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# Numerical Investigation of EGR Cooler Using RNG Turbulence Model

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**ABSTRACT:** The combustion in diesel engines leads to excessive generation of NO<sub>x</sub>, water vapor and CO<sub>2</sub>. The NO<sub>x</sub> is harmful pollutant and Euro 6 norms limits its emission to 0.18g/km to 0.08 g/km. The reduction of NO<sub>x</sub> emission from diesel engine is possible with the use of Exhaust Gas Recirculation coolers (EGR). The current research investigates the effect of multiple exhaust gas inlet entry on cooling characteristics of EGR cooler using RNG k-epsilon turbulence model. The CFD analysis of EGR cooler is conducted using ANSYS 18.1 software and CAD model is developed in Creo design software. The temperature distribution, pressure drop is evaluated for all design types.

**KEYWORDS:** EGR Cooler, CFD, NO<sub>x</sub>Emission

## I. INTRODUCTION

The combustion in diesel engines leads to emission of toxic and nontoxic substances. The CO<sub>2</sub> and water vapor emission is not toxic while NO<sub>x</sub> emission along with sooth particles are hazardous for atmosphere and human body especially eyes and lungs. The high temperature of exhaust gases leads to higher emission and the temperature can be lowered using EGR system which recirculates the exhaust gases back to the engine to reduce NO<sub>x</sub> emissions. Now a days most of the heavy-duty vehicles are fitted with EGR coolers

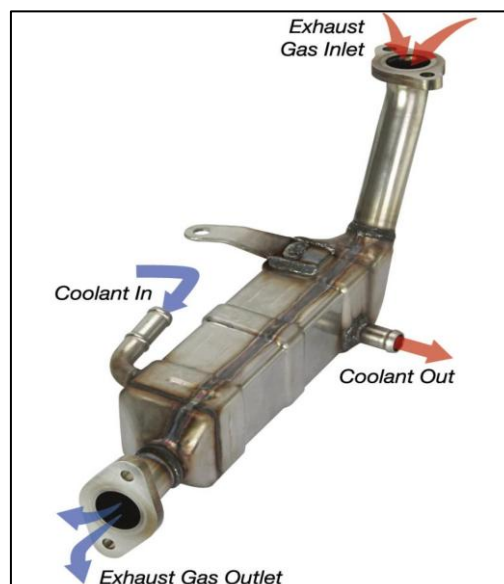


Figure 1: EGR cooler used in automobiles

## II. LITERATURE REVIEW

N.V. Deshpande, P.V. Walke et al., [1] conducted experimental investigation on four stroke diesel engine to determine the effect of EGR rate on emission characteristics and findings have verified the effect of EGR rate on emission and brake thermal efficiency.

A.K. Agrawal, S.K. Singh et al., [2] has also worked on air cooled IC engines and results have shown that increasing EGR rate results in lower NO<sub>x</sub> emissions.

D.T. Hountalas, G.C. Mavropoulos, et al., [3] investigated HDDI engines performance and effect of EGR rate. The CFD analysis was conducted using multizone combustion model. The results have shown that EGR rate affected the thermal, dilution and chemical of emission and particulates.

### III. PROPOSED WORK

The cooling capacity of EGR cooler is hugely restricted due to single inlet configuration of shell design. When EGR cooler fails to cool EGR gases to a desired level, it results in increase of NO<sub>x</sub> emissions thus causing pollution. As the previous designs were limited to single inlet configuration thereby limiting the cooling characteristics it necessitated the investigation of cooler using multiple inlet configurations. The current research investigates the effect of multiple fuel inlet configuration of EGR cooler using techniques of Computational Fluid Dynamics. The effect of multiple fuel inlet configuration on heat transfer and pressure drop is evaluated using RNG k-epsilon turbulence model.

### IV. METHODOLOGY

The numerical analysis of EGR cooler is conducted using techniques of Computational Fluid Dynamics. The CAD model of EGR cooler is developed in Creo design software and converted to .iges file. This CAD model is then imported in ANSYS design modeler where it is checked for errors and geometric clean up is performed. The CAD model of EGR cooler is shown in figure 2 and exploded view of EFR cooler is shown in figure 3 below.

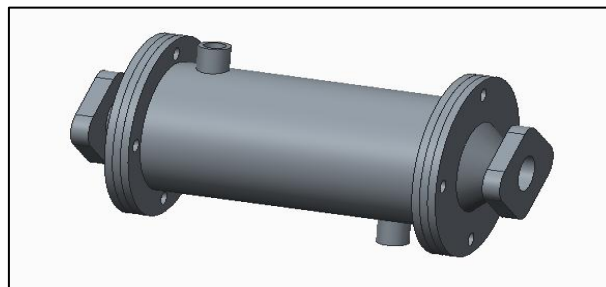


Figure 2: CAD model of EGR cooler

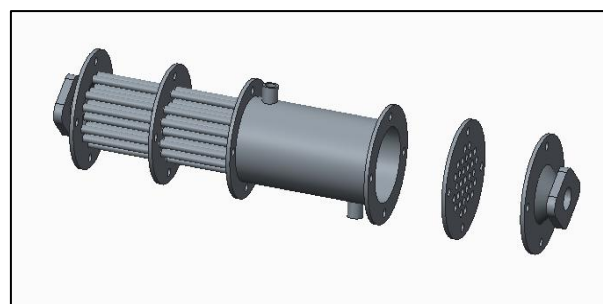


Figure 3: Exploded CAD model of EGR

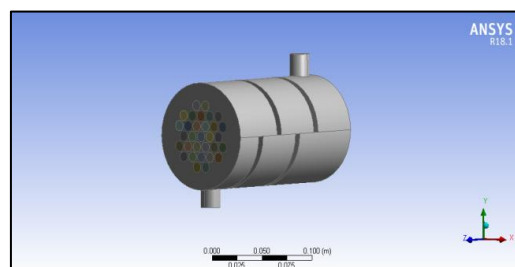


Figure 4 CAD model of EGR cooler

The CAD model of EGR cooler is imported in ANSYS design modeler and meshed using tetrahedral elements and fine sizing as shown in figure 5 below.

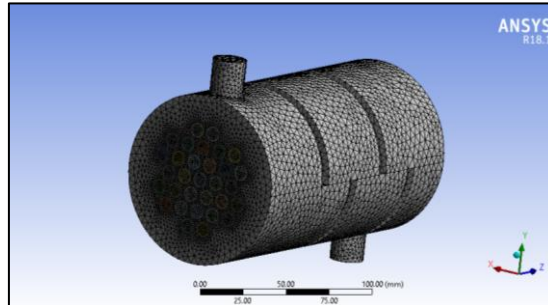


Figure 5: CAD model of EGR cooler

The number of nodes generated is 586278 and number of elements generated is 1525578. The computational domain is defined for each fluid (hot and cold). The hot fluid domain is of EGR gas and cold fluid domain is of coolant.

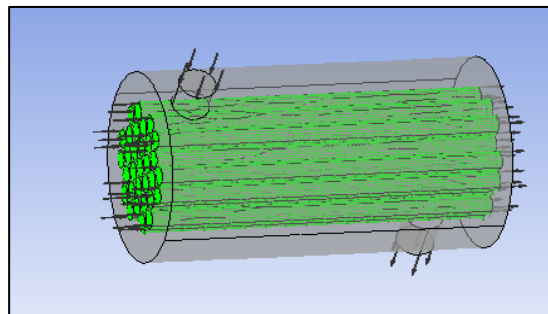


Figure 6: Loads and Boundary conditions

The simulation is run for different temperatures of EGR gas i.e. 692.92K, 862.85K, 961.05K, 1059.26K and using RNG k-epsilon turbulence model. The shell domain and tube domains are defined and inlet velocity of EGR gas is defined at 15.87m/s. The convergence criteria is set to RMS value of .00001 and maximum 200 iterations.

## V. RESULTS AND DISCUSSION

The CFD analysis is conducted on EGR cooler with different inlet design configurations and contour plots of temperature and pressure are generated. The velocity contour along sectional plane inside EGR cooler is shown in figure 7 below for 692.92K exhaust gas temperature. The velocity of coolant is maximum near inlet as shown by red color contour which reduces as coolant circulates inside shell and again increases on moving towards exit.

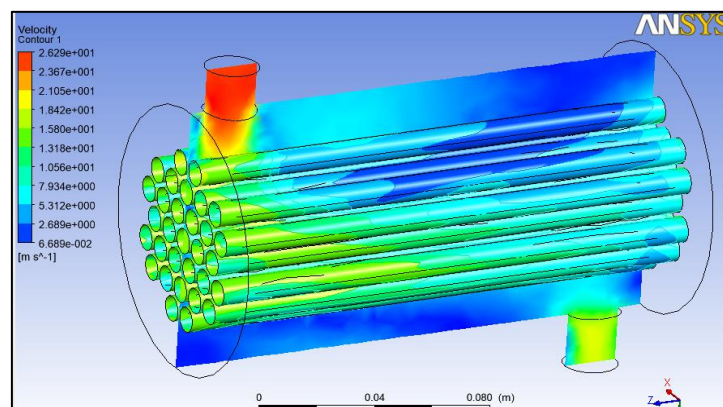


Figure 7: Velocity contour at 419.9°C temperature

The pressure value at EGR gas inlet is high with magnitude of 175Pa and reduces on moving towards right end of shell and further reduces on moving towards exit.

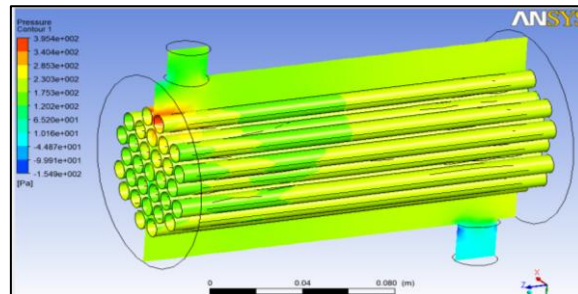


Figure 8: Pressure contour at 419.9°C temperature

The temperature plot across mid-section plane of EGR cooler is shown in figure 9 below. The high temperature of EGR gas is shown in red color near inlet and it decreases on moving towards outlet as shown in figure 9 below. The temperature of coolant is low near inlet and it increases on moving towards outlet. This is due to heat exchange between coolant and exhaust gas

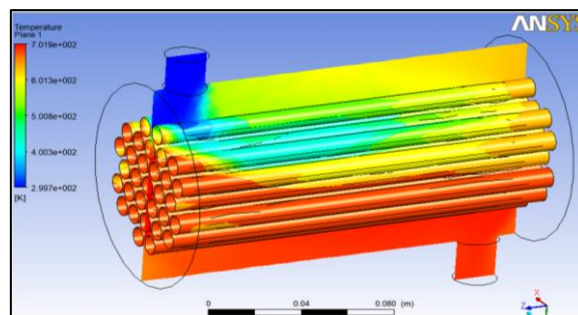


Figure 9: Temperature contour at 419.9°C temperature

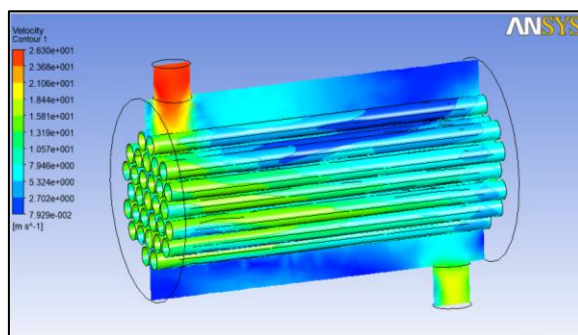


Figure 10: Velocity contour at 688°C temperature

The velocity contour along sectional plane inside EGR cooler is shown in figure 10 above for 688°C exhaust gas temperature. The velocity of coolant is maximum near inlet as shown by red color contour which reduces as coolant circulates inside shell and again increases on moving towards exit.

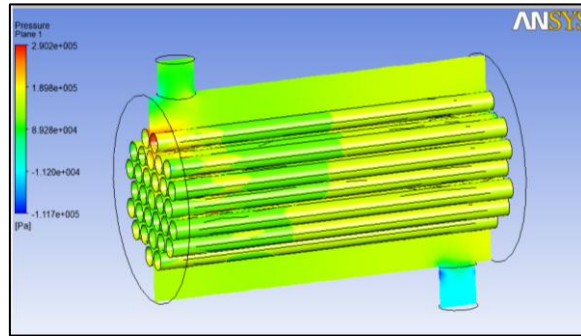


Figure 11: Pressure contour at 688<sup>0</sup>C temperature

The pressure value at EGR gas inlet is high and reduces on moving towards right end of shell and further reduces on moving towards exit. This is shown by green colored zone at inlet and light blue colored zone at outlet.

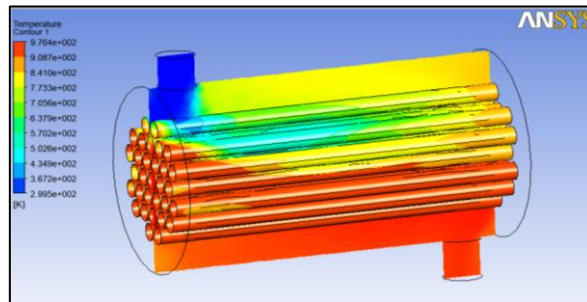


Figure 12: Temperature contour at 688<sup>0</sup>C temperature

The temperature plot across mid-section plane of EGR cooler is shown in figure 12 above. The high temperature of EGR gas is shown in red color near inlet and it decreases on moving towards outlet as shown in figure 9 below. The temperature of coolant is low near inlet as shown by dark blue color and it decreases on moving towards outlet. The

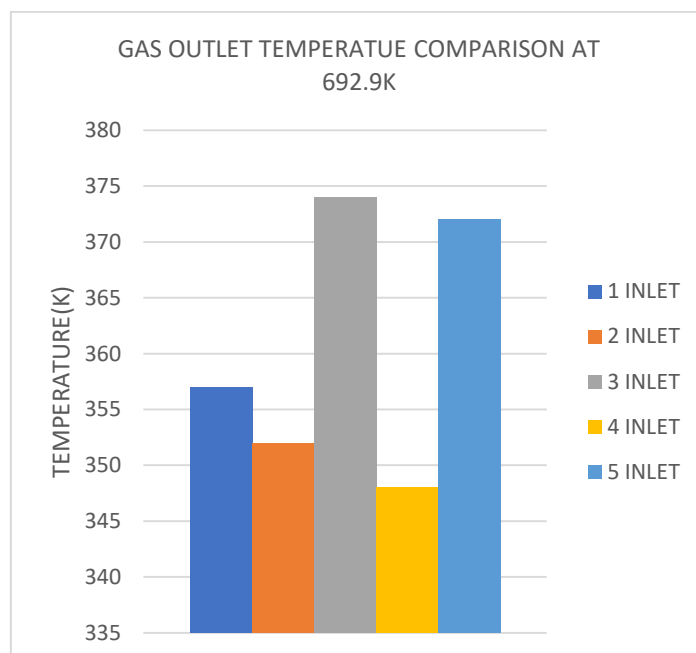


Figure 13: EGR gas outlet comparison at 692.9K

As can be observed from figure 13 above, the minimum temperature is for 4 gas inlet configuration and maximum is for 3 inlet configurations. The proper fluid circulation enables to attain higher heat transfer coefficient between hot and cold fluids which is evident in 4 fuel inlet configurations.

## VI. CONCLUSION

EGR cooler with 4 inlets has shown better results as compared to 1,2,3 and 5 inlets. This is due to low turbulence generated thus resulting in less turbulent flow heat transfer. The coolant flow is not uniform in these configurations as compared to 4 inlets. Pressure drop is the pressure difference of EGR cooler inlet gas and EGR cooler outlet gas. Pressure drop is affected from the fouling of the heat exchange surfaces as well as the erosion of these surfaces throughout the lifetime. Among all of the EGR system parts, the biggest contributor to pressure drop is the EGR cooler.

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