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Experimental and Numerical Delving Of Full Spiral Shell and Tube EGR Cooler

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Abstract: ***Exhaust gas recirculation (EGR) coolers can profoundly reduce hazardous NO_x emissions from Diesel engines. In this project flow and heat transfer characteristics of Full spiral shell and tube EGR cooler is investigated experimentally and numerically using CFD (ANSYS FLUENT V16.4) software. Geometrical parameters of modification of spiral corrugated tubes include diameters (inside and outside), effective length, thickness, Pitch, number of revolutions were made by constructing 5 models of EGR coolers with A-7 tubes, B-9 tubes, C-11 tubes, D-13 tubes and E-15 tubes using ANSYS FLUENT. Model D with 13 tubes is found to be efficient and economical. Using spiral corrugated tubes shown improvement in Heat transfer effectiveness and heat transfer coefficient experimentally and numerically for 13 tubes EGR Cooler. Also almost 22% increase in effectiveness is observed using spiral corrugated tubes instead of plain tubes. Both experimental and numerical results are obtained and are compared. BS-VI is a significant advancements with regard to NO_x limits having 0.06 gm/km. EGR cooler with spiral corrugated tubes can help in reducing NO_x limits to great extent.***

Keywords : EGR Cooler, Heat transfer effectiveness, Heat transfer coefficient, CFD Fluent, Diesel Engine, Full Spiral corrugated tubes.

I. INTRODUCTION

The use of diesel engines in transportation sector has made the availability of things very easy. But it has made to think over environmental issues. Today diesel engines emit large pollutants in the atmosphere. Most emitted pollutant from diesel engine is NO_x. NO_x in the diesel engine is formed at maximum temperature of combustion. So it becomes necessary to reduce the maximum temperature of combustion in diesel engine. One of the way to reduce the maximum temperature of combustion is by cooling the recirculating exhaust gases. The device which does this work is known as EGR cooler. In EGR cooler we can cool the exhaust gases upto 750^0C and recirculate in engine to reduce the temperature of combustion. By this process we can significantly reduce NO_x pollutant from diesel engines. S.S. Hoseini, G. Nakadi, B. Ghobadian simulated three types of EGR coolers. Plain type, semi-spiral type and full spiral type with 6 tubes and semi-spiral type was found with more efficient.

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So Semi-spiral type was considered to manufacture.[1] Nasser Ghassembaglou, Leila Totka man use spiral corrugated tubes for EGR cooler to increase the efficiency of EGR cooler. Also effects of pressure drop was reduced. They also found that reducing pitch and depth of spiral of corrugated tubes has effect on heat transfer and pressure drop.[2]

Riad HADJAB, Mahfoud KADJA created four models and simulated on ANSYS fluent. They used rectangular finned tubes, spiral finned tubes and dimpled tubes. Dimpled tube type EGR cooler was found to be most effective.[3]

Ibrahim H. Shah, Pawan Detwal Created different models. Model-1 is simple shell and tube type and simulates its result on ANSYS by fluent 16.0 (Academic) solver. Model-2 was replaced simple tubes by internally rectangular finned type circular tube and increased effectiveness of the same cooler. And in the model-3, they replaced the plane tube in same model by spiral (rectangular cross-section) finned tube, and the Model-4, we replace simple tubes by Dimpled type tubes. So the comparisons were made between shell & finned tube EGR cooler and shell & Dimpled tube type EGR cooler. And predicted the NOx emission for different EGR rate for most effective Model i.e. Model-4 (Dimpled-tube).[3]

Nasser Ghassembaglou, Armin Rahmatfam, Faramarz Ranjbar found that use of spiral corrugated tubes can increase effectiveness upto 10%.[4]

Ibrahim Hussain Shah, Bhupendra Singh performed simulation analysis on three types of models model-a, model-b and model-c. Results were shown that finned tubes were found to be most effective.[7]

Siddesh C. Karanje, Dr. S.S. Bhusnoor simulated EGR cooler on basis of temperature distribution and pressure distribution. They reduced the temperature of EGR cooler almost 400^0C.[13]

EGR COOLER NUMERICAL ANALYSIS

A. Geometric Model

In this study three dimensional geometry of EGR cooler is developed by ANSYS GEOMETRY which is used in the analysis. Model – D is a complete assembly of EGR Cooler (shell and tube type- 13 tubes). Here the main objective to use ANSYS Fluent for simulation is to calculate the Effectiveness and heat transfer coefficient.. ANSYS gives us temperature profile of the model we can calculate the effectiveness of that cooler and compare all the models according to their effectiveness.

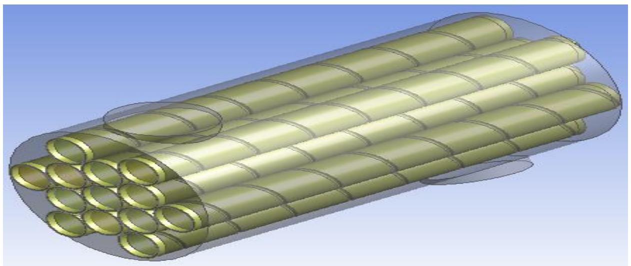


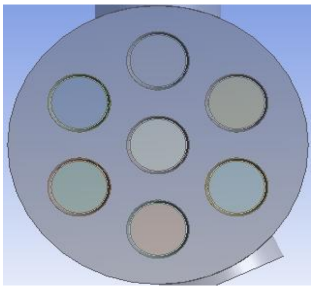
Fig. 1. Model – D EGR cooler (13 tubes)

Specifications of the Geometry of EGR cooler is given below:-

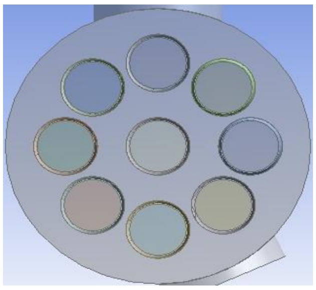
Table- I: Specifications Of Geometry Of Egr Cooler

Full Spiral EGR Cooler	Dimensions and description	Material
Tube Parameters		Stainless Steel
Number	13	
$^{d_o}/_{d_i}$(mm)	9/8	----
Pitch (mm)	12	
Effective Length (mm)	94	
Shell Parameters		Stainless Steel
$^{D_o}/_{D_i}$(mm)	45/43	
Thickness (mm)	1	

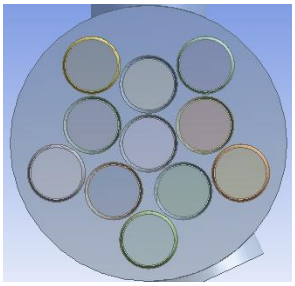
Below Fig.2 shows models of EGR cooler with different tubes. Model-A (7 tubes), Model B (9 tubes), Model C (11 tubes), Model D (13 tubes), Model E (15 tubes). Also below table 1 shows the geometrical parameters of tubes considered for maximum reduction of temperature of exhaust gases from inlet of the tubes to outlet.



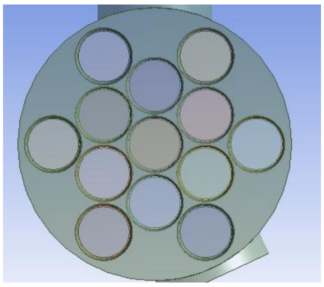
Model-A (7 tubes)



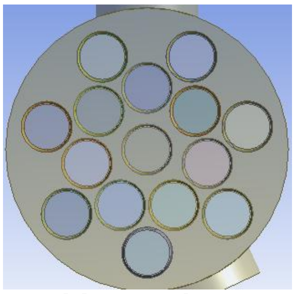
Model-B (9 tubes)



Model-C (11 tubes)



Model-D (13 tubes)



Model-E (15 tubes)

Fig. 2. Number of tubes and their arrangement

B. Grid Generation

Grid generation or meshing is a very critical part within the CFD simulation process as it not only dictates the simulation time but also the accuracy of results of the study. Generating a very coarse and poor quality mesh/ grid often leads to non-physical or highly inaccurate simulation results though may be solved on a very powerful solver. Hence the grid generation skills, capability and its exposure are of equal importance as much as that of the solver operations. Grid generation is a challenging operation during which the engineer has to maintain accurate mesh density as well as ensure that the mesh count is not impractically high. To achieve these skills there are various aspects a fresher CFD engineer has to understand and get familiar with.

A view of the mesh structure considered in this study for a part of the model is shown in Fig. 3. and Fig. 4. The statistics of both the mesh is given in the Table II.

Table- II: Statistics of Mesh of Shell and Tubes

	Mesh of the Shell	Mesh of Tubes
Nodes	1754048	5164892
Elements	185480	5289744
Mesh Metric	Aspect Ratio	
Min	1.0265	1.0269
Max	50.857	60.144
Average	5.0747	6.545
Standard Deviation	5.1712	5.425
Mesh metric	Skewness	
Min	0.021	0.045
Max	0.9121	0.8445
Average	**0.821**	**0.734**

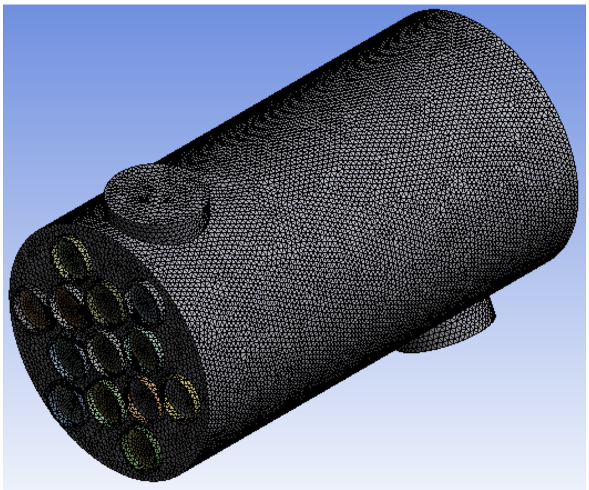
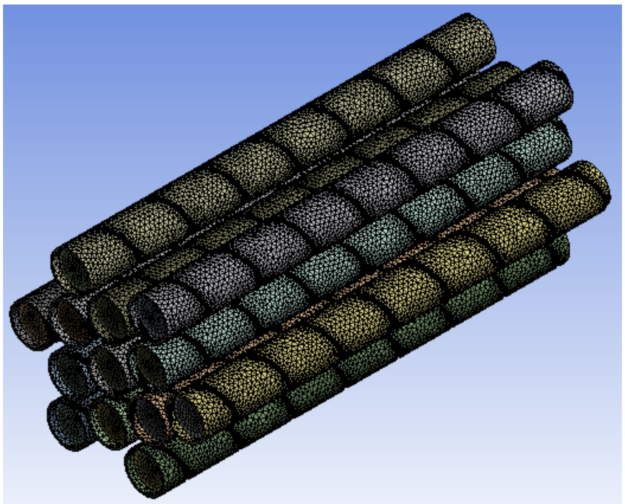


Fig. 3. Mesh overview of Shell



C. Boundry Conditions

Between shell and tube interfaces coupled boundary condition was used. Reynolds number was kept constant for all
different number of tubes. The boundry conditions for tube side and shell side for simulation is shown in table III and Fig. 5 below.

Table- III: Boundry Conditions of EGR Cooler

Boundary Location	Boundary Type	Description
Tube Side Inlet	Mass Flow Inlet (Velocity is normal to area)	Mass Flow Inlet = Constant Temperature = 140 °C
Shell Side Inlet	Mass Flow Inlet (Velocity is normal to area)	Mass Flow Inlet = Constant Temperature = 28°C
Tube Side Outlet	Pressure Outlet	Pressure = 0 *Pa*
Shell Side Outlet	Pressure Outlet	Pressure = 0 *Pa*

Reynolds number was kept constant for all different number of tubes.

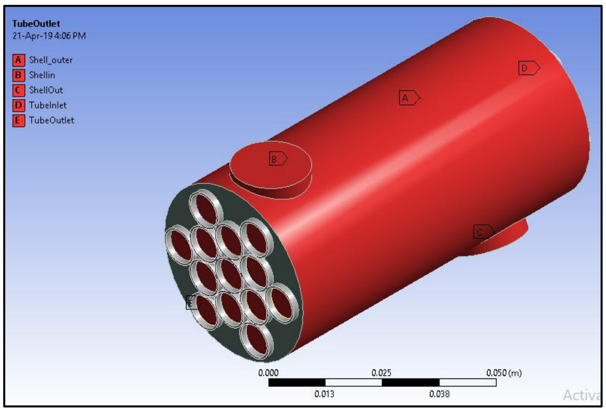


Fig. 5. EGR Cooler with Boundry Conditions

D. Temperature Analysis

The temperature contour of the models shows the variation of temperature along the tube. Red colour shows the inlet temperature of the exhaust gases as gas move forward heat is extracted by the coolant water and temperature of gases is reduced and the temperature of coolant is increased because it takes heat from exhaust gases. The variation os colour from red to the blue shows the decrease in temperature of exhaust gases as the coolant flows over the tubes which is indicated by blue colour. The temperature at any point can be measured in kelvins by matching the colour at that point to tha colour of scale. Temperature Contour for tubes from 7 to 15 is shown in figures from 6 to 10.

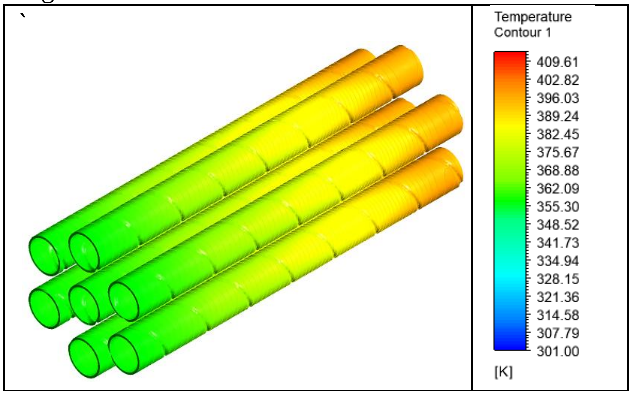


Fig. 6. Temperature contour of 7 tubes

Above Fig. 6 shows the temperature contour of 7 tubes along the tube length. Inlet temperature of exhaust gas is 390.15 K which is indicated by light orange colour. This temperature is reduced upto 370.12 K as shown by green colour. So the temperature change shown by numerical analysis was 19.95K.

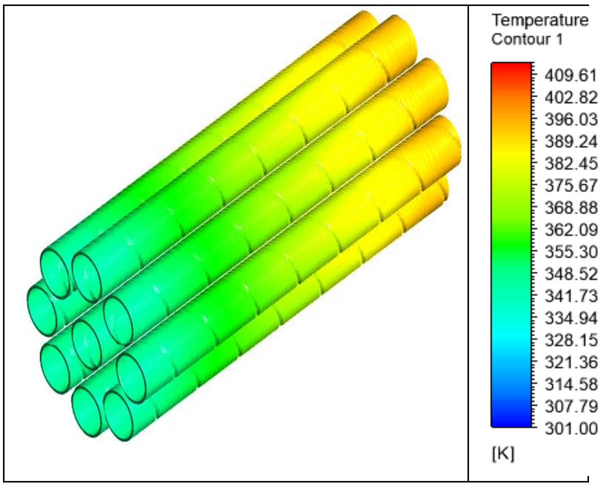


Fig. 7. Temperature contour of 9 tubes

Above Fig. 7 shows the temperature contour of 9 tubes along the tube length.At Inlet the temperature of exhaust gas is about 380.50 K which is indicated by light orange colour. This temperature is reduced upto 354.76 K as shown by green munsen colour. So the temperature change shown by numerical analysis was 25.74 K.. Below Fig. 8 shows the temperature contour of 11 tubes along the tube length. In this contour hot exhaust enter of about 381.21K temperature inside the tubes and as they move ahead the temperature of gases found to be decreasing about 337.54 K can be read out by the temperature scale on contour. So the temperature change shown by numerical analysis was about 43.67 K.

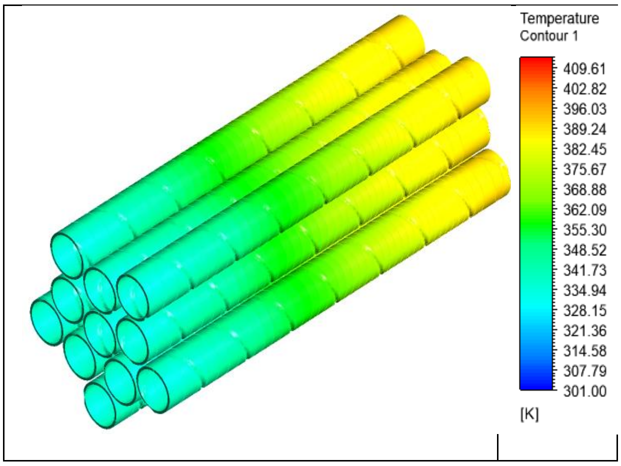


Fig. 8. Temperature contour of 11 tubes

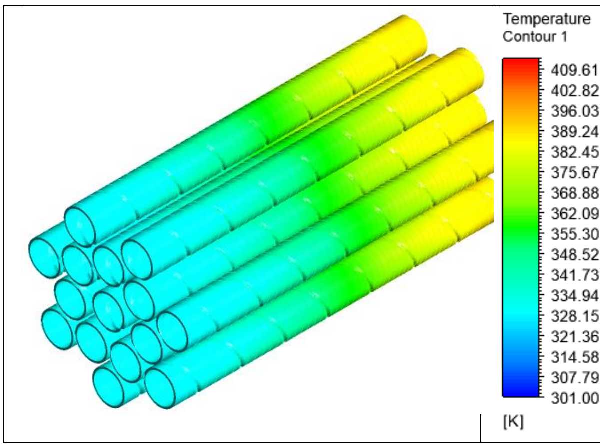


Fig. 9. Temperature contour of 13 tubes

Above Fig. 9 shows the temperature contour of 13 tubes. This contour shows the variation of temperature along the length of the tube. In this contour hot exhaust enter at about 383.78 K indicated by yellow colour and can be matched by temperature contour scale. As the gases move along the tube heat is extracted bt the coolant flowing over the tubes. As a result temperature of exhaust gases is reduced and the temperature of coolant is increased as it takes heat from exhaust gases. Exit temperature of exhaust gases in the tubes is indicated by sky blue colour which can be matched by temperature contour scale. The temperature at exit of the tubes is found to be about 331.27K. difference in temperature of inlet and exit of the tubes is about 52.51K. So this temperature drop exhaust gases in 13 tubes is more as compared to 7, 9 and 11 tubes.

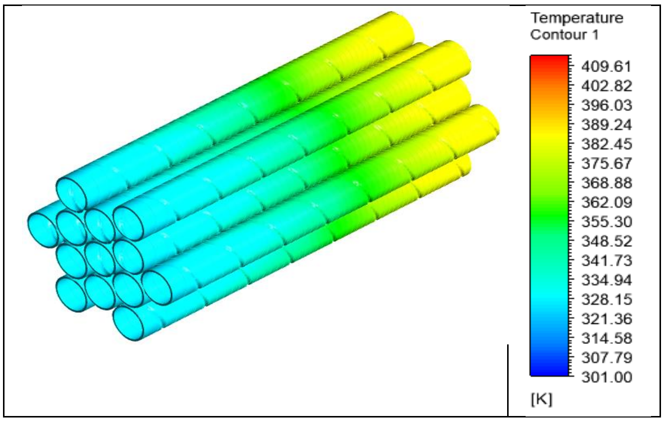


Fig. 10. Temperature contour of 15 tubes

Above Fig. 10 shows the temperature contour of 15 tubes. The inlet temperature of exhaust gas is indicated by yellow colour of about 383.56K and the exit temperature of gases coming out of the tubes is about 328.15K as shown by sky blue colour which is few degrees less than the temperature difference of inlet and exit of exhaust gases for 13 tubes. So 13 tube model is considered for experimentation of the work

II. EXPERIMENTAL WORK

Fig. 11 shows the EGR cooler and Fig. 12 shows the complete project model of EGR cooler. Here pipes of ½" was connected to inlet and outlet of EGR cooler. An expander of ¾" is connected to to a bend pipe of ¾". Also 1½" expander was connected to ¾" pipe to connect to exhaust system of vehicle.

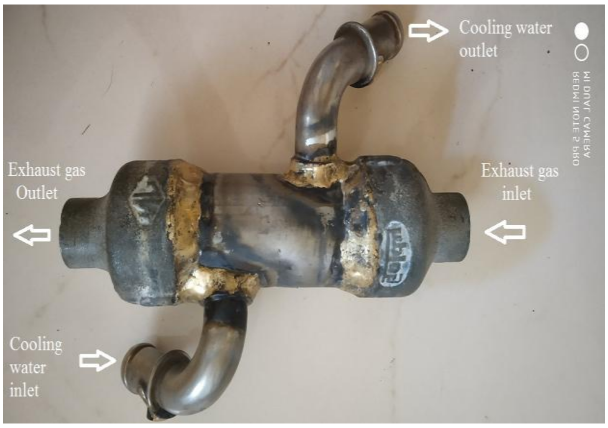


Fig.11. Shell and tube EGR Cooler

A. Test Engine

The main aim of the project was to increase the performance of EGR cooler replaing plain tubes with spiral corrugated tubes. So necessary changes were made by changing parameters like diameter, pitch, thickness, length and number of tubes for the improving effectiveness of the EGR cooler both experimentally and numerically. The EGR Cooler setup was connected to Maruti Suzuki Ertiga ZDI version whose specification are given below in table IV:-

Table- IV: Specifications Of Engine of Ertiga ZDI

Parameters	Specifications
Type	Inline 4cyliner, four stroke
Displacement	1248 cc
Fuel type	Diesel
Max Power (bhp @rpm)	89bhp @ 4000rpm
Max Torque (Nm@rpm)	200 Nm @ 1750 rpm
Bore (mm) x Stroke (mm)	69.6 mm x 82mm

B. Experimental Set-up and Procedure

The arrangement of the Test set-up is shown in Fig. 12. Four K-Type thermocouples (SS) with an -25°C to 600 °C temperature range were used to measure the temperature of the EGR and cooling liquid. The temperature data of the thermocouple were recorded by 12 channel temperature indicator of JP Techno instruments. To measure the flow rate of cooling liquid (water) measuring flask was used. The cooling water flow rate was kept constant as for to fill 1 litre of water and time required was measured. The observations were taken @ 2.00 PM afternoon.

Fig. 12. EGR Cooler test setup

The Vehicle was run at three different speeds and temperatures of EGR cooler and cooling water were recorded by digital temperature indicator. Since the performance of EGR depends on engine rpm, three readings were taken whose observations are below:-

Table- V: Observation table of Experimental set-up

Sr. No.	RPM (rev/ min)	T_{hi} (°C)	T_{ho} (°C)	T_{ci} (°C)	T_{co} (°C)	T (sec)	m_{ex} (kg /hr)
1	1000	76	50	31	34	401	3.1
2	2000	96	57	29	32	401	6.2
3	3000	122	88	38	66	401	9.8

C. Experimental Calculations

Inner Diameter of Shell = $D_i = 43\ mm$
Outer Diameter of Shell = $D_o = 45\ mm$
Water is selected as shell fluid

Heat Balance for 3000 RPM

- Heat transfer from exhaust gases

$$Q_{ex} = m_{ex} \times C_{pex} \times \Delta T_{ex} \quad (1)$$

Specific heat of exhaust gases C_{pex} = 1.007 KJ/KgK

$$\therefore\ Q_{ex} = \frac{9.8}{3600} \times 1.007 \times (122 - 88)$$

$$Q_{ex} = 93.20\ Watts$$

- Heat transfer from Cooling water

$$Q_{cw} = m_{cw} \times C_{cw} \times \Delta T_{cw} \quad (2)$$

$$Q_{cw} = \frac{1}{401} \times 4.179 \times (66 - 38)$$

$$\therefore\ Q_{cw} = 255.58\ Watts$$

The actual heat transfer of EGR cooling system can be considered as the average heat transfer of the coolant side and recirculation side which is given by,

$$Q = \frac{Q_{ex} + Q_{cw}}{2} \quad (3)$$

$$= \frac{93.20+255.58}{2}$$

$$= 174.415\ \text{Watts}$$

- Heat transfer effectiveness

The amount of heat transfer effectiveness is given by,

$$\varepsilon = \frac{Q}{Q_{max}} \quad (4)$$

Where,

$$Q_{max} = C_{min}\,(T_{hi} - T_{ci}) \quad (5)$$

C_{min} = Minimum heat capacity rate
C_{max} = Maximum heat capacity rate

$$C_{min} = m_{ex} C_{pex} \quad (6)$$

$$C_{min} = \frac{9.8}{3600} \times 1.007$$

$$= 2.74127 \times 10^{-3}\ \text{KJ/K}$$

$$C_{max} = m_{cw} C_{pcw} \quad (7)$$

$$C_{max} = \frac{1}{401} \times 1.007$$

$$= 0.0104\ \text{KJ/K}$$

$$Q_{max} = 2.74127 \times 10^{-3} (122 - 38)$$

$$= 230.26\ \text{Watts}$$

$$\therefore\ \varepsilon = \frac{174.415}{230.26}$$

$$\therefore\ \varepsilon = 75.74\ \%$$

- Log mean temperature difference for Shell and tube EGR cooler as counter flow heat exchanger

Log mean temperature difference for EGR cooler as a counter flow heat exchanger is given by ,

$$\Delta T_m = \frac{\Delta T_1 - \Delta T_2}{\ln\frac{\Delta T_1}{\Delta T_2}} \quad (8)$$

$$\Delta T_1 = T_{hi} - T_{co} = 122 - 66 = 56\ ℃$$

$$\Delta T_2 = T_{ho} - T_{ci} = 88 - 38 = 50\ ℃$$

$$\therefore\ \Delta T_m = \frac{56 - 50}{\ln\frac{56}{50}} = 52.94$$

- Overall heat transfer coefficient

To determine Overall heat transfer coefficient we have equation,

$$A_o = \frac{Q_{avg}}{U_o\, \Delta T_m} \quad (9)$$

Where,

$A_o = Outside\ heat\ transfer\ surface\ area\ (m^2)$
$\Delta T_m = Log\ mean\ temperature\ difference\ for\ counter\ flow\ heat\ exchanger$
$U_o = Overall\ heat\ transfer\ coefficient\ W/m^2K$

$$Also,\ A_o = N_t\ \pi\ d_o\ L \quad (10)$$

Where,

$N_t = Number\ of\ tubes$
$d_o = outer\ diameter\ of\ tube\ (mm)$
$L = Length\ of\ the\ tube\ (mm)$

$$\therefore A_o = 13 \times \pi \times 0.009 \times 0.092$$

$$\therefore A_o = 0.03381\ m^2$$

Substituting in above equation,

$$0.03381 = \frac{174.415}{U_o \times 52.94}$$

$$U_o = 97.212\ W/m^2K$$

Therefore overall heat transfer coefficient for shell and tube EGR cooler is 97.212 W/m^2K.

- Heat transfer coefficient of water side:-

Since the heat exchanger is designed for single tube and single pass . LMTD for counter flow is true temperature difference. It doesn't require any correctio=n factors.
The shell side or bundle cross flow area a_{s-}
Flow area $a_s = a_{shell} - a_{tubes}$

$$a_s = \frac{\pi}{4} D_i^2 - \frac{\pi}{4} d_i^2 \times N_t \quad (11)$$

$$\therefore a_s = \frac{\pi}{4} \times (43 \times 10^{-3})^2 - \frac{\pi}{4} \times (8 \times 10^{-3})^2 \times 13$$

$$= 1.4522 \times 10^{-3} - 6.5345 \times 10^{-4}$$

$$= 7.9875 \times 10^{-4}\ m^2$$

$$\text{Mass velocity } G_s = \frac{m_w}{a_s} \quad (12)$$

$$= \frac{\frac{1}{401} \times 3600}{7.9875 \times 10^{-4}}$$

$$= 11239.50 \frac{kg}{hr\ m^2}$$

$$\text{Reynolds Number } R_e = \frac{D_e \times G_s}{\mu} \quad (13)$$

$$\text{Equivalent diameter } D_e = \frac{4 \times a_s}{wetted\ perimeter}$$

$$= \frac{4 \times P_t^2 - \pi \times \frac{d_o^2}{4}}{\pi \times d_o} \quad (14)$$

$$= 0.01189\ \text{m}$$

$$R_e = \frac{0.01189 \times 11239.50}{0.52994 \times 10^{-2} \times 3600}$$

$$= 70.04$$

As Per Reynolds Number obtained
$J_H = 4.9$

At $T_{avg} = 52°C$

Thermal conductivity of water at average temperature,
$k = 0.6305\ W/mK$

Heat transfer coefficient of shell side,

$$h_o = J_H \left(\frac{k}{D_e}\right) \left(\frac{\mu\ C_{cw}}{k}\right)^{0.33} \times \varphi \quad (16)$$

$$h_o = 4.9 \left(\frac{0.6305}{0.1189}\right) \left(\frac{0.52994 \times 10^{-3} \times 4.179}{0.6305}\right)^{0.33}$$

$$= 40.24\ W/m^2K$$

- Nussult Number for Shell side

$$N_u = h_o \frac{D_e}{k} \quad (17)$$

$$= 40.24 \frac{0.01189}{0.6305}$$

$$= 7.5884$$

- Heat transfer coefficient of tube side:-

Flow area from single tube,

$$a_t = \frac{\pi}{4} \times d_i^2 \quad (18)$$

$$= \frac{\pi}{4} \times (8 \times 10^{-3})^2$$

$$= 5.0265 \times 10^{-5}\ m^2$$

Area for 13 tubes,

$$A_t = \frac{a_t \times N_t}{n} \quad (19)$$

$$A_t = \frac{5.0265 \times 10^{-5} \times 13}{1}$$

$$= 6.5345 \times 10^{-4}\ m^2$$

$$\text{Mass velocity } G_t = \frac{m_{ex}}{A_t} \quad (20)$$

$$G_t = \frac{9.8}{6.5345 \times 10^{-4}}$$

$$= 14997.2 \frac{kg}{hr\ m^2}$$

Reynolds number for tube side fluid or exhaust gases,

$$R_e = \frac{D_i \times G_t}{\mu} \quad (21)$$

$\mu\ at\ T_{avg} = 52\ °C\ is\ 0.043\ Cp$

$$\therefore\ R_e = \frac{8\ \times 10^{-3} \times 14997.2}{0.043\ \times 10^{-3}}$$

$$= 774.015$$

Heat transfer coefficient

$$h_i = h_o = J_H \left(\frac{k}{d_i}\right)\left(\frac{\mu\, C_{ex}}{k}\right)^{0.33} \times \varphi \qquad (22)$$

$$= 6\left(\frac{0.04245}{8\times10^{-3}}\right)\left(\frac{0.043\times10^{-3}\times1.005}{0.04245}\right)^{0.33}$$

$$= 26\,.68\ W/m^2K$$

$$h_{io} = h_i\left(\frac{d_i}{d_o}\right) \qquad (23)$$

$$= 26.68\ \times \left(\frac{8}{9}\right)$$

$$= 23.71\ W/m^2K$$

- Nussult Number for tube side

$$N_u = 3.66 + \frac{0.668\frac{d_i}{L}}{1+0.04\left[\left(\frac{d_i}{L}\right) R_e P_r\right]^{\frac{2}{3}}} R_e P_r \qquad (24)$$

$$N_u = 3.66 + \frac{0.668\frac{8}{92}}{1+0.04\left[\left(\frac{8}{92}\right) 774.015\times1.013\right]^{\frac{2}{3}}} 774.015\ \times\ 1.013$$

$$= 49.94$$

III. RESULT AND DISCUSSION

1) Heat transfer effectiveness comparison with Number of tubes

Fig. 13 shows Effectiveness of each tubes with their respective number. Heat transfer effectiveness goes on increasing with increasing number of tubes due to increasing number of tubes more cooling of exhaust gases is done.

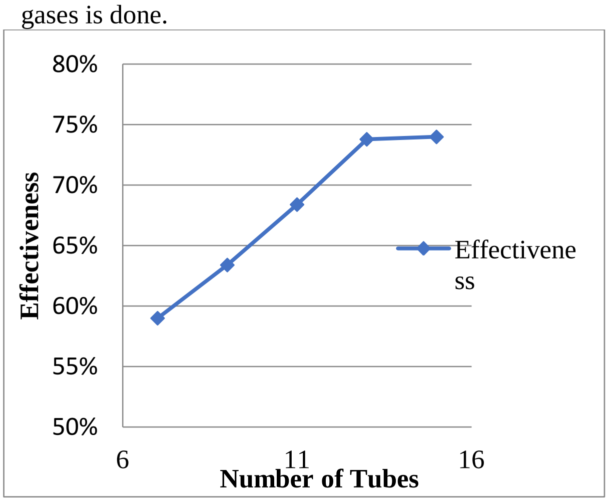


Fig. 13. Effectiveness versus Number of tubes

2) Overall heat transfer coefficient versus number of tubes

Fig. 14 shows overall heat transfer coefficient versus number of tubes. Here overall heat transfer coefficient increases with increasing number of tubes. Due to increasing number of tubes difference in temperature between inlet and outlet is more which increases in average heat transfer and thus the overall heat transfer coefficient.

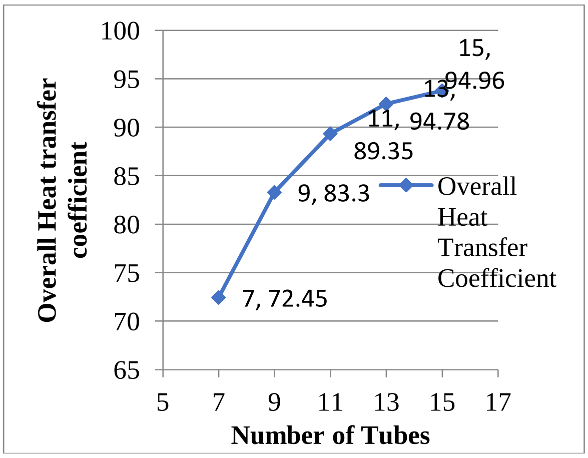


Fig. 14. Overall heat transfer coeff. for different number of tubes.

Below table VI shows numerical results of effectiveness, overall heat transfer coefficient with their respective number of tubes.

Table- VI: Numerical results of Model A to Model E

Sr. No.	No. of tubes	Average temp. at outlet of EGR cooler (K)	Effectiv-eness (%)	OHTC (W/m^2K)	Nu
1	7	367.08	59	72.45	39.31
2	9	372.008	63	83.3	43.17
3	11	377.608	68	89.35	52.98
4	13	383.656	74	94.78	56.18
5	15	383.88	74	94.96	57.45

3) Nusselt Number versus number of tubes

According to the Fig. 15 plotted it is observed that at the same Reynolds number, the predicted tube-side Nusselt number for 13 tube model is more than the other systems . For the full spiral corrugated tube cooling system, the numerical results obtained are 2–3% higher than the experimental results. The results show that the geometric structure of the Full-spiral corrugated tube cooling system is better than the other models and plain tube cooling system. The result is quite consistent with the theory of heat transfer.

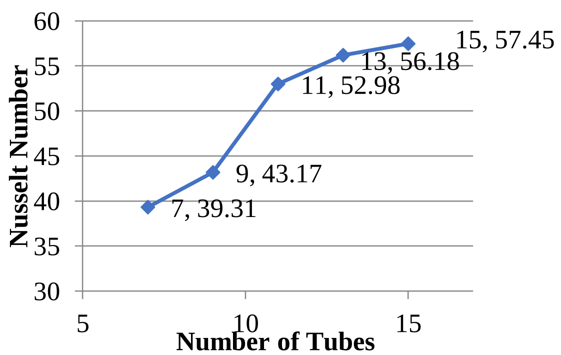


Fig. 15. Nussult Number versus Number of tubes

Below table VII shows Comparison of Experimental and numerical results. So the error obtained was 2.5% for overall heat transfer coefficient and 2.2 % for effectiveness.

Table- VII: Experimental and Numerical results comparison of EGR Cooler

Parameter	Experimental	Numerical (CFD)	% Error
OHTC (W/m^2K)	97.212	94.78	2.5
Effectiveness (%)	75.74	74	2.2

Also in table VIII, a comparison is made between the heat transfer effectiveness and heat transfer coefficient of shell and tube EGR cooler with plain tubes and Spiral corrugated tubes. Heat transfer effectiveness of Spiral corrugated tubes is found to be more than plain tubes.

Table- VIII: Experimental and Numerical results comparison of EGR Cooler

Sr. No.	No. of tubes	Tube type	Effectiv-eness (%)	OHTC (W/m^2K)
1	13	Plain	45.9	60.50
2	13	Spiral Corrugated	74	94.78

IV. CONCLUSION

In this project the heat transfer and fluid flow characteristics of Full spiral corrugated tubes of EGR cooler is investigated experimentally and numerically. 5 models Model A having 7- tubes , Model B having 9- tubes , Model C having 11-tubes , Model D having 13- tubes, Model E having 15-tubes of EGR cooler of spiral corrugated tubes with variations in geometrical parameters were analysed numerically using ANSYS FLUENT V16.4 software. Model-D is found to be most efficient and cost effective as it reduces size cost of EGR cooler as compared to plain tubes and we preferred this for experimentation. Results shows that,

1. Model-D having 13 tubes shown more temperature difference between inlet and outlet of the tubes of EGR cooler with fluid flow being constant.
2. Using spiral corrugated tubes shown increase in 22 % effectiveness than using plain tubes also increase in heat transfer coefficient is found.
3. By increasing number of tubes and changing geometrical parameters of spiral corrugated tubes we can reduce the temperature of exhaust gases upto 750°C.

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