

The Effects of Cylinder Head Gasket Opening on Engine Temperature Distribution for a Water-Cooled Engine

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Abstract. In a liquid-cooled engine, coolant is pumped throughout the water jacket of the engine, drawing heat from the cylinder head, pistons, combustion chambers, cylinder walls, and valves, etc. If the engine temperature is too high or too low, various problems will occur. These include overheating of the lubricating oil and engine parts, excessive stresses between engine parts, loss of power, incomplete burning of fuel, etc. Thus, the engine should be maintained at the proper operating temperature. This study investigated the effects of different cylinder head gasket opening on the engine temperature distributions in a water-cooled motorcycle engine. The numerical predictions for the temperature distribution are in good agreement with the experimental data within 20%.

1.Introduction

In an engine, 33% of combustion energy must be removed by the cooling system. If the engine temperature is too high or too low, various problems will occur. Therefore, the design of the water jacket is very important for engine design. Many studies of the engine have been analyzed by CFD simulations. Deger et al. [1] used CFD simulation to analysis a diesel engine exhaust manifold and got the temperature distribution of manifold. Mulemane and Soman [2] analyzed the cooling system of a four-cylinder water-cooled engine. It is shown that nucleate boiling tends to occur in the regions where the flow is not regular and the temperature is high. Jafarabadi et al. [3] analyzed a 12-cylinder diesel engine. They found that the heat transfer performance is enhanced by the boiling. Fontanesi and Giacomini [4] optimized the cooling water jacket of a six-cylinder diesel engine. Agarwal et al. [5] analyzed the heat transfer performance of the water jacket in a diesel engine. This study uses 3-D computational fluid



dynamics finite difference method to investigate the effects of different cylinder head gasket openings on the engine temperature distributions in a water- cooled motorcycle engine.

2.Mathematical Analysis

A 3D model that is a 400c.c four strokes single cylinder water-cooled motorcycle engine was established, as shown in Fig. 1. Four different gasket openings, as shown in Fig. 2, are examined. Case1 (holes 1 and 2 are open, other 6 holes are closed) is the original design from the locomotive manufacturer. Case 2: holes 2 and 3 are open, others 6 holes are closed. Case 3: holes 2, 3 and 4 are open, other 5 holes are closed. Case 4: holes 1, 2, 3 and 4 are open, other 4 holes are closed. The fluid is considered 3-D incompressible turbulent flow with k- ϵ flow model and the flow is assumed to be steady with no viscous dissipation.

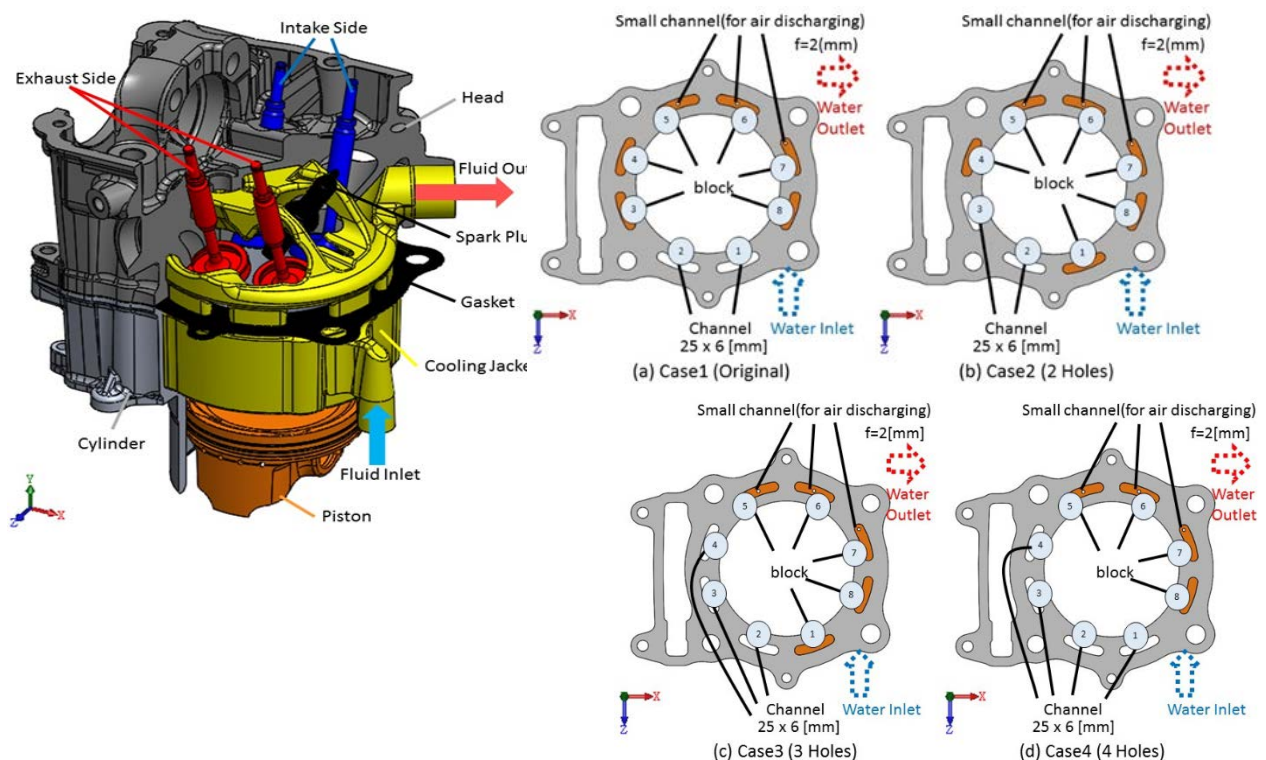


Fig.1 Physical model

Fig.2 Four different Gasket openings

. Each component of motorcycle engine is subjected to hot gases with gas temperature and heat transfer coefficient by Newton's law of cooling. To investigate the effects of

different gasket openings on the uniformity of the valve seat temperature, coefficient of variation is defines as:

$$V = \frac{\sqrt{\frac{\sum (T_i - \bar{T})^2}{n}}}{\bar{T}} \times 100(\%) \quad (1)$$

In this study, the governing equations are solved numerically using a control volume based finite difference formulation, ANSYS FLUENT [6]. The convergence criterion is satisfied when the residuals of all variables are less than 1.0×10^{-7} . Computations were performed in parallel calculation, and the computer consummation time is around 2 hours.

3.Results and Discussion

The experimental data of Case 1 are provided by the locomotive manufacturer. It is found that the calculated temperature data are in good agreement with experimental data within 20%. This verifies our theoretical model and numerical accuracy. The water volume flow rate and flow field for different gasket openings are shown in Table 1 and Fig 3, respectively. It is seen that as the number of the hole on the gasket is increased from 2 to 4, the flow rate is increased up to 18.30 %. After the water flows into the water jacket, fluid is divided into two parts. For Case 1, about 50% of the water flow rate enters the cylinder head through hole 1 in the clockwise direction, while about 37% enters the cylinder head through hole 2 in the counterclockwise direction. There is vortex between the hole 1 and hole 2. For Case 2, the flow rate is increased by 3.57% compared to the original design. About 50% of the water flow rate enters the cylinder head through hole 1, while about 46% enters the cylinder head through hole 2.

The heat transfer coefficient distribution and average heat transfer coefficient for different gasket openings are shown in Fig 4 and Table 2, respectively. It is interesting to note that for cases 3 and, 4, both water flow rates are increased due to the gasket opening holes are increased compared to case1, while the corresponding average heat transfer coefficients are reduced around 3%. For case 2, the average heat transfer coefficient is increased by around 6 %. For the original design of Case1, there is low h value under the gas exhaust side because there is vortex between hole 1 and hole 2. One can observe that the local heat transfer coefficient around the gas exhaust side is more uniform for case 2 compared to Case1. For cases 3 and 4, the local heat transfer coefficients are increased only around the gas intake side.

The temperate distributions of the cylinder head for different gasket openings are shown in Fig. 5. The highest temperature region appeares between the two exhaust valve seats in a combustion chamber. It is also seen that , case 2 has the lowest low and most uniform temperature distribution around the region of exhaust valve seats. Table 3 shows the exhaust

valve seat mean temperature and coefficient of variation for different gasket openings. It is seen that for case 2, its has the minimum exhaust mean temaperaure and coefficient of variation.

Table 1 water flow rate for case1 to 4

	\dot{Q} (L/min)	V_{in} (m/s)	$\frac{\dot{Q} - \dot{Q}_{case1}}{\dot{Q}_{case1}}$ (%)
Case 1	28.0	2.04	-
Case 2	29.0	2.11	3.57
Case 3	32.5	2.37	16.07
Case 4	33.1	2.41	18.30

Table 2. heat transfer coefficient for case1 to 4

	\bar{h} (W/m ² -K)	$\frac{\bar{h} - \bar{h}_{case1}}{\bar{h}_{case1}}$ (%)
Case1	8129.31	-
Case2	8667.56	6.62
Case3	7836.69	-3.61
Case4	7878.85	-3.08

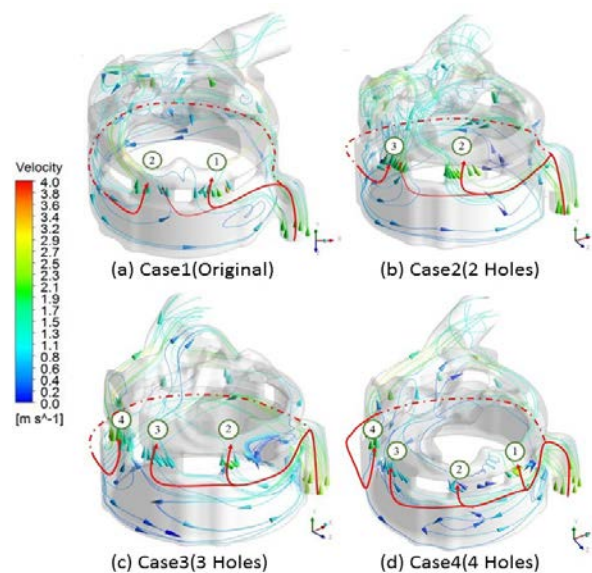


Table 3 Exhaust valve seat mean temperature and coefficient of variation for case1 to

	\bar{T}_{plug} (°C)	\bar{T}_{chain} (°C)	V_{plug} (%)	V_{chain} (%)
Case1	312.71	313.67	13.41	11.78
Case2	305.15	312.20	12.12	11.57
Case3	317.32	334.78	12.57	11.87
Case4	319.71	317.48	13.16	11.18

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Fig.3 Flow field for cases 1 to 4

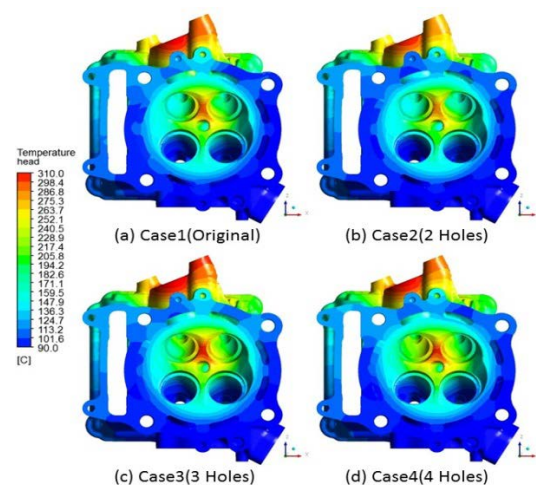
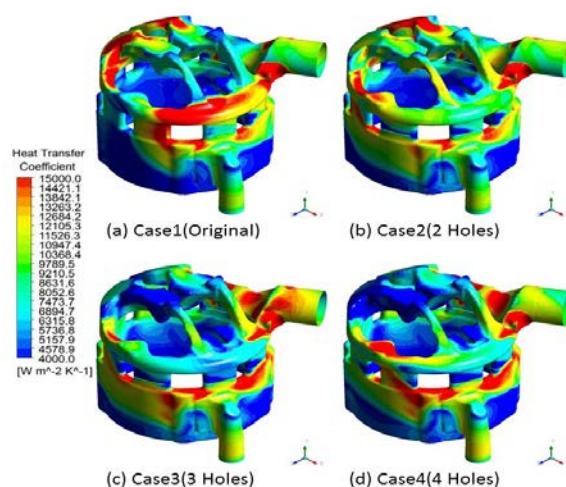


Fig.4 Heat transfer coefficient for cases 1 to 4 Fig.5 cylinder head temperature for cases 1 to 4

4. Conclusion

This study investigated the effects of different cylinder head gasket opening on the engine temperature distributions in a water-cooled motorcycle engine. Compared to the original design of case 1, the water volume flow rate for case 2 is increased by 3.57 %, and the average heat transfer coefficient is increased by around 6 %. For cases 3 and 4, the water flow rates are increased by 16 to 18 %, while, the average heat transfer coefficients are reduced by around 3 %. Case 2 has the lowest and most uniform temperature distribution around the region of exhaust valve seats.

5. Acknowledgements

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6. References

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