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Design and Development of Intercooler for Turbocharged Diesel Engine

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Abstract: ***In our day to day life more vehicle are use because it consume less time. But it is the major cause of environmental pollution to over from this effect in BS3 engines intercooler is used to cool down the compressed air temperature from the turbo charged unit. The purpose of project is to take an intercooler and reduce the outlet temperature by cooling it down with the some modification in design of an intercooler and the present automobile radiator system.***

Keywords: Intercooler, CFD, Radiator, Turbocharger.

I. INTRODUCTION

Turbocharger used in BS2 for increasing the air flow rate and output power of the engine. The advantages of increasing pressure increases the inlet air density and temperature during pressure raising process. Once the temperature increases, air density decreases, so the power of the engine increases and the emission rate also increases.

After that in BS3 intercooler was used to cool down the compressed air temperature from the turbocharger. After cooling the density will increase under the condition of same air fuel ratio. Moreover diesel engine efficiency also increases with the temperature of turbo charged air. Meanwhile the application of intercooler can reduce the emission of pollutant and improve the engine performance.The purpose of research paper is to take an intercooler and reduce the outlet temperature by cooling it down with the some modification in design of an intercooler and the automobile radiator system. For the conceptual design the plan is to eliminate the fins of the intercooler and add rectangular cuboid for water circulation inside the rectangular cuboid over the flat tube surface. To cool down the temperature of air instead of using air to air cooling process and also add an additional system to radiator.

The inlet and outlet temperature were measured to record the temperature changes across the system by computational fluid dynamics (CFD) fluent16.0 analysis technology software.

II. MATERIAL AND METHODS

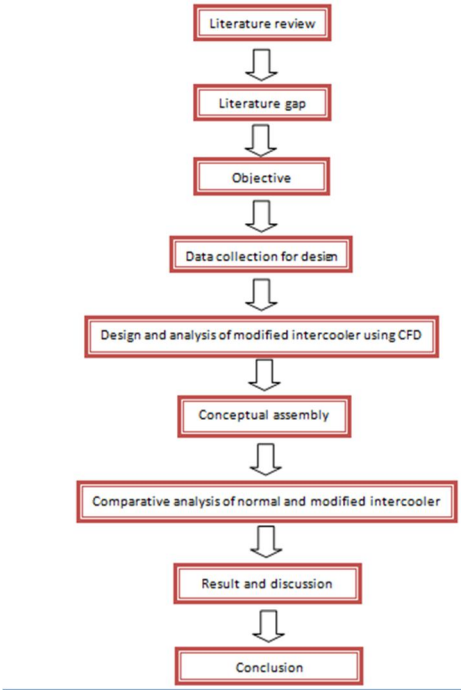


Figure1: flow chart

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1) *Step1*- Initially literature viewed and on identified gaps in literature various objective of proposed work set
2) *Step2*- From the literature review data has been collected to modify the design of an intercooler similar to fire tube boiler concept. During modification of an intercooler fins get eliminated and instead of fins a rectangular cuboid or chamber was selected.
3) *Step3*- Analyse the collected data help of CFD software and using heat transfer process in mathematical modelling.
4) *Step4*- Prepared conceptual assembly for set up.
5) *Step5*- Comparative analysis is carried out using various techniques such as CFD software and mathematical modelling.
6) *Step6*- From comparative analysis the result has been discussed and on the basis of result the conclusion was made to illuminate the gaps which were carried out.

Table1: Standard Properties of Inlet Air

Temperature in (K)	Density in (Kg/m^3)	Viscosity in (Kg/m-s)	Thermal Conductivity in (Wt/m-K)	Specific Heat (J/Kg-K)
365.44	0.9718	2.139e-5	0.03024	1008
368.32	0.9586	2.1595e-5	0.0309	1010
371.34	0.9458	2.181e-5	0.03095	1009
377.42	0.93323	2.2019e-5	0.031626	1011
400.25	0.83	2.290e-5	0.0331	1013

III. DESIGN PROCEDURE OF INTERCOOLER IN CFD

Dimensions are calculated with the help of mathematical equations. to begin with draw the trapezoidal shape on XY plane and extrude it up to 80mm depth in Z direction with the help of extrude toolbar. Create a new plane and draw one circle of 80mm diameter and extrude it up to 30mm in X direction to construct inlet of an intercooler. Create a new plane on 100mm distance from the origin and made 8 tubes of equal length, height and width and extrude it up to 452mm in X direction. Another new plane is created on 452mm distance from the 100mm distance which already created earlier plane in the direction of X and made same trapezoidal and extrude it up to 80mm depth in Z direction. Same process is used for making the outlet of intercooler with same dimension on another new plane which was created on 552mm distance.

Boolean toolbar was used for creating the rectangular cuboid shape for circulating the water over the surface of flat tube for this create a new plane on the height of 170mm on Y direction and 356mm in X direction from the origin and firstly subtract the tube which are inside the Boolean for making the two bodies and then choose another Boolean to unite two cylinder shape pipe on the back side of intercooler and one cylinder shape pipe on the bottom of an intercooler. After completion this step give the name to the bodies, 1) air body 2)water body as show in figure 1 and 2.

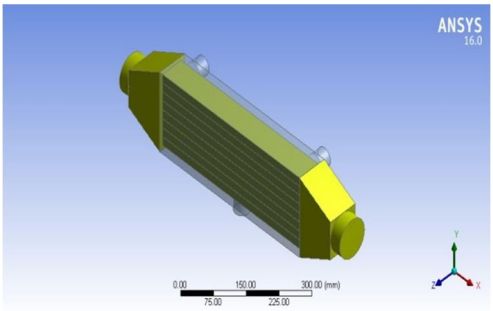


Figure2: Air Body in Intercooler

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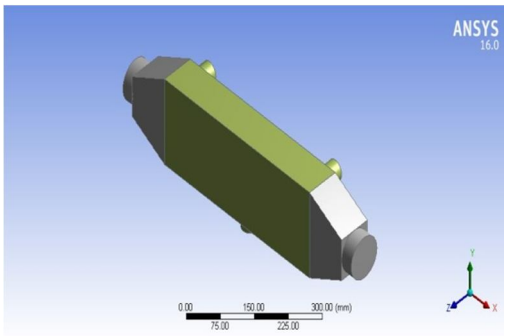


Figure3: Water Body in Intercooler

A. Meshing Procedure of Intercooler in CFD

Under the meshing process various steps are in use for better results.

Steps

RELEVANCE CENTER-fine
Initial size seed-full assembly
Smoothing –high
Transition-fast
Then right click on mesh and click on insert and various methods of meshing are open like
Sizing
Contact sizing
Refinement
Face meshing
Match control
Pinch
Inflation
For this component used body sizing method for meshing.
Then meshing of component used two times body sizing method for two bodies (air and water bodies) and in body sizing field some data like behaviour of mesh is hard and element size is 0.01 for both methods.
Then check statics of mesh like
No of nods- 142005
Elements -81824
Aspect ratio-2.586
In statics also check aspect ratio which is most important during meshing. It is must be less than 5 the aspect ratio must be lie between 1 and 3 is better for meshing .The aspect ratio during the various meshing method is up to average 2.586 which is better for this component.
After complete the mesh provide name to the various section of geometry which is useful for boundary conditions and creating the setup for analysis.

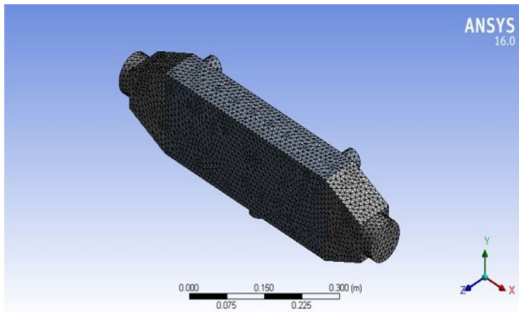


Figure4: Intercooler after Meshing

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B. Setup in CFD

1) Selection of Mode and Flow Properties
2) Processing
3) Post-Processing
4) Specification of Initial and Boundary Conditions

The simulation model a selected based on the physics of the problem**.** The first step is to select the simulation type (incompressible, compressible and natural convection etc.) once the simulation type is selected, set the other physical problem parameter. Assigned the material properties, initial conditions, and boundary conditions. Numerical simulations are based on solving the partial differential equations on the given domain, and these equations require the initial and boundary conditions—depending on the problem type—to be well posed.

The next step is specifying the numerical parameters, i.e. setting up solver parameters, discretization schemes, etc. Depending on the simulation type, every problem has its own unique structure. The flow fields are analyzed by different filters like streamlines, contour plots, etc. Post-processing is the final step in the CFD workflow, and it allows you to visualize your simulation results and make decisions for design optimization.

C. Preparation of Conceptual Design and Assembly

Initially normal assembly of a car is taken for study normally in Front Mount Intercooler (FMIC) intercooler is mounted in front of the car and at backside of the intercooler the radiator is mounted at some distance. However, in BS3 the intercooler is being used to cool down the air coming from the turbocharger. The temperature of the compressed air is very high hence it is required to cool down it before sending in intake manifold. In present assembly work two pumps and five pipes has utilized.. Fin chamber are made, under this chamber the flat tube is mounted and the air is pass through the tube. All over again two inlets is made for the water inlet and on the back side further two pipes is employed. In this one end of pipe is connected to water inlet and other with the water pump outlet. Similarly, water pump inlet is connected with the one end of pipe. Besides another end of pipe is connected with the lower tank of the radiator. The detailed conceptual assembly of modified intercooler is shown in figure 6.

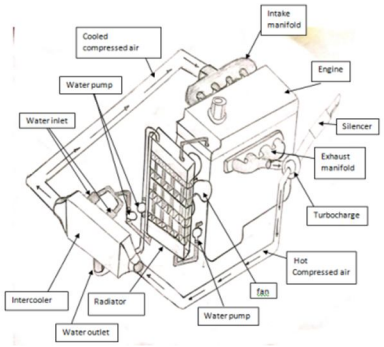


Figure6: Modified Engine Assembly

D. Comparative Analysis

Table 2 indicates Comparative Analysis of Existing and Modified Intercooler for various significant parameters.

Table2: Comparative Analysis of Existing and Modified Intercooler

Engine RPM	Mass flow rate	Inlet temperature and density		Existing intercooler			Modified intercooler using CFD	
RPM	$\dot{m}$ (Kg/s)	T_i	ρ_i	T_o	T_i-T_o	ρ_o	T_o	T_i-T_o
1333	0.00958	365.44	0.9718	343.28	22.16	1.0291	332	33.44
1913	0.0140	368.32	0.9586	345.28	23.04	1.0231	342	26.32
2397	0.0177	371.34	0.9458	346.12	25.22	1.0198	345	26.34
2706	0.0234	377.42	0.9332	348.71	28.71	1.0123	348	29.41
3503	0.0461	400.25	0.83	370.87	29.38	0.9518	365	35.25

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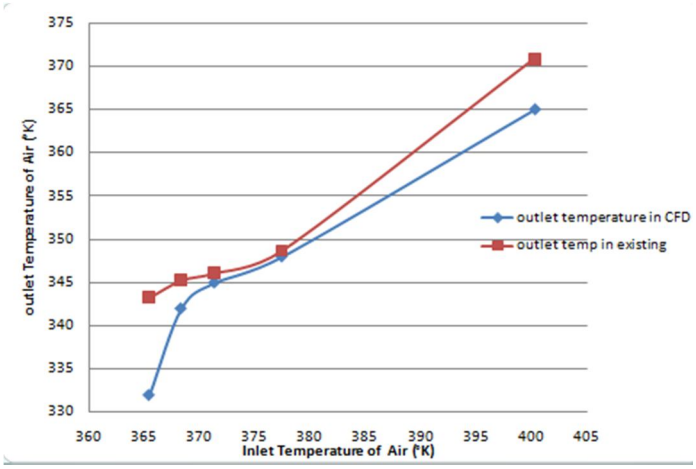


Figure7: Temperature difference between existing and modified intercooler

In this graph discussed that properties of air at different temperature are substitute in the software. Under this software the boundary condition was given to Air In i.e. mass flow inlet which was finding from literature review. Then from the software various results was analyses due to change in the mass flow rate of air.

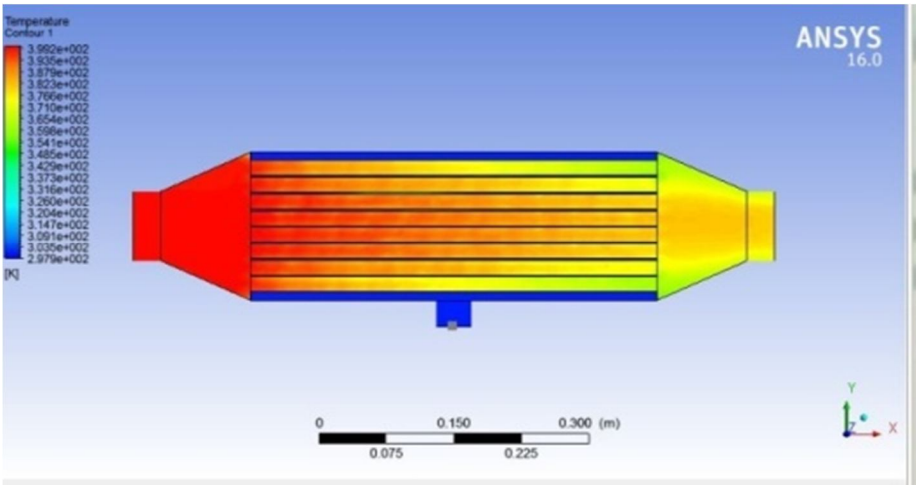


Figure8: Temperature contour

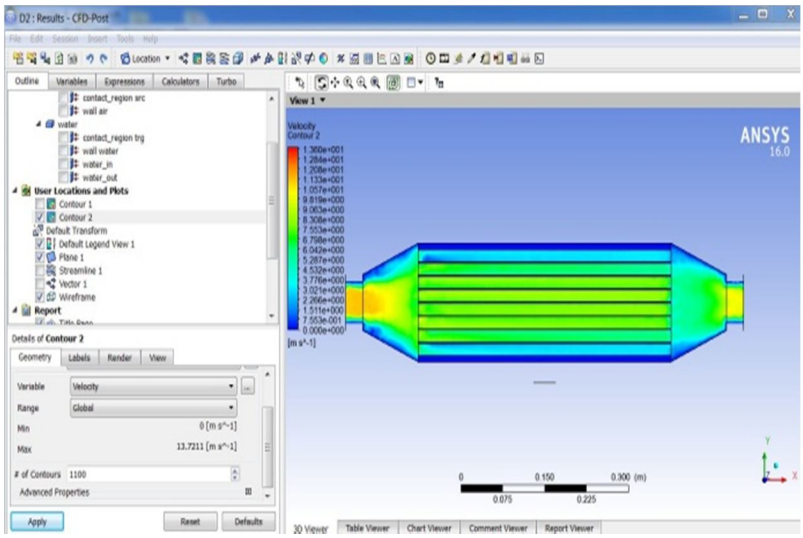


Figure9: Velocity contour

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IV. CONCLUSION

The easiest and smartest way to overcome the today's problem that is the modified intercooler. The modified intercooler was successfully analysed and it was found to be satisfy increasing the combustion rate due to increase in density while the compressed air temperature was reduced up to 45°C.However normal commercial intercooler temperature of compress air up to 20^0C. It is found that density is increased for same air furl ratio.

Achieving lot of advantage over the present existing method made this modification very successful and useful to the world.

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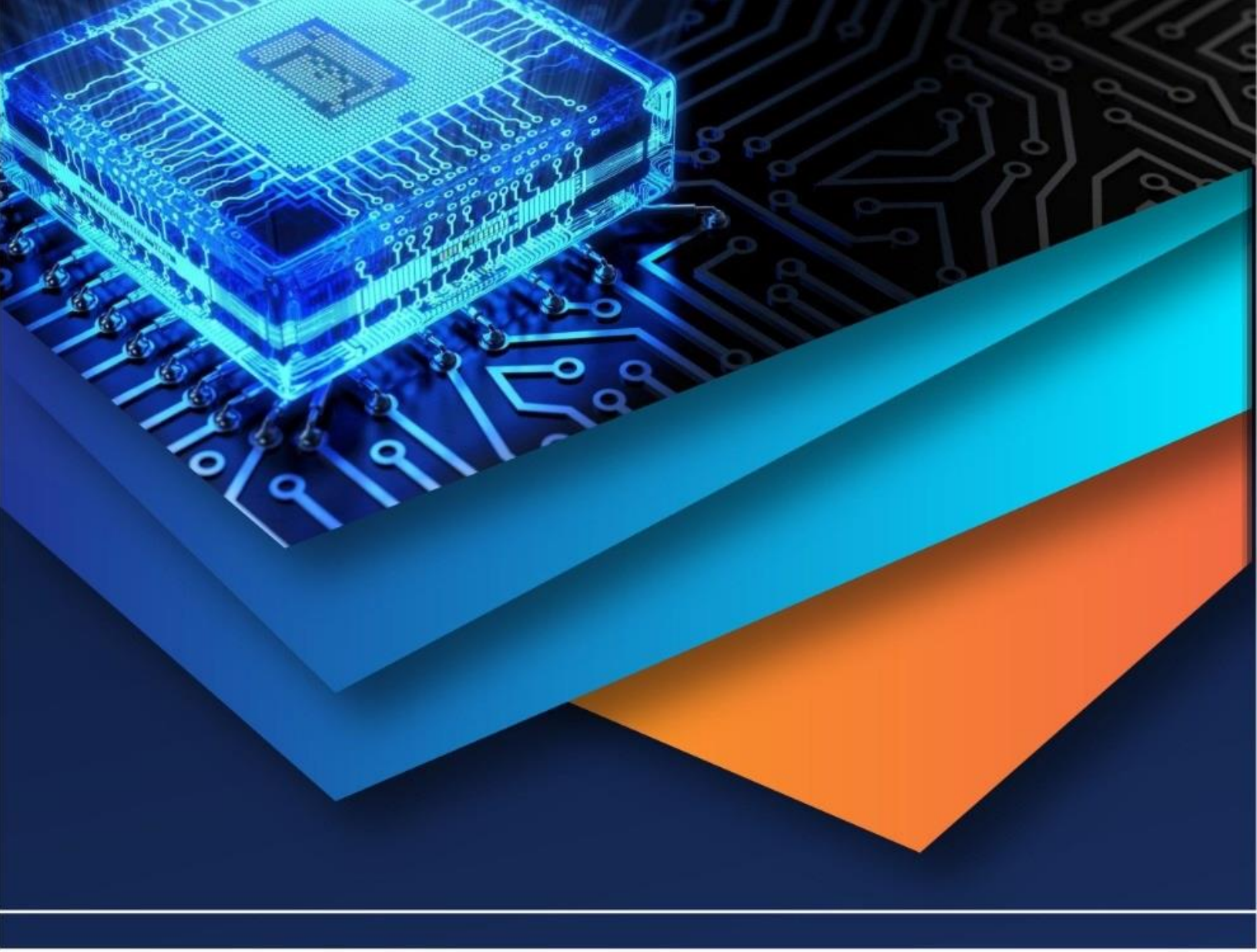
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