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The Optimization Analysis of Diesel Engine Intake Manifold based on UG and FLUENT

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ABSTRACT:- In this paper, the software FLUENT is used to make three-dimensional flow field simulate of a kind of diesel engine intake manifold. At the same time, the flowing characteristic of internal manifolds are analysed，comparative analysis of the two kinds of intake manifold structure of the exit velocity, manifold air flow velocity and turbulence kinetic energy. The results show that narrow the distance between the manifold is good to improve diesel engine intake uniformity of each cylinder, and the performance of the engine will be improving with the volume increasing.

I. INTRODUCTION

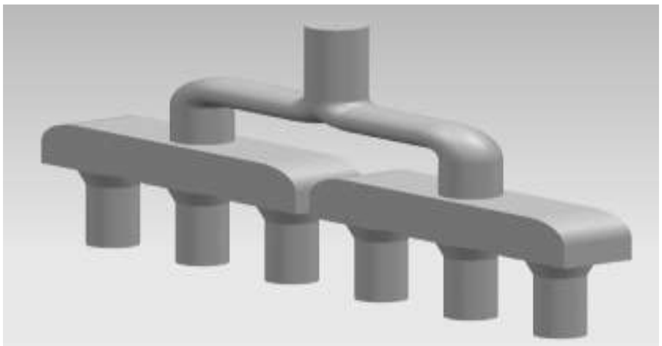
For the multi-cylinder engine, it is difficult to get the the best ignition advanced angle and excess air coefficient of each cylinder because of the existence of inhomogeneous cylinders working, as a result, it makes the power, economic, emission characteristics hard to optimize, what is more, the noise and vibration will also be increased. Due to the improper design of the intake manifold, the dynamic effects of intake pipes and the cylinder intake overlap interference, this lead to the actual cylinder charging coefficient inhomogeneous. Therefore, structure parameters and layout of the intake system will directly affect the engine combustion quality and the performance of the engine.

The air movement in the air intake system of the engine is usually regarded as compressible, non-isentropic, unsteady flowing and complex, the simulation software FLUENT is used for the analysis of three dimensional flow field of the model, through contrasting the velocity contours and the turbulent kinetic energy images, some targeted measures will be provided to optimize the structure of the intake manifold, as a result, the intake uniformity and the intake charge can be improved, the performance of engine will become better, too.

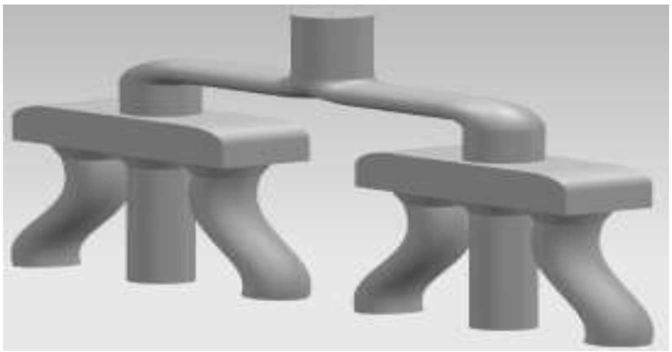
Ⅱ.MODEL ESTABLISHMENT AND CRITICAL CONDITION

A. MODEL ESTABLISHMENT

In this paper, the intake manifold of 4.0L diesel engine as the object of study, its rated power and rated speed are 94kW and 1600r/min, respectively. At first, two kinds of three-dimensional model of inlet pipe system are built by UG software, and the model is simplified in order to make our work convenient. the intake manifold model of three-dimensional map of simplified as shown in Figure 1 (a), the intake manifold is composed of inlet manifold, resonance box, manifold. Intake manifold improved as shown in Figure 1 (b). The difference between them is that there is a certain distance between manifolds in the former, but it is smaller in the latter, what is more, the shape also has bigger change.



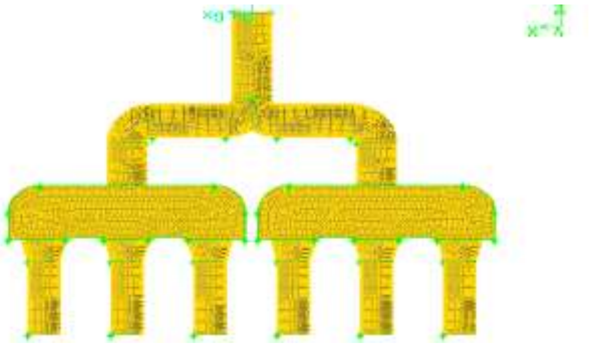
(a) The diesel engine intake manifold before improvement



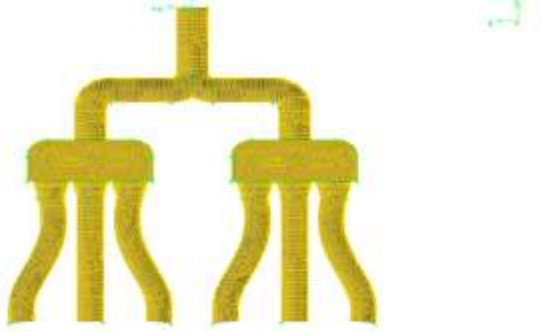
(b) diesel engine intake manifold after improvement

Figure 1 Three-dimensional model diesel engine intake manifold

The model is imported into GAMBIT software to mesh, and tetrahedral mesh is adopted. The finite element model can be obtained as shown in Figure 2, figure 2 (a) has in a total of 452431 grids, Fig. 2 (b) has in a total of 485413 grids.



(a) Before improvement



(b) After improvement

Figure 2 The finite element model diesel engine intake manifold

B. CRITICAL CONDITION

Diesel engine rated speed of about 1600r/min are maintained. In the process of calculation, we assume that the density of air is 1.29 kg/m^3, the critical condition of entrance pressure and outlet pressure is used in the import and export, and the wall surface with no slip boundary condition. We suppose that air motion of the air intake system is steady turbulent flow of incompressible viscous fluid in the explosion-proof diesel engine. The k-ε turbulence model can be used for flow model. The critical conditions are shown in table 1.

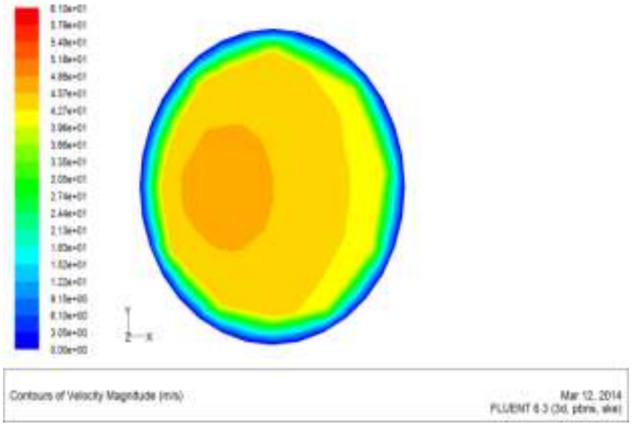
Table1 Boundary conditions of parameters

Wall surface teperature (K)	entrance pressure (kpa)	outlet pressure (kpa）	density of air (kg/m^3)	Kinematic viscosity (m^2/s)	Rotate speed (r/min)
420	86.3	89.3	1.25	1.51×10^{-5}	1600

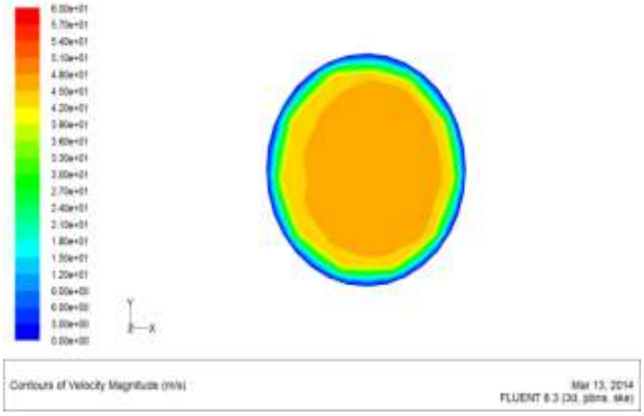
Ⅲ. FLOW FIELD ANALYSIS

A. VELOCITY ANALYSIS OF INTAKE MANIFOLD EXIT

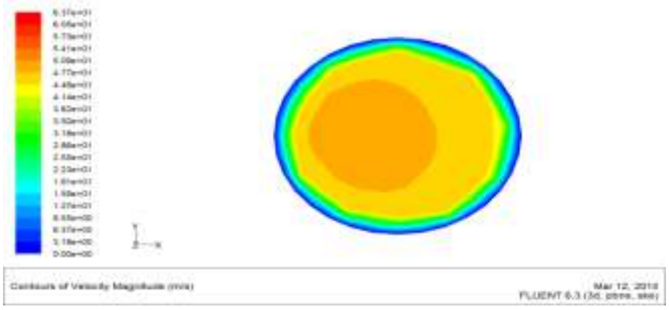
The before and after improvement model is impoered into FLUENT to simulat, because the model is bilateral symmetry about the axis of inlet manifold, we can just need the simulation of one side.



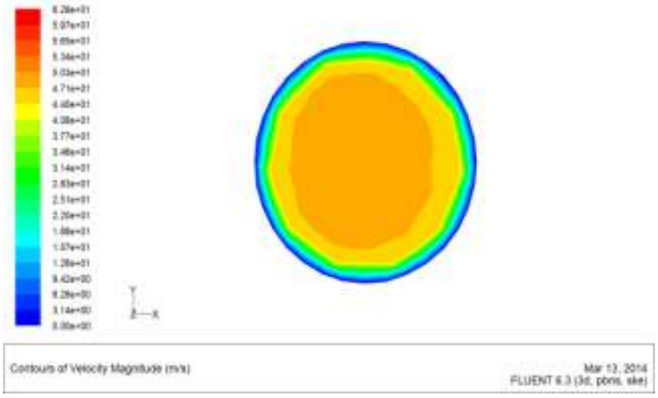
(a) No. 1 intake manifold before improvement



(b) No. 1 intake manifold after improvement



(c) No. 3 intake manifold before improvement



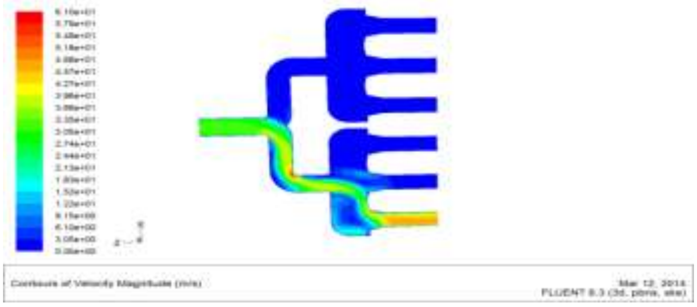
(d) No. 3 intake manifold after improvement

Figure 3 Diesel engine intake manifold exit of the velocity distribution cloud

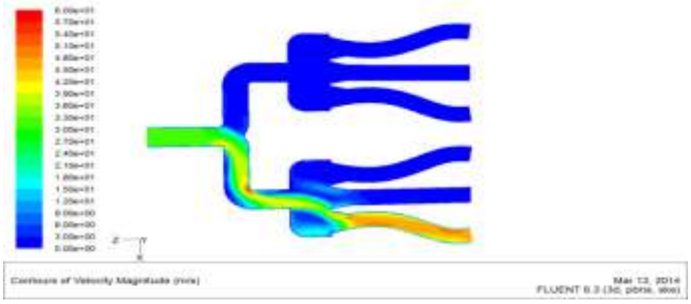
Figure 3 is the velocity distribution cloud of intake manifold exit, it can be seen that the gas velocity surrounding the intake manifold is almost not changing, it indicates that the improved manifold wall surface friction resistance has little change, therefore, we can consider it is the same effect on the flow friction in two ways. After improvement, the speed of each manifold are increased than before, that is because the volume of resonant box is reduced after improvement, with the resonant box volume reducing, the gas pressure difference gradually increases, all these have great benefits to improve overall engine volumetric efficiency. However, after improvement, with the intermediate velocity manifold increasing, although the air intake will be raised, the air intake system in air distribution is worse than before.

B. VELOCITY ANALYSIS OF DIESEL ENGINE INTAKE MANIFOLD

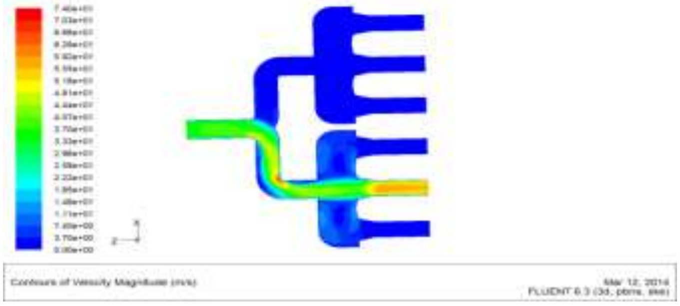
From Figure 4 we can see, before the intake manifold improvement, while gas flowing to NO.1 and NO.3 manifold, a speed reduction "dead zone" in the left and right "shoulder" of intake manifold resonant box appears, it is equal to decrease the flowing cross-sectional area. This phenomenon is caused by the unreasonable design of intake manifold resonant tank. When gas enters into the resonant tank from inlet manifold, the flowing sectional area suddenly increases, the resonant tank can not be immediately filled by gas, so the "dead zones" in left and right side of resonant tank is easily coming into being. The circulation path close to the vertical direction is short, on the contrary, deviating from the vertical direction is longer. When gas flows into NO.2 cylinder, the distance is short, however, the distance is longer while gas flowing into NO.1 and NO.3 cylinder, what is more, the "dead zones" exists in the edge. This is the reason why the intake air quantity of NO.2 is more than the other two.



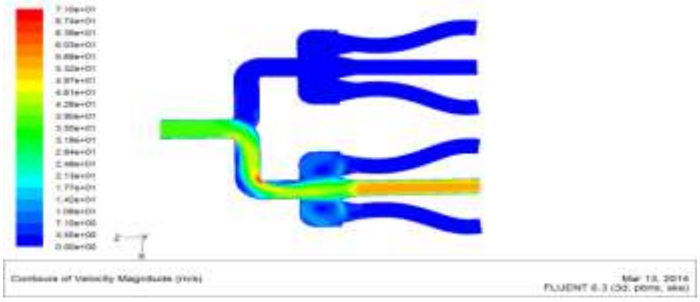
(a) No. 1 intake manifold before improvement



(b) No. 1 intake manifold after improvement

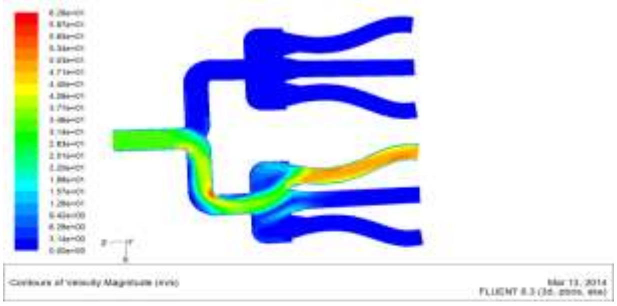


(c) No. 2 intake manifold before improvement



(d) No. 2 intake manifold after improvement

(e) No. 3 intake manifold before improvement



(f) No. 3 intake manifold after improvement

Figure 4 Diesel engine intake manifold of the velocity distribution cloud

The distance is narrowed between a resonant tank cylinder and cylinder after improvement of the manifold which can reduce the resonant box volume. With the volume decreasing, gas will be filled with resonant tank more faster, the area of "dead zone" is relatively reduced, flow area will be also relatively increased, which helps to improve the gas mass flow rate. Secondly, due to the smaller volume and shorter length of the resonance box, while gas flowing into NO.1 and NO.3 manifold, the fluid loss along the way will be reduced, it will also enhance the amount of intake gas, as a result, the uniformity of the inlet can be improved.

Ⅳ. SIMULATION RESULTS AND ANALYSIS

The maximum non-homogeneous E is used to indicate intake air inhomogeneity of engine,

$$E = \frac{Q_{max} - Q_{min}}{Q_{me}}$$

In this formula, Q_{max} —the maximum export mass flow of the manifold; Q_{min} —the minimum export mass flow of the manifold; Q_{me} —mean mass flow. The intake manifold is bilateral symmetry about the axis of inlet manifold, so we can just calculate uniformity of the air intake about the first three cylinder.

Table 2 Before improved the intake manifold of the mass flow rate

Manifold No.	No.1	No.2	No.3
Mass Flow（g/s）	100.06	117.02	103.58

Table 3 After improved the intake manifold of the mass flow rate

Manifold No.	No.1	No.2	No.3
Mass Flow（g/s）	108.02	114.39	106.25

We can see the air intake uniformity is worse before improvement according to the calculation of the formula, it is up to 19.48%. After improvement, it is down to 12.47%. At the same time, each corresponding manifold mass flow rate are increased, so that we can make the diesel engine burn more fully, and the emission of pollutants will cut down.

Ⅴ. CONCLUSION

Through three-dimensional numerical simulation about two kinds of intake manifolds, and the velocity distribution cloud is used to analyze the inlet flow field, the results show that: when gas enters into the resonant tank from inlet manifold, the flowing sectional area suddenly increases, the resonant tank can not be immediately filled by gas, so the "dead zones" phenomenon in left and right side of resonant tank is easily coming into being, the circulation area of the air flow will be influenced. With the resonant box volume increasing, the fluid loss along the way of both sides manifold will be also increased. Therefore, narrowing the distance between the manifold, reducing the resonant box volume, gas will be filled with resonant tank more faster, decreasing the fluid loss along the way, and improving the amount of intake gas, the uniformity of the inlet and intake efficiency, it is good to boost the burning quality of the engine.

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