Journal of Mechanical Engineering Research and Developments
ISSN: 1024-1752
Website: http://www.jmerd.org
Vol. 38, No. 2, pp. 36-42

Simulation of Heat Transfer by Fluid Structure Interaction of Diesel Engine Block - Coolant Jacket

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ABSTRACT: It is always the main obstacle of the engine's development that the thermal load. Taking the diesel engine block-coolant jacket as an example, this paper establishes the fluid structure interaction model, and simulates and calculates the flow and the heat transfer of the block-coolant jacket. The results agree well with the measured data. And then this paper makes appropriate optimization to the structure of the coolant jacket according to the simulation results, puts forward two structure improvement projects, and also compares their simulating results, so proves the rationality of the structure improvement.

KEYWORDS: Engine block, Coolant jacket, Heat transfer, Fluid structure interaction, Structure improvement.

INTRODUCTION

It is the obstacle limiting diesel engine to develop continuously and forward that the heat load of the diesel engine. The combustion chamber of diesel engine directly connects with the gas of high-temperature and high-pressure, and endures complex and alternate thermal load, appears the problem of reliability and durability easily, so it is necessary to study the heat load of diesel engine [1-5]. Coolant jacket plays a big role for the combustion chamber components especially piston's heat load reduction, therefore the flow and cooling condition of cooling water and the body's temperature distribution influence each other, are a process of flow and heat transfer coupling each other [6-7].

Taking the diesel engine block-coolant jacket as an example, this paper establishes the fluid structure interaction model, and simulates and calculates the flow and the heat transfer of the block-coolant jacket. The results agree well with the measured data. And then this paper makes appropriate optimization to the structure of the coolant jacket according to the simulation results, puts forward two structure improvement projects, and also compares their simulating results, so proves the rationality of the structure improvement.

THE NUMERICAL SIMULATION OF THE ENGINE BLOCK-COOLANT JACKET HEAT TRANSFER SYSTEM

Based on diesel engine block and coolant jacket, the fluid structure interaction model is established and divided the grid, and the grid model is shown in Figure 1.

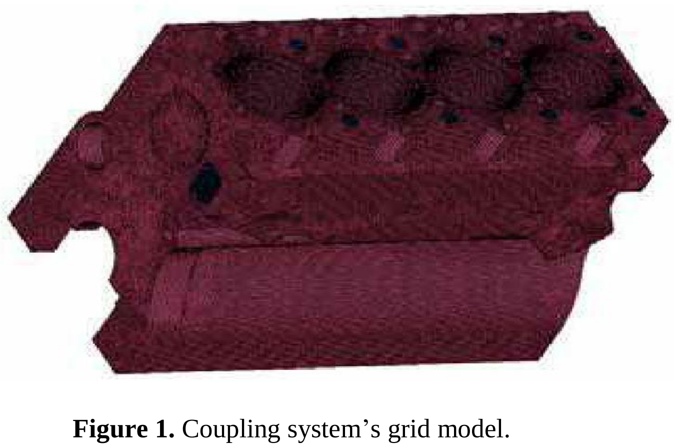
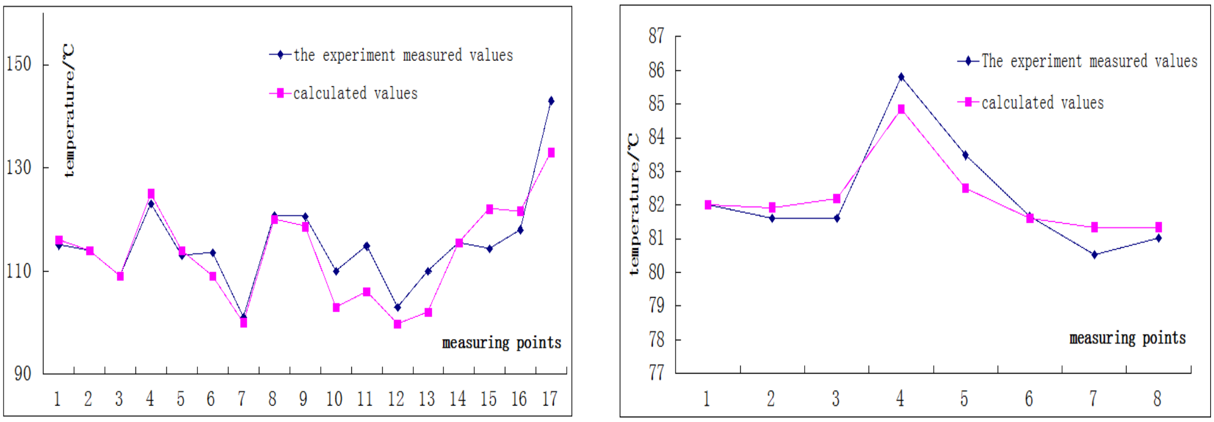


Figure 1. Coupling system's grid model.

The model is simulated in Fluent and the temperature field has been computed. The diagram of temperature field calculated is compared with experimental results in Figure 2. From the graph, we can see that the error about simulation results and measurement is less than 5%, so the model can well simulate the water flow and heat transfer conditions between engine body and coolant jacket.

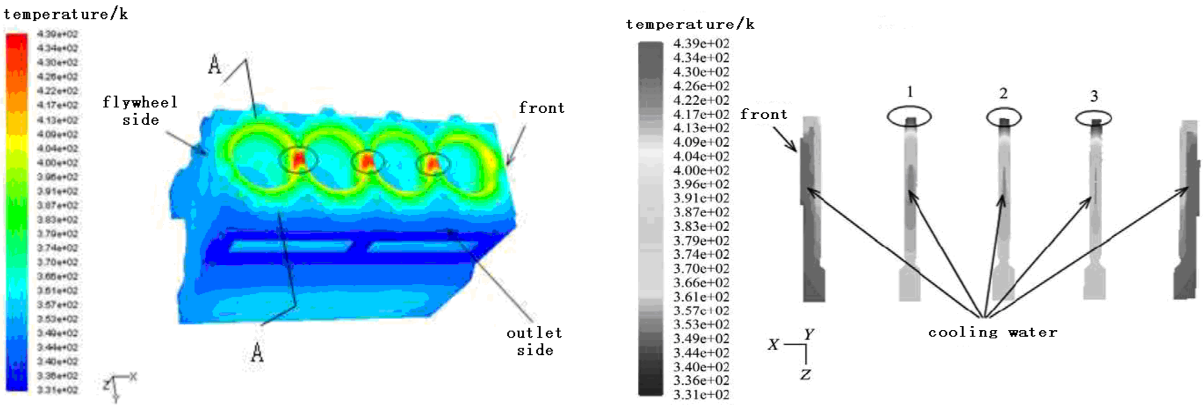


a. Temperature on the body.

b. Temperature on the coolant jacket.

Figure 2. Comparison of temperature between calculation and test in system model.

SIMULATION FOUND THE PROBLEM, NEED TO MAKE IMPROVEMENT ON STRUCTURE



a. Air inlet side.

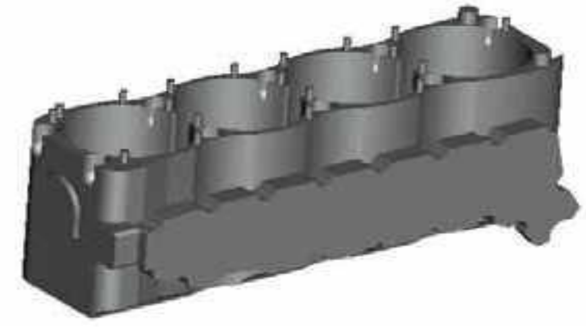
b. Longitudinal profile.

Note: 1, 2, 3 -- representing junction between the first cylinder to the fourth cylinder.

Figure 3. Calculated temperature field of the system model under a rating condition.

Steady temperature field is shown in Figure 3, which is calculated under rated working condition using the coupling model shown in figure 1. From the graph, we can see that: 1) The temperature of the body's internal surface which contact with coolant jacket is much higher than the body's outside surface; 2) In the temperature field simulated, the highest temperature is obtained. on the border of two adjacent cylinders because that the area where on the border of two adjacent cylinders is at high temperature and high pressure gas of the combustion chamber for a long time, and it also cannot get enough cooling; 3) The highest temperature in the temperature field is 166 degrees, which is located in the junction between the third and fourth cylinder. The reasons for this phenomenon is that cooling water cools in order from 1 to 4 cylinder in the body, therefore the behind to the cooling, the worse the cooling effect.

From the results calculated by the coupling model, we can see that cooling effect of the original coolant jacket is not good, and it needs to make relevant improvements. Considering process technology, it has presented two kinds of improved projects which based on the original coolant jacket, [8] shown in Figure 4. The original coolant jacket has been changed into a short one in the first improved project. The original water jacket has been shortened 10 mm from the bottom, and the surface shape located at two sides of the inlet and outlet in the coolant jacket has been changed into curved surface, and has changed the location, size and number of the inlet and outlet holes on the body; In the second project, based on the first improvement project, we have added a inclined-upward hole in the coolant jacket. At the same time, we have increased cooling water flow between the cylinder and the cylinder.



(1) Model of the first improved project.

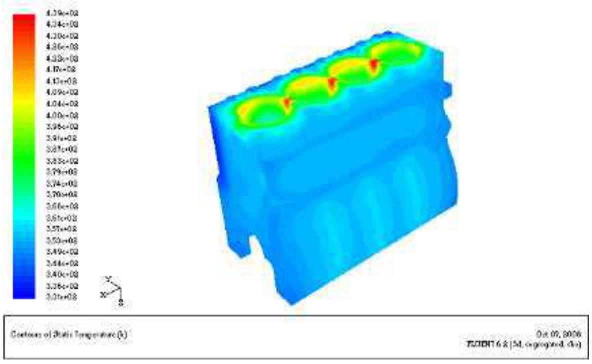
(2) Model of the second improved project.

Figure 4. The improved project models of coolant jacket.

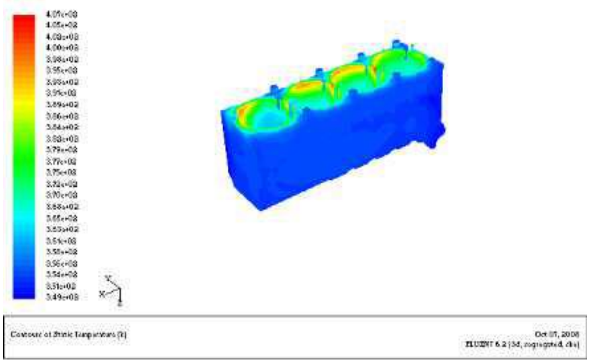
HEAT TRANSFER ANALYSIS OF THE ORIGINAL MODEL AND IMPROVED MODEL

Using boundary conditions and load conditions of the original model, heat transfer simulation of the two kinds of improved projects' models have been calculated again. Finally, results obtained from the improved models have been compared with the original model.

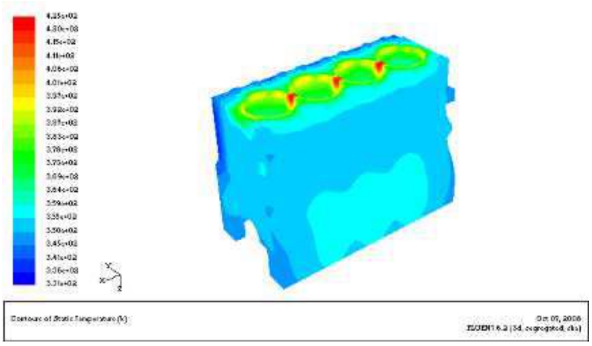
Comparison of the Temperature Field Distribution



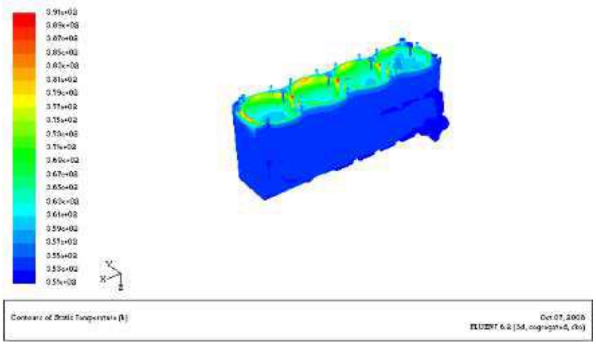
(1) Coupling bulk temperature field of the original mode.



(2) Temperature field of outer wall of the original model.



(3) Coupling bulk temperature field of the first project.



(4) Temperature field of outer wall of the first project.

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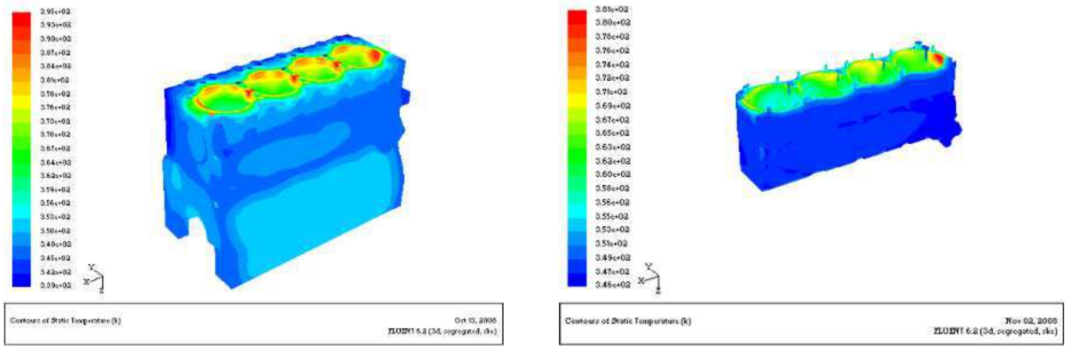
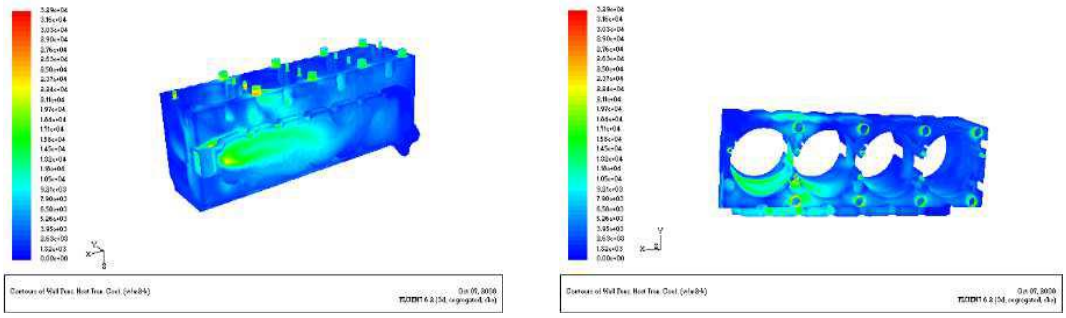
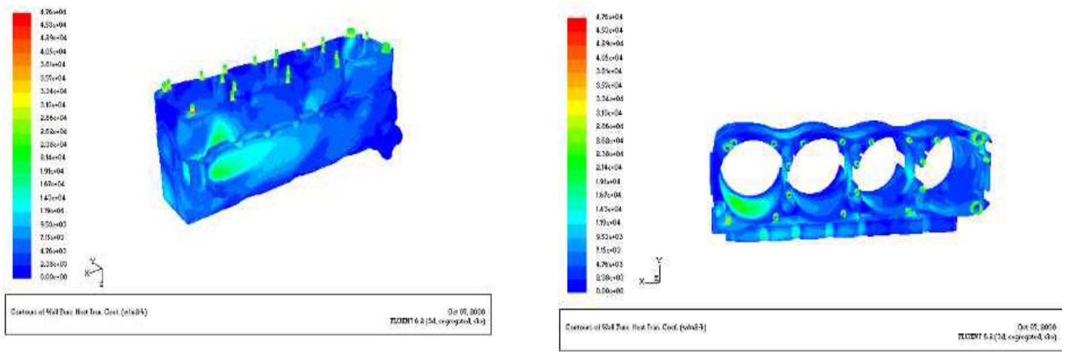


(5) Coupling bulk temperature field of the second project. (6) Temperature field of outer wall of the second project.

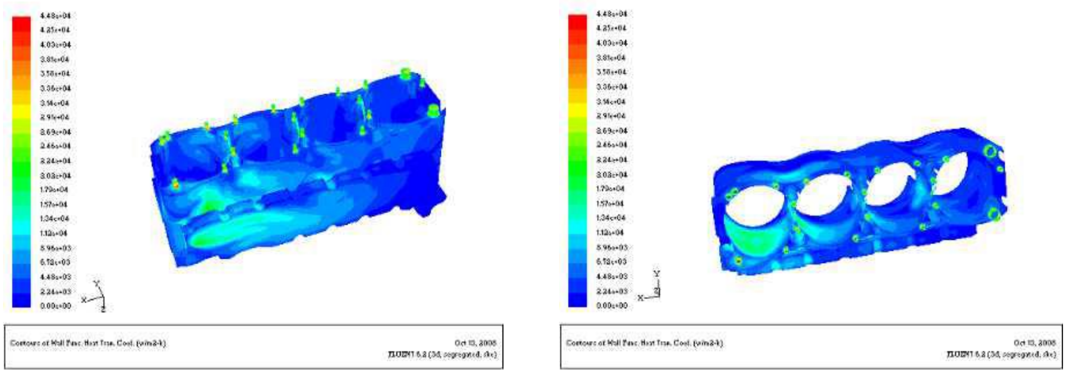
Figure 5. Comparation of temperature field between improved models and primary model.



(1) Heat-transfer coefficient distribution of the original model's coolant jacket surfaces.



(2) Heat-transfer coefficient distribution of the first improved project's coolant jacket surfaces.



(3) Heat-transfer coefficient distribution of the second improved project's coolant jacket surfaces.

Figure 6. Comparation of convection coefficient contours along the surfaces of block water jacket.

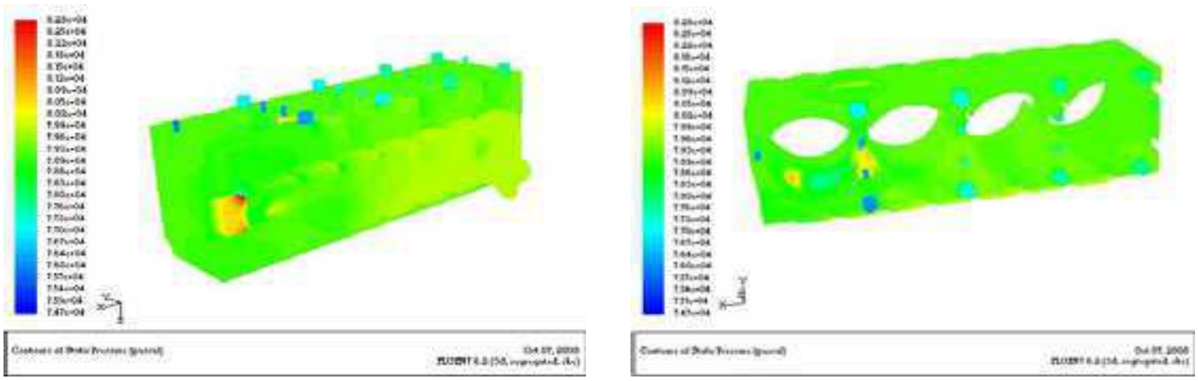
Temperature field obtained from four kinds of models is shown in Figure 5. Obtains following conclusion via analysis and comparison from the graph: The temperature field distribution obtained from two kinds of improved project and the original model's is approximately identical, especially upper area on the body and surface area in the cylinder. The maximum temperature obtained from the first improved projects is also appeared in the junction between the third and fourth cylinder, is the same as the original model's, but the maximum temperature has decreased from original 166 ℃ to 152 ℃; The second improved project has the best cooling effect, its maximum temperature obtained from simulating is 122 ℃. Comparing with the original model, the maximum temperature has been reduced by 44 ℃. The maximum temperature area shown in red on the diagram is different from previous. It has appeared on the top area of each cylinder's inner surfaces, nor at the junction between two adjacent cylinder; From the temperature field calculated from outside wall of the cylinder on the body, we can see that the second improved project works best, and its temperature has decreased most obviously.

Comparison of the Heat Transfer Coefficient Distribution of the Coupling Wall of the Cooling Water and the Body

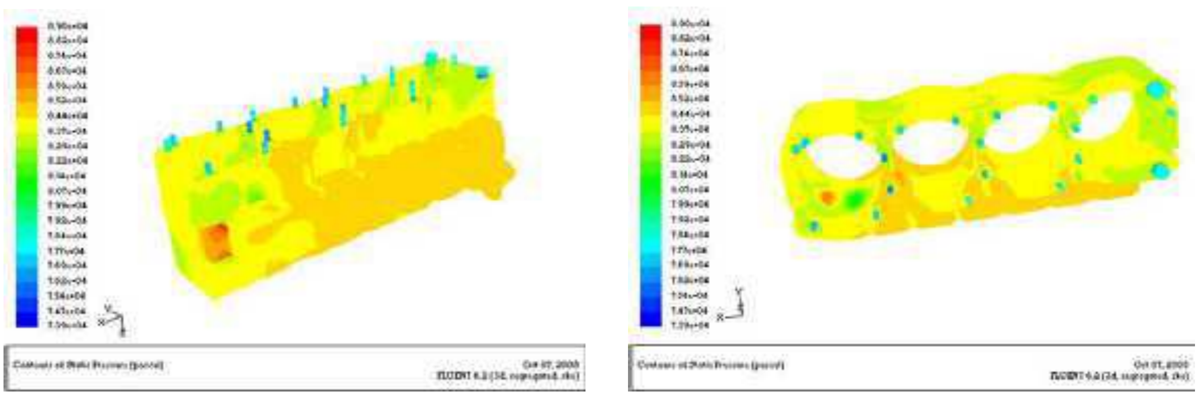
Heat transfer coefficient distribution obtained by simulating from coupling wall of the cooling water and the body has been shown in Figure 6. We can see that heat transfer coefficient distribution trend of the two improved projects is the same with the original model's. The average heat transfer coefficient of the two improved projects has significantly increased than the original model's, especially the first. It has increased from 4488 to 5903 $W/m^{2}\cdot k$.

Comparison of the Coolant Jacket's Pressure Field Distribution

From the water jacket's pressure field by simulating shown in Figure 7, we can see that the two improved projects have not improved their water jackets' pressure loss obviously, and the inlet and outlet hole of cooling water still is the place where the pressure loss is bigger. Fortunately, the pressure loss of other areas has been improved greatly. Comparing two kinds of improved projects, it can be seen that the first and the second kind of improved projects' stress field distribution of cooling water is more reasonable than the original model, and their cooling water flows more smoothly. The total pressure loss of the water jacket of the cylinder block: the original model as an example is 14.4 kP_a, the first improvements is 15.2 kP_a, and the second improvement is 15.8 kP_a.



(1) Pressure distribution of the original model's water jacket.



(2) Pressure distribution of the first improved project's water jacket.

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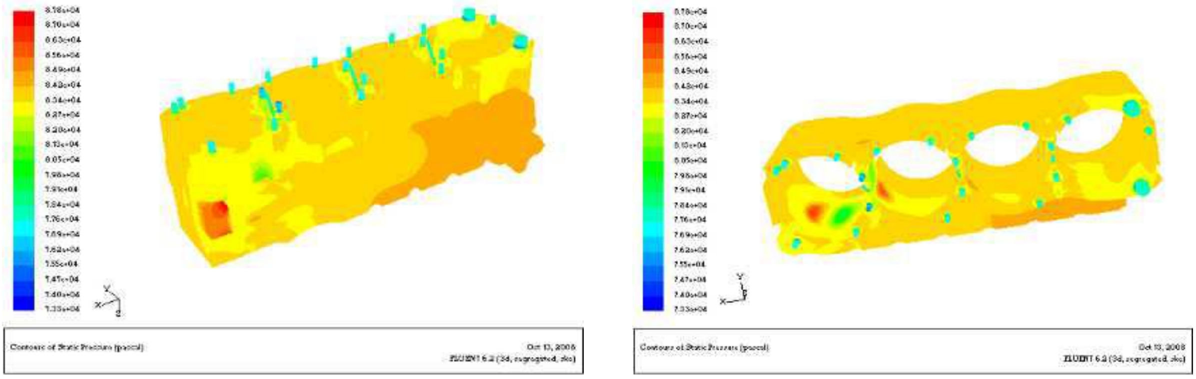

(3) Pressure distribution of the second improved project's water jacket.

Figure 7. Comparation of pressure contours of block water jacket.

CONCLUSION

By using software Fluent, numerical simulation for the flow and heat transfer of diesel engine body - cooling water jacket of fluid-solid coupling system is carried out. From the simulation results, we can see that cooling effect of the original coolant jacket is not good, and it needs improvement. This paper presents two kinds of improvement projects of the cooling jacket structure, and simulated calculation has been done respectively.

The cooling water flow field velocity and coupling surface heat-transfer coefficient are improved to some extent, which obtained by simulation calculation from two kinds of improved projects. Temperature of the body decreased, comparing with the original model. They can more effectively improve heat load on the engine. 1) Average heat-transfer coefficient of the coupling wall: the original models' is 4488$W/m^{2}\cdot k$, the firsts' is 5903 $W/m^{2}\cdot k$, the seconds' is 5310 $W/m^{2}\cdot k$; 2) Pressure distribution：Two kinds of improved projects do not reduce the pressure loss of the water jacket. Losses larger areas are concentrated in the holes on the body. But in addition to the import and export areas (cooling water inlet and the hole), the pressure loss on the other areas got improved greatly; 3) Temperature distribution: The temperature distribution on the top surface of the body is very similar to which on the interface, but a drop in the temperature is relative to the original model. The maximum temperature of the body is 14 degrees lower than the original model in the first improved projects. But the bulk temperature has reduced significantly in the second improved project, the maximum temperature compared to the original model has reduced by 44 degrees.

CONFLICT OF INTEREST

The author confirms that this article content has no conflict of interest.

ACKNOWLEDGEMENTS

This work was financially supported by the Natural Science Foundation of the Higher Education Institutions of Jiangsu Province, China (14KJA470001) and Ph. D. Graduate Student research and creative projects of Jiangsu Province, China (CXLX13_0657).

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