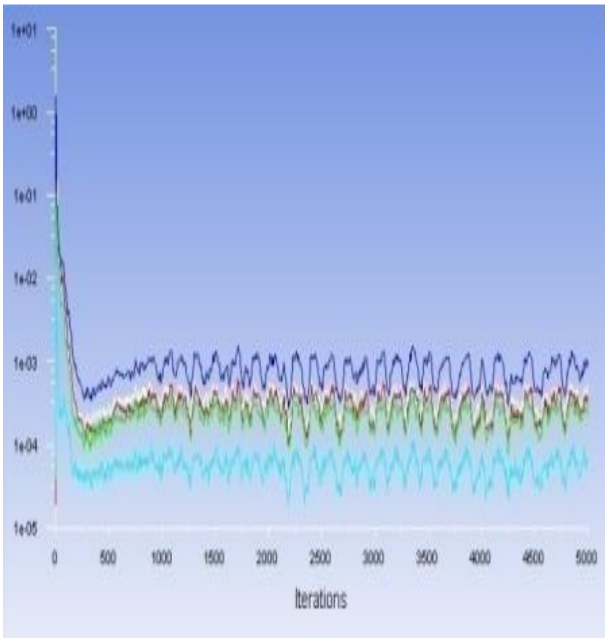

Fig 9: Heat Extraction by Empty Shell

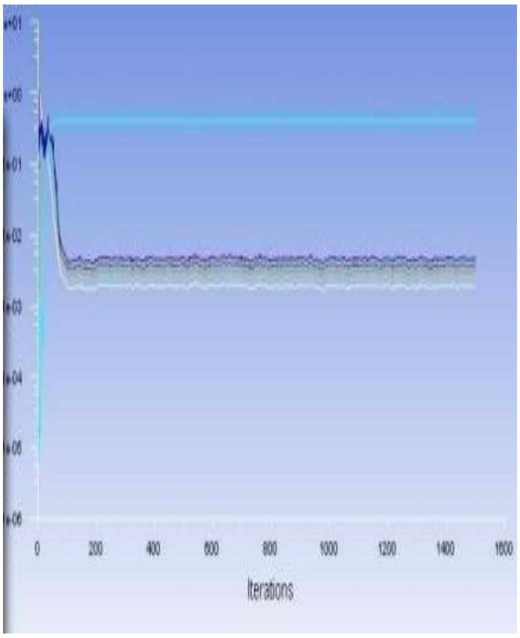

Fig 10: Heat Extraction by Inclined Shell

Fig 11: Heat Extraction by Parallel Shell

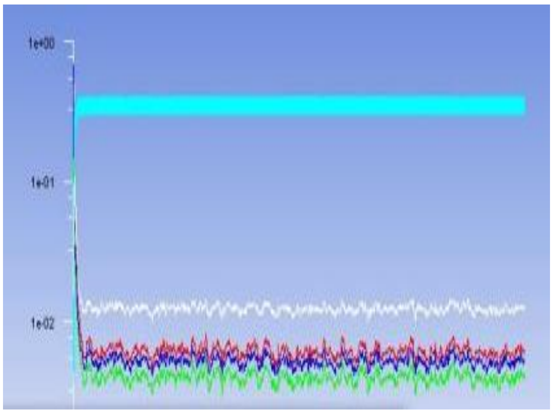

Fig 12: Heat Extraction by Serial Shell

Table 4: Results for Steel Structure

Heat Exchanger Structure	Amount of Heat Extracted(w)
1.Empty Shell	-210.4987
2.Inclined Plates	-463.7875
3.Parallel Plates	-74085.369
4. Serial Plates	-166358.66

Simulation Results

Velocity is, of course, a function of the flow rate of the fluid and the volume of the path that the fluid must follow. Probably the most common error in heat exchanger design is to allow too low a fluid velocity. It turns out that this can create multiple issues with system performance. The first problem with reduced velocity is settling in the fluid itself. If the velocity of the fluid is not sufficient to create enough turbulence to maintain the solids in suspension, settling will occur.

Empty Shell

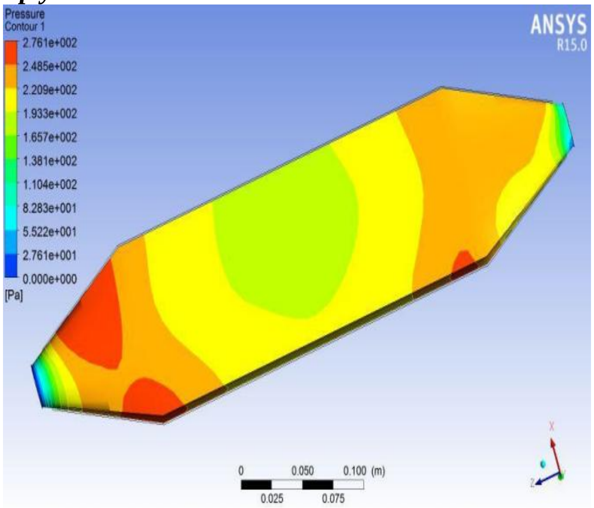

Fig 13: Pressure Contour of Empty Shell

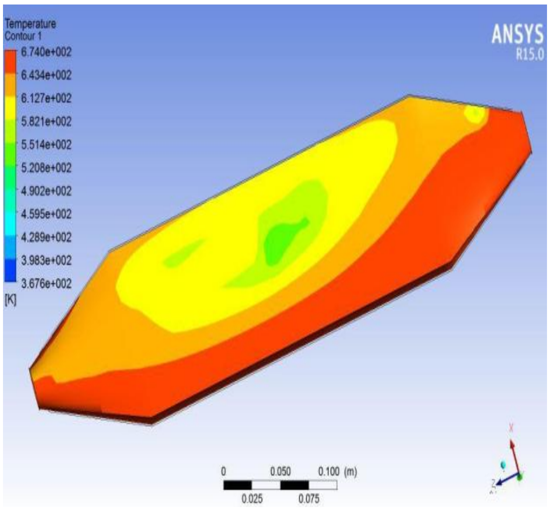

Fig 14: Temperature Contour of Empty Shell

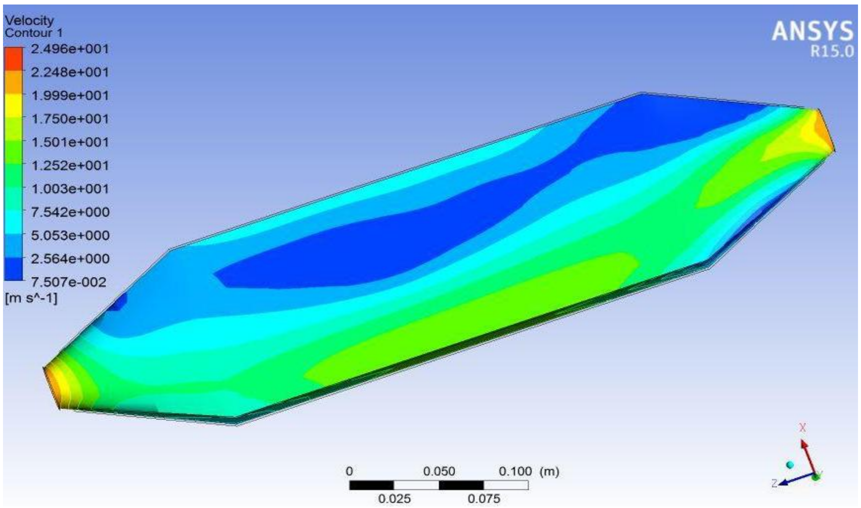

Fig 15: Velocity Contour of Empty Shell

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Inclined Plates

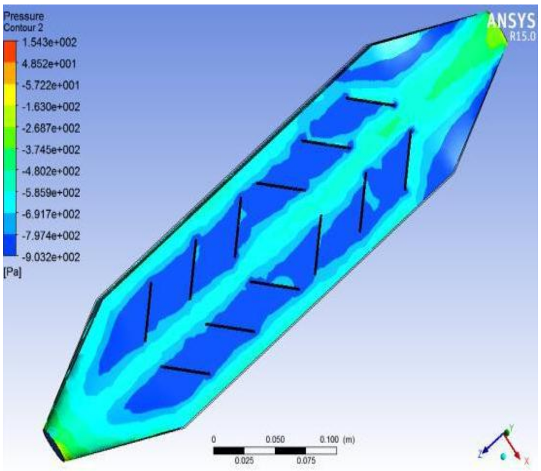

Fig 16: Pressure Contour of Inclined Shell

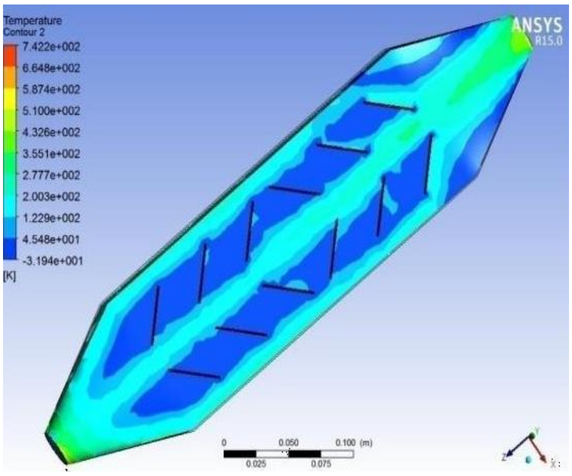

Fig 17: Temperature Contour of Inclined Shell

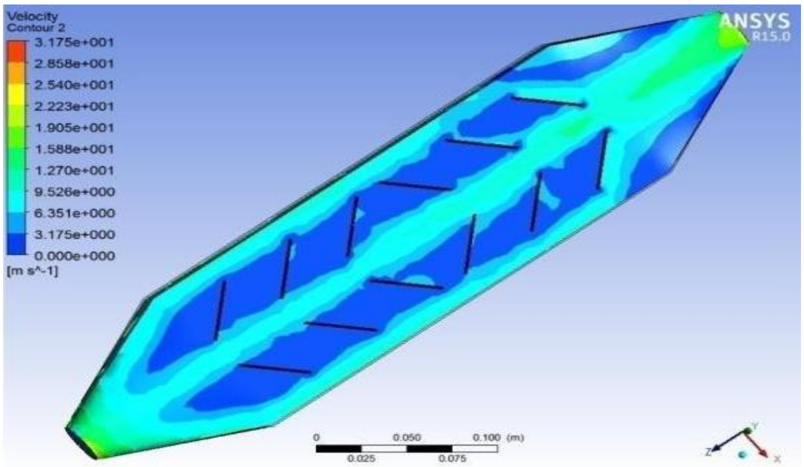

Fig 18: Velocity Contour of Inclined Shell

Parallel Plates

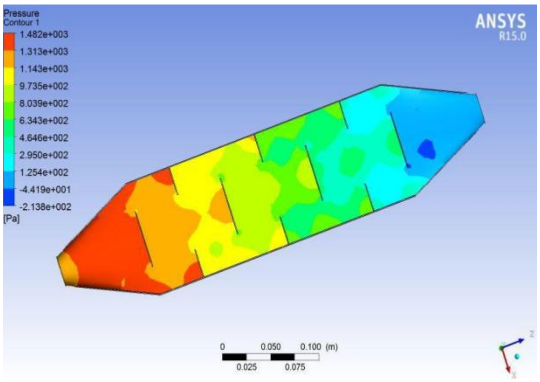

Fig 19: Pressure Contour of parallel Plate

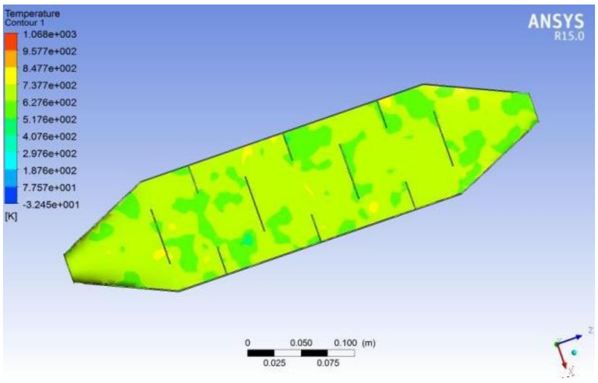

Fig 20: Temperature Contour of parallel Plate

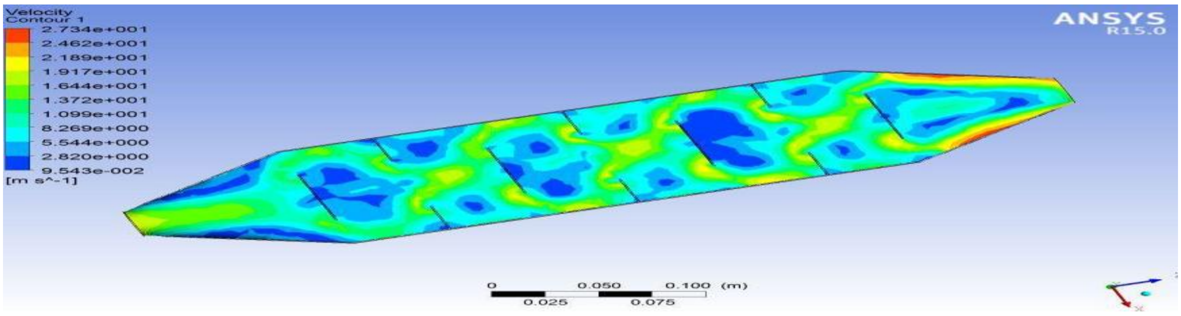

Fig 21: Velocity Contour of parallel Plate

Serial Plate

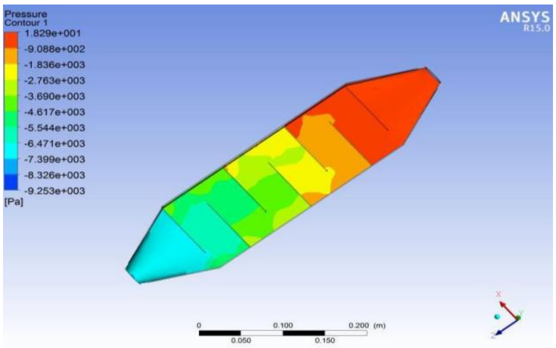

Fig 22: Pressure Contour of Serial Plate

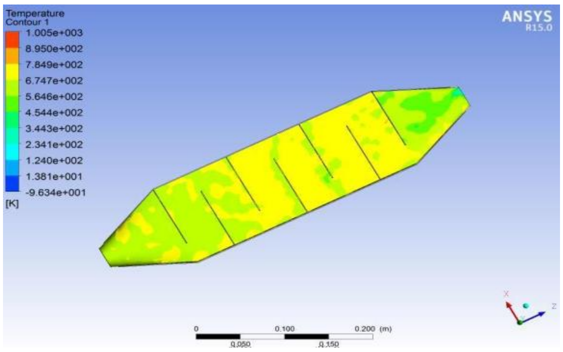

Fig 23: Temperature Contour of Serial Plate

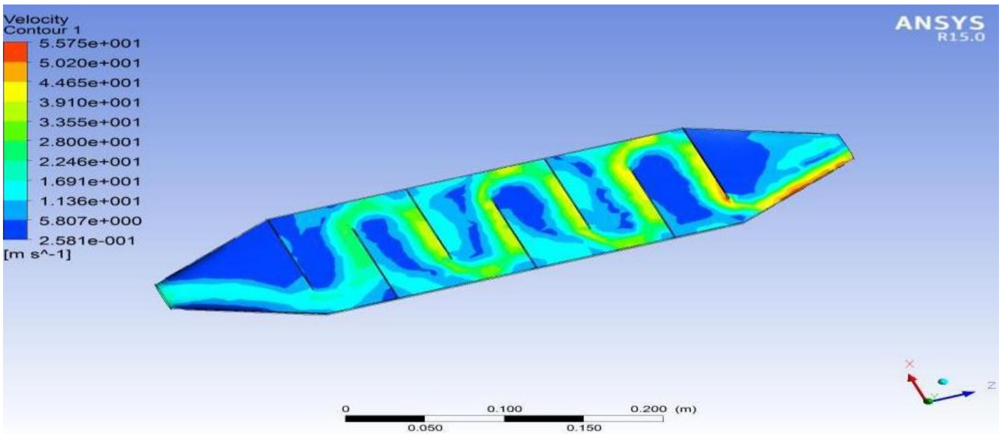

Fig 24: Velocity Contour of Serial Plate

Result For The Steel (Aisi4140 Grade) Structure

Maximum heat transfer occurs for structure with series of baffles because of the high pressure drop and the heat transferred is **90.389kw** and the pressure drop occurred is **6.35Kpa**.

Table 5: Results for Steel (AISI4140 GRADE)

Heat Exchanger Structure	Amount of Heat Extracted(w)
1.Empty Shell	-36894.03
2.Inclined Plates	-40876.73
3.Parallel Plates	-76811.69
4. Serial Plates	-90389.125

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CONCLUSIONS

1. Design and analysis were carried out for 4 exhaust heat exchangers to simulate the pressure, temperature field and the velocity field.
2. The heat exchange process in heat exchangers can be described by the principle of conduction, convection, radiation and evaporation or condensation
3. Therefore, the thermal designing of heat exchangers can be based on the knowledge of shape, size, material and type of heat exchanger.
4. A comprehension treatment of heat exchanger design would involve many factors besides the heat transfer analysis like size, weight ,structural strength, pressure drop and cost ,which beyond our scope .
5. In this we shall briefly deal with thermal analysis, simulation (mathematical modeling) and cost optimization of the more common types of heat exchangers

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