ISSN : 0974 - 7435 Volume 10 Issue 20

2014

BioTechnology

An Indian Journal

FULL PAPER

BTAIJ, 10(20), 2014 [12095-12101]

Heat transfer research of high-speed diesel engine block-coolant jacket

Zhang Zenglian

[1]School of Automobile and Traffic Engineering, Jiangsu University, Zhenjiang, Jiangsu, 212013, (P.R.CHINA)

[2]School of Energy and Power Engineering, Jiangsu University of Science and Technology, Zhenjiang, Jiangsu, 212003, (P.R.CHINA)

E-mail: sunping@ujs.edu.cn

ABSTRACT

The thermal load of engine is always the main obstacle of the development of the engine. Based on diesel engine block-coolant jacket, the fluid structure interaction model is established, and the flow and the heat transfer of the block-coolant jacket are simulated and calculated. The results agreed well with the measured data. At the same time, according to the simulation results, the structure of the coolant jacket is made appropriate optimization, 3-structure improvement projects are put forward, and their simulating results are also compared. The cooling velocity of flow field, the coupling surface heat transfer coefficient simulated by 3-structure improvement projects are all increased in some degree comparing with the original models, and the whole block temperature is lowered in some degree than the original model, so as to verify the rationality of the structure improvement.

KEYWORDS

Engine block; Coolant jacket; Heat transfer; Fluid structure interaction; Structure improvement.

INTRODUCTION

The heat load of the diesel engine has been the obstacle that limits diesel engine to develop continuously and forward. 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].

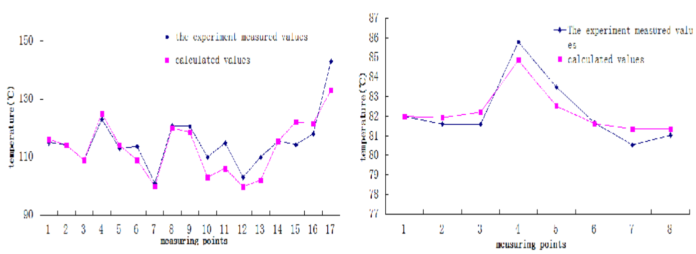
Based on diesel engine block-coolant jacket, the fluid structure interaction model is established, and the flow and the heat transfer of the block-coolant jacket are simulated and calculated. At the same time, according to the simulation results, the structure of the coolant jacket is made appropriate optimization, 3-structure improvement projects are put forward, and their simulating results are also compared, so as to verify the rationality of the structure improvement.

THE NUMERICAL SIMULATION OF THE ENGINE BODY-COOLANT JACKER HEAT TRANSFER SYSTEM

With diesel engine block-coolant jacket, the coupling model is established and divided the grid, and is shown in Figure 1.

Figure 1 : Coupling system’s grid model.

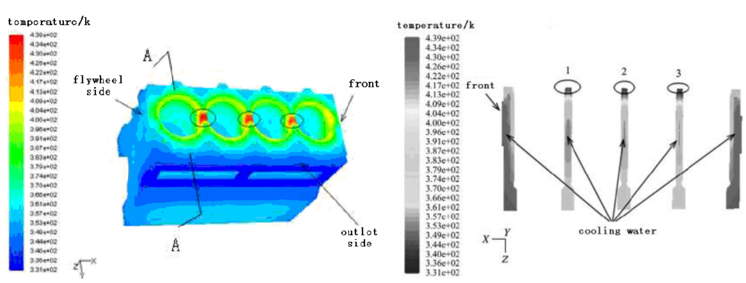
The model is simulated in Fluent and the temperature field has been computed. The diagram of temperature field calculated is compared with experimental results in Figure 2. From the graph, we can see that the error about simulation results and measurement is less than 5%, so the model can well simulate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



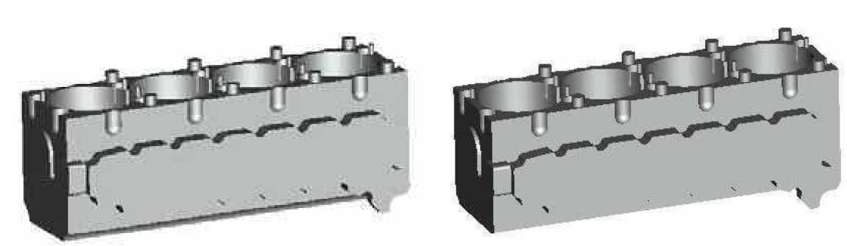
a air inlet side **b longitudinal profile**

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

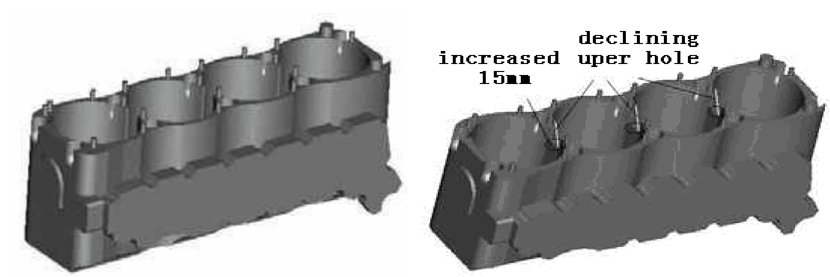
Figure 3 : Calculated temperature field of the system model under a rating condition

Steady temperature field has been used in Figure 3, which is calculated under rated working condition in 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 can not 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 three 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; On the basis of the first project, the surface shape located at two sides of the inlet and outlet in the coolant jacket has been changed into curved surface in the second project, and has changed the location, size and number of the inlet and outlet holes on the body; In the third project, based on the second 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)original model **（2)model of the first improved project**



(3)model of the second improved project (4)model of the third improved project

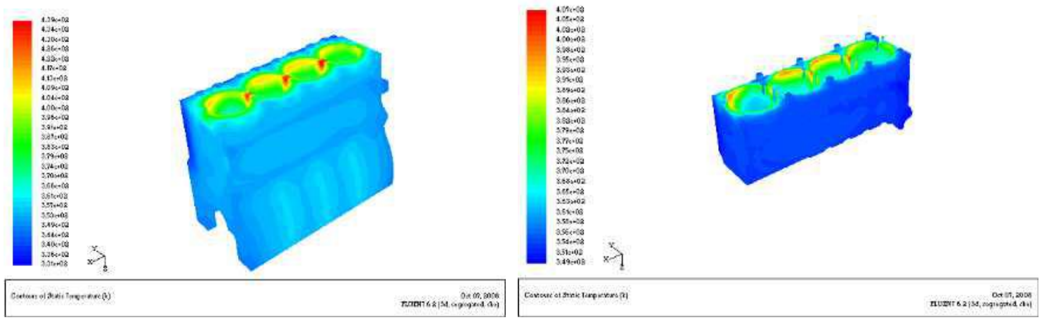
Figure 4 : The improved project models of coolant jacket

HEAT TRANSFER ANALYSIS OF THE ORIGINAL MODEL AND IMPROVED MADEL

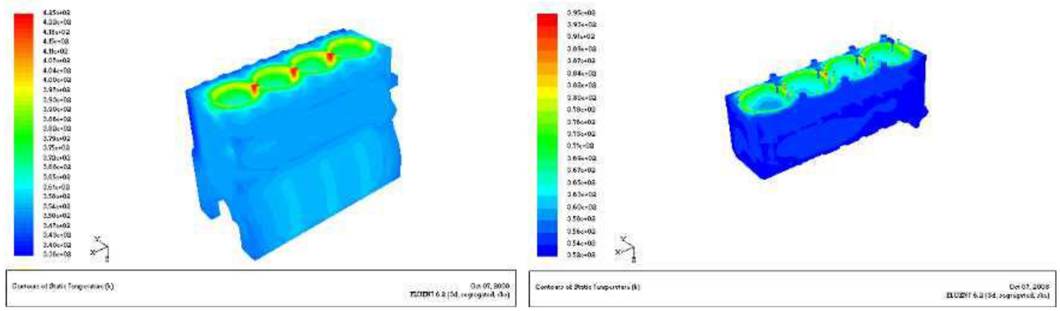
Using boundary conditions and load conditions of the original model, heat transfer simulation of the three kinds of improved projects’ models have been calculated again. Finally, results obtained from the improved models have been compared with the original model.

Comparison of the temperature field distribution

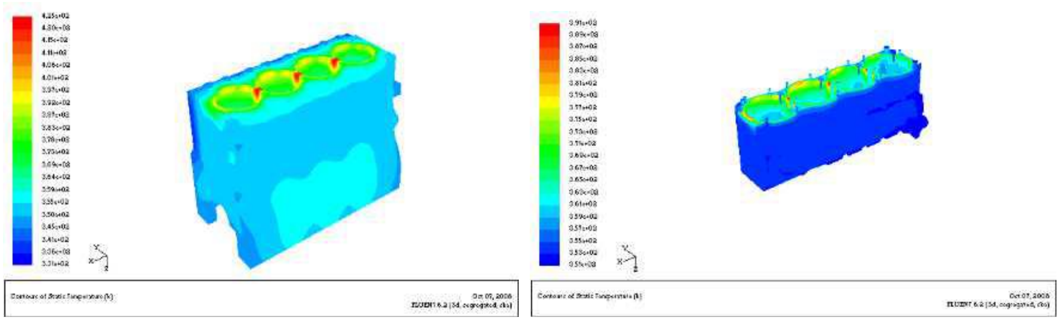
Temperature field obtained from four kinds of models is shown in Figure 5. Obtains following conclusion via analysis and comparison from the graph: The temperature field distribution obtained from three kinds of improved project and the original model’s is approximately identical, especially upper area on the body and surface area in the cylinder. The maximum temperature obtained from the first and the second 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 third 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 third improved project works best, and its temperature has decreased most obviously.



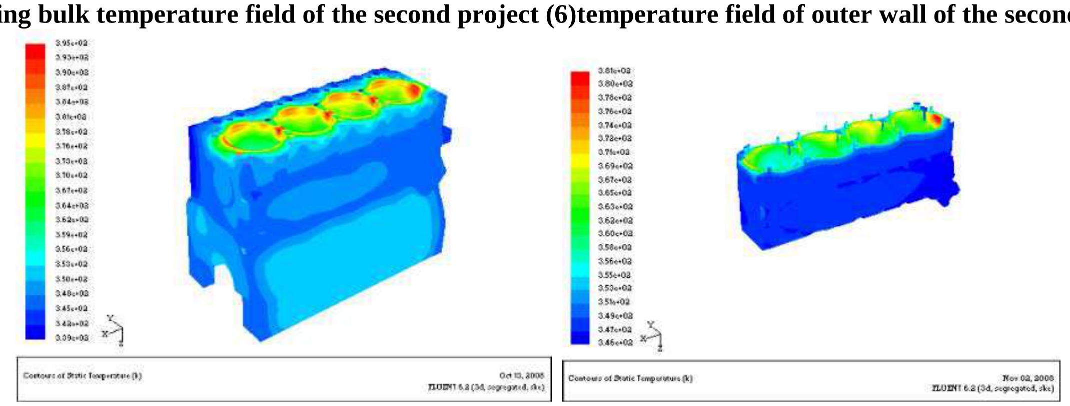
(1)coupling bulk temperature field of the original model (2)temperature field of outer wall of the original model



(3)coupling bulk temperature field of the first project (4)temperature field of outer wall of the first project



(5)coupling bulk temperature field of the second project (6)temperature field of outer wall of the second project



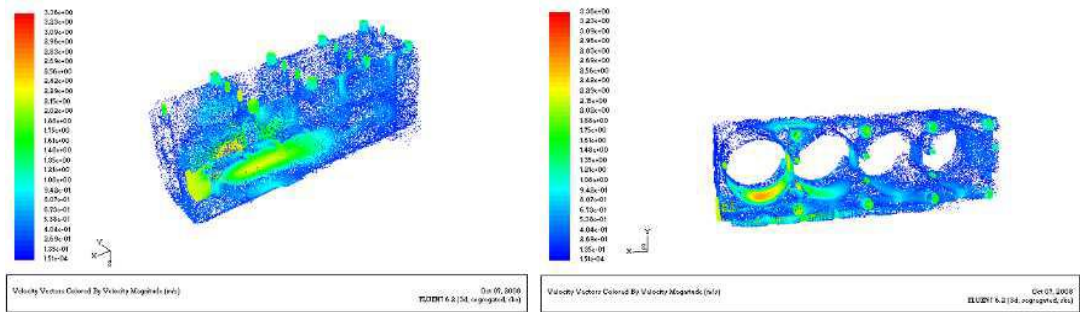
(7)coupling bulk temperature field of the third project (8)temperature field of outer wall of the third project

Figure 5 : Comparison of temperature field between improved models and primary model

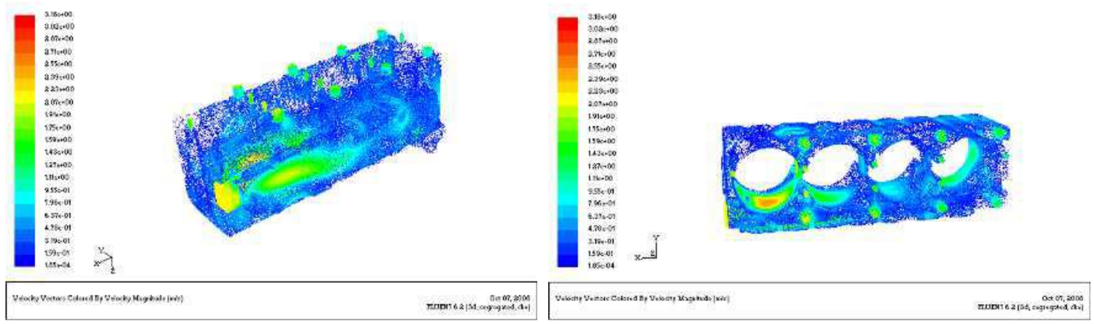
Comparison of the cooling water flow field distribution

From the cooling water flow field distribution obtained by simulating in Figure 6, we can see that cooling water's average flow velocity of the three kinds of improved projects is better than the original model's. Among them, the velocity of the first improved project ranges from 0.000185 to 3.18m/s, and its average flow velocity has increased 0.08 m/s; The velocity of the second improved project ranges from 0.0000625 to 4.11m/s, and its average flow velocity has increased 0.18

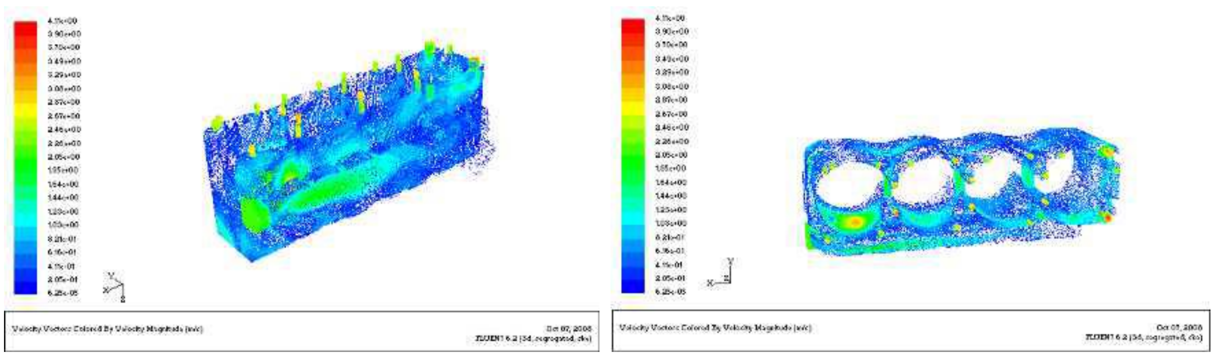
m/s; The velocity of the third improved project ranges from 0.0000771 to 3.78m/s, and its average flow velocity has increased 0.52 m/s. The second and the third project can satisfy the design requirements of the coolant jacket in comparison although there is flow of the dead zone and vortex area in the three improved projects' cooling water flow field[9,10].



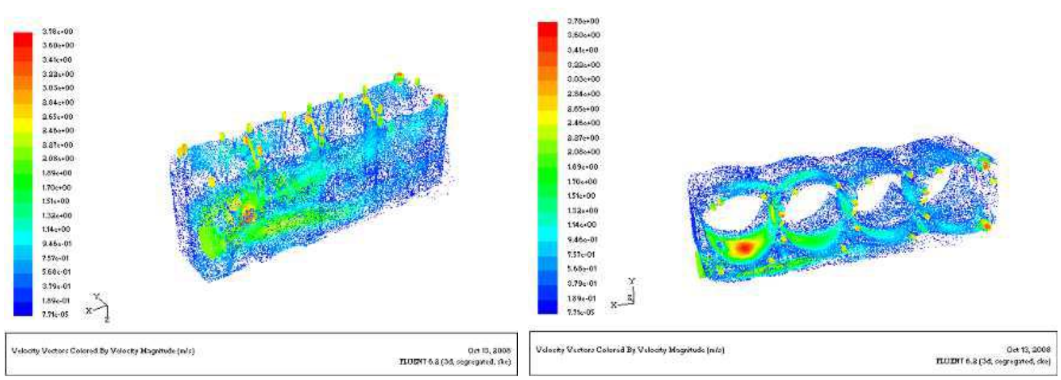
(1)velocity vector distribution of cooling water of the original model



(2)velocity vector distribution of cooling water of the first improved project



(3)velocity vector distribution of cooling water of the second improved project

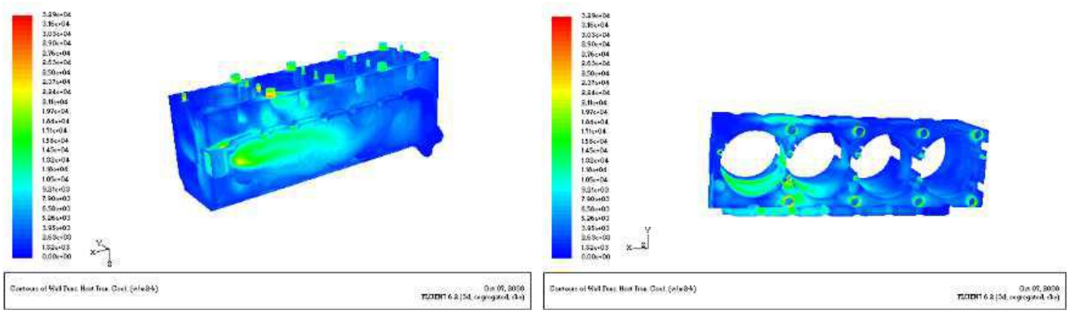


(4)velocity vector distribution of cooling water of the third improved project

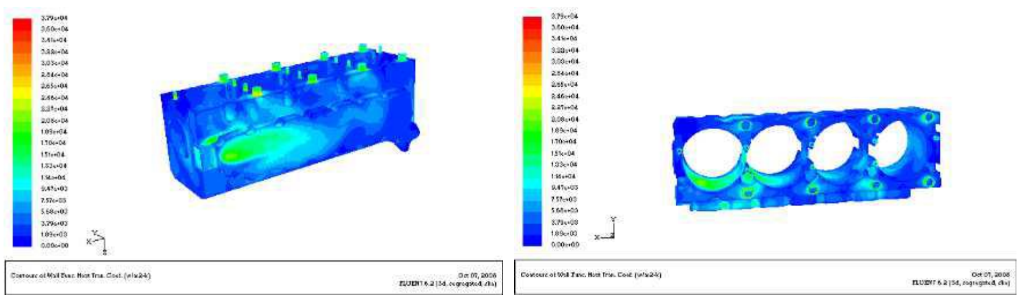
Figure 6 : Comparison of velocity vectors of coolant jacket

Comparison of the heat transfer coefficient distribution of the coupling wall of the cooling water and the body

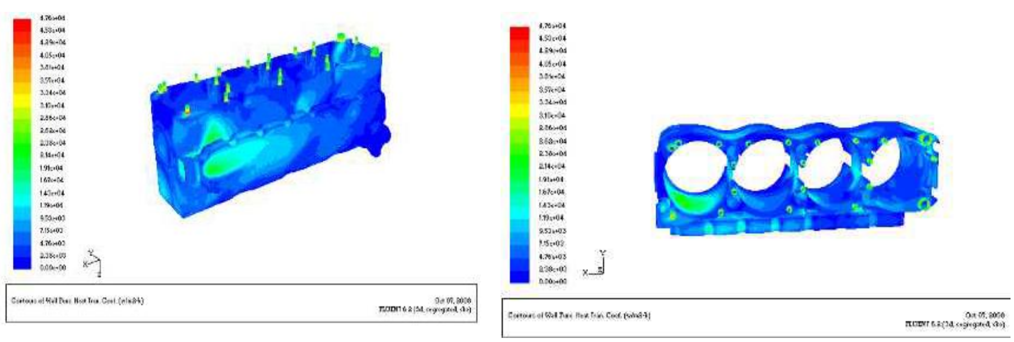
Heat transfer coefficient distribution obtained by simulating from coupling wall of the cooling water and the body has been shown in Figure 7. We can see that heat transfer coefficient distribution trend of the three improved projects is the same with the original model's, and it consistent with the velocity vector distribution trend shown in Figure 6. The average heat transfer coefficient of the three improved projects has significantly increased than the original model's, especially the second. It has increased from 4488 to 5903 $W/m^{2}\cdot k$.



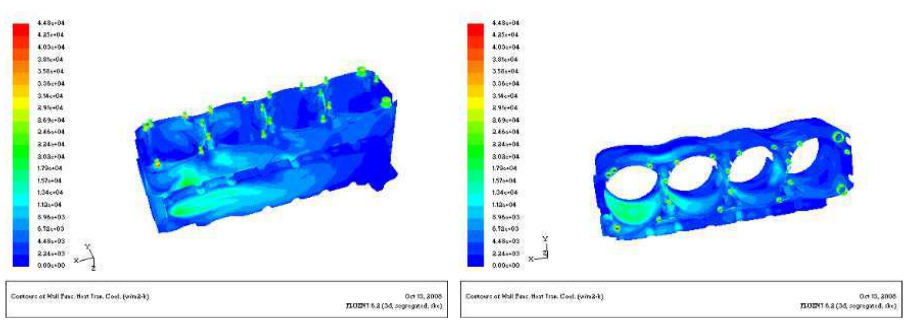
(1)heat-transfer coefficient distribution of the original model's coolant jacket surfaces



(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



(4)heat-transfer coefficient distribution of the third improved project's coolant jacket surfaces

Figure 7 : Comparison of convection coefficient contours along the surfaces 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 three 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 three 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) The flow field: Average flow velocity in the original model is 0.40m/s. The first, second and the third improvement project are respectively 0.48 m/s, 0.58 m/s, 0.52 m/s; 2) Average heat-transfer coefficient of the coupling wall: the original models' is 4488W/m^{2}·k, the firsts' is 5252W/m^{2}·k, the seconds' is 5903 W/m^{2}·k, the thirds' is 5310 W/m^{2}·k; 3) Pressure distribution: Three 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.

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).

REFERENCES

[1] H.Q.Ning, P.Sun, D.Q.Mei, S.M.Xiao, P.Hu; "Temperature Experiment and Thermo-Mechanical Coupled Simulation of High-Speed Diesel Engine Piston", Chinese Internal Combustion Engine Engineering, **35(1)**, 105-109 **(2014)**.

[2] T.E.Zhang, W.Z.Zhang, L.Y.Song, Y.F.Cao; "Research on parameter design of boiling cooling bridge zone of cylinder head", Huazhong Univ. of Sci.＆ Tech.（Natural Science Edition), **42(1)**, 14-17 **(2014)**.

[3] M.L.Bai, S.Q.Shen, J.H.Chen, Z.T.Zhang; "Progress of complete model simulation research on heat transfer of internal combustion engine", Transactions of CSICE, **21(1)**, 96-99 **(2000)**.

[4] K.V.Mohan, O.Arich, S.L.Yang, J.H.Johnson; "A Computer Simulation of the Turbocharged Vehicle Engine Cooling System Simulation", SAE, 971804 **(1997)**.

[5] L.X.Guo, H.T.Yang, X.L.Xia; "Thermal load analysis of a gasoline engine cylinder head", Modern Vehicle Power, **3(4)**, 17-20 **(2006)**.

[6] F.Dong, C.H.Guo, Q.Y.Fan, Y.X.Cai, S.L.Jiang; "Simulation on Boiling Heat Transfer in Cooling Water Jacket of Engine", Chinese Internal Combustion Engine Engineering, **32(4)**, 76-82 **(2011)**.

[7] H.Y.Zhang, Z.Y.Hao, X.Zheng; "Optimization design of heat transfer performance for diesel cooling water jacket", Journal of Zhejiang University (Engineering Science), **48(1)**, 70-75 **(2014)**.

[8] W.D.Wang, P.Sun, R.Zhang, T.J.Liu; "Simulation of heat transfer by liquid-solid coupled method of engine block and cooling water jacket", Transactions of the CSAE, **26(7)**, 118-122 **(2010)**.

[9] M.L.Bai, S.Q.Shen, J.H.Chen, Z.T.Zhang; "Progress of complete model simulation research on heat transfer of internal combustion engine", Transactions of CSICE, **22(6)**, 525-531 **(2004)**.

[10] H.B.Chen, X.M.Yu, Z.C.Yuan;, "Comparison and Analysis on IC Engine Cooling Water-jacket Design Scheme", Energy Conservation Technology, **26(3)**, 232-236 **(2008)**.