Static pressure simulation for air intake manifold

Hao Wang [1]

Abstract: Pressure loss plats an important role for engine performance, therefore, it is very necessary for air intake manifold designer to do the simulation and test for it. A standard for simulation has been discussed and compared with the testing results which show that the standard is applicable for air intake manifold pressure loss simulation. For validation, a manifold has been applied for simulation and testing correlation.

Key word: Air intake manifold, pressure drop

1.0 Introduction:

Simulation has been proved that it is a very powerful tool for design, especially for intake and exhaust manifold design of automotive industry with the purpose of saving time, money and other costs. Consequently, a lot of automotive companies have developed their own method for CAE prediction. As one of the leading companies in component suppliers, MAHLE also defined our own standard for simulation and testing for every product [1], and test bench as well for simulation correlation. As for the air intake manifold, here, the simulation and testing methods are presented.

1.1 Boundary condition for simulation:

The sketch map of a manifold is shown in Fig.1. For comparison, the runner number has been defined as below:

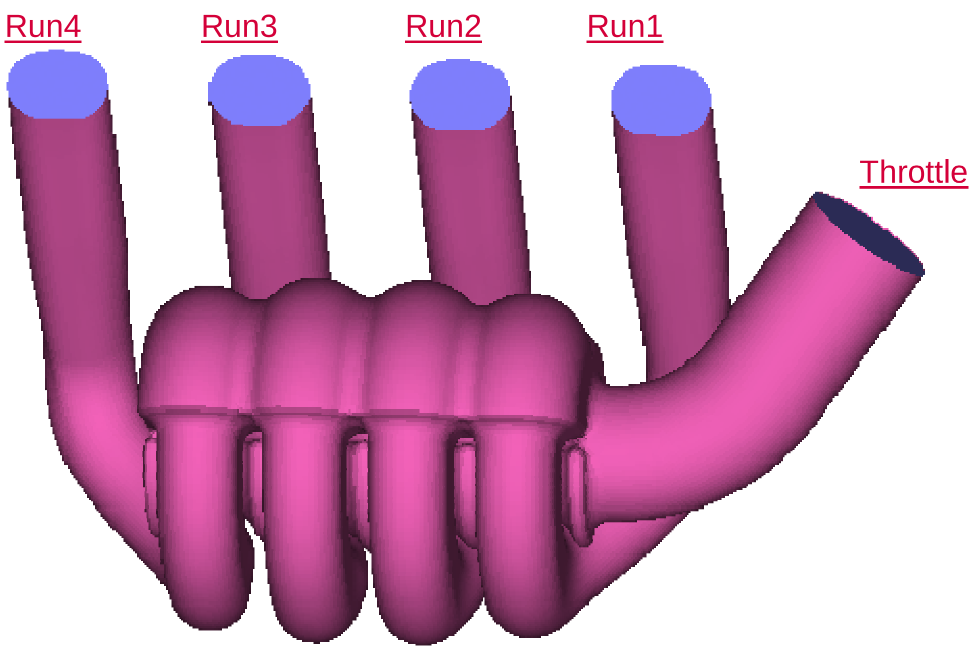

Fig.1 Sketch map of manifold

During the engine work, the manifold always has only one runner open and others closed, so here in simulation, only 1 runner and manifold is opened with the rest runners are closed And the pressure drop of manifold will calculate 4 times for every runner.

1.1.1 B.C for runners

Since the air travels from the throttle body tube to the plenum where the air is distributed into 4 runners and then goes into cylinder, in the simulation, velocity boundary condition has been applied,

The velocity of each runner is decided by the flow rate of engine RPM, usually the rated RPM is applied with a volumetric efficiency[2]. A short description for VE can be seen from Fig.2

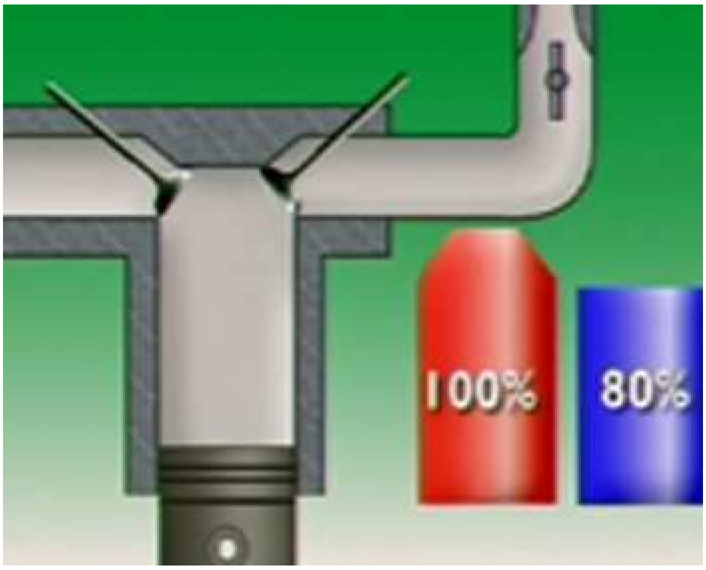

Fig.2 VE discription

1.1.2 B.C for throttle body

Air which travels through the throttle body come from the air cleaner system, but it is pretty difficult to define the pressure of it. So here ambient pressure defined at the throttle body. Usually, the pressure is 101300 pa is defined here.

1.1.3 Temperature and humidity

Since the testing is performed at room temperature and 50% humidity, to get a good correlation, the same temperature and humidity are also defined in simulation. And according to the simulation analysis, the temperature and humidity doesn’t play an import role in the pressure drop simulation results.

1.1.4 Model modification

As for the plastic component, surface is very smooth and fine, so the boundary layer isn’t that much for simulation, but for the aluminum ones, since the surface is very rough, so a different method has to be applied for the surface roughness definition.

But it is pretty difficult for CFD to perform the rough surface processing, consequently, a bit more thick boundary layer has to be defined. As for the plastic component, boundary should not be more than 1 mm. But for the aluminum ones, the boundary layer must be defined more than 3.1mm for a better correlation between simulation and testing.

1.2 Testing methods

Since the inlet of throttle body would lead to a big pressure drop without any flow fixture, so here a bell mouth is applied which can be seen from the Fig.2. With a well designed bell mouth, artificial pressure drop of throttle body inlet could be reduced to 50pa, which shows a good ideal flow fixture.

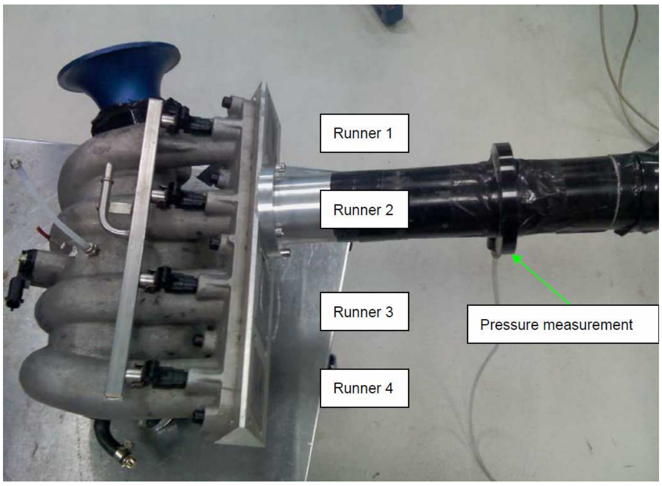

Fig.3 testing setup

1.3 Simulation results

As mentioned above, the pressure loss of manifold is the basic item for CFD simulation, so here, the pressure drop of simulation and testing for manifold is displayed below:

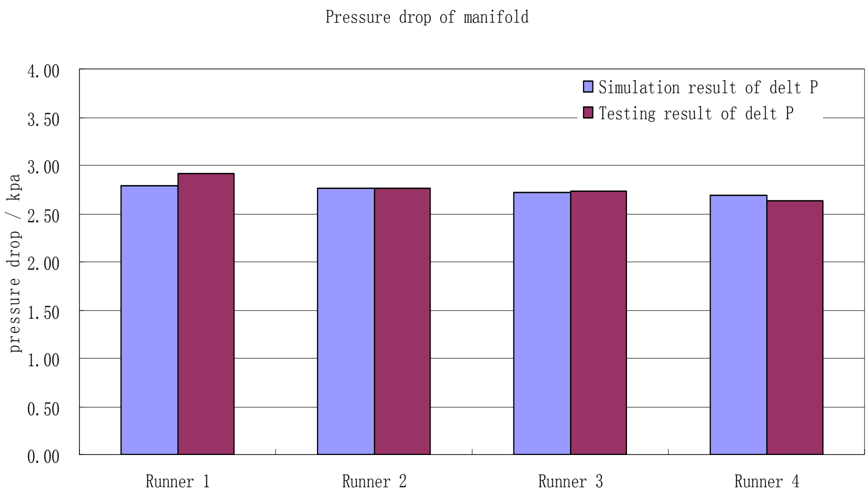

Fig.4 Pressure drop correlation

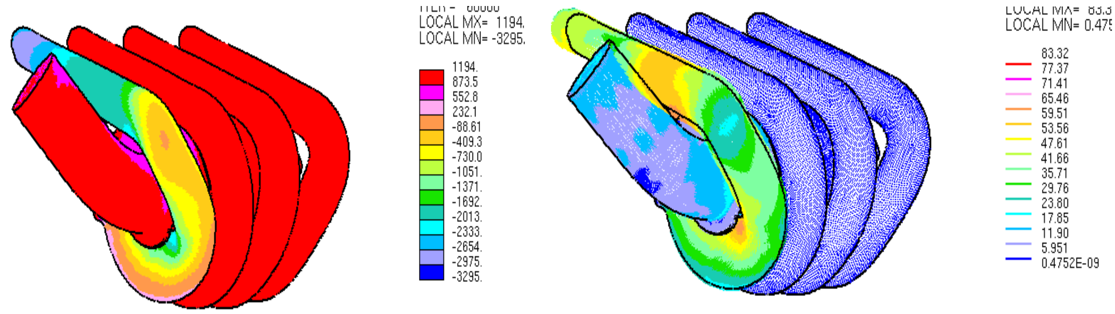

Fig.5 Velocity and pressure distribution for Runner 1

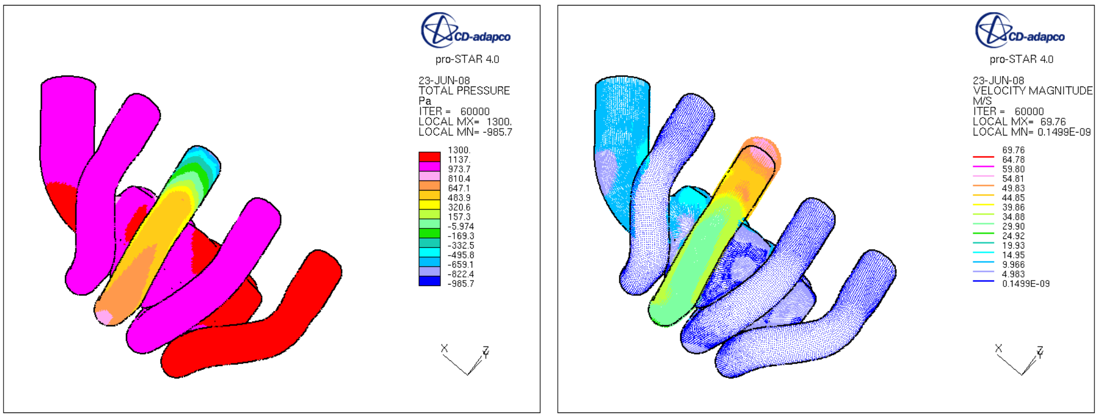

Fig.6 Velocity and pressure distribution for Runner 2

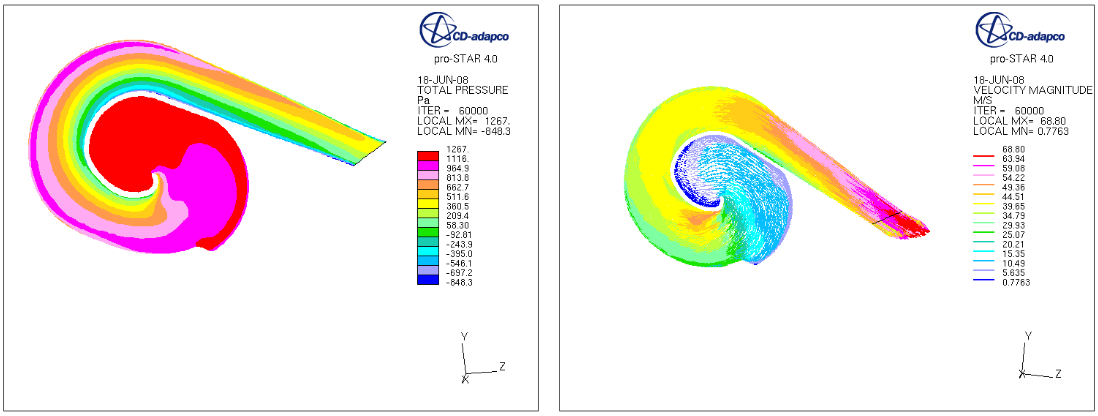

Fig.7 Velocity and pressure distribution for Runner 3

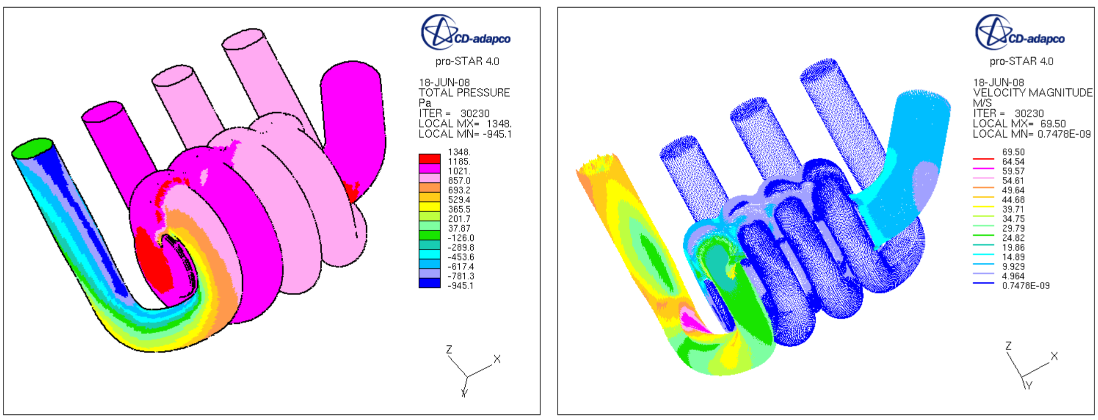

Fig.8 Velocity and pressure distribution for Runner 4

It can be seen from the comparison in Fig.4-8, the standard defined above shows us a good correlation between simulation and testing. So this can be applied for other components.

Reference

[1] MAHLE testing standard
[2], Advanced engine technology, Heinz Heisler, 2003