ISSN 2616-5767 Vol.3, Issue 4: 109-120, DOI: 10.25236/AJETS.2020.030411

The Optimize Design of Limiting Valve in FSAE Racing

Xiaolong Cheng, Bo Wu*, Bangzhen Huang, Feng Tian, Li Zhi

Harbin University of Science and Technology, School of Mechanical & Power Engineering, Harbin, China
ChengXiaoLong658@163.com

ABSTRACT. The gist of this paper is to optimize the design of the intake valve of the FSAE racing car so as to improve the intake efficiency of the engine. First, compare the flow limiting valves with different outlet cone angles in FLUENT to select the best outlet cone Angle. Then, in order to optimize the flow limiting valve structure, the finite element analysis of the flow limiting valve was carried out in UG. This paper provides a reference method for the design of the limiting valve of FSAE racing car.

KEYWORDS: *FSAE, limiting valve, optimized design*

1. Introduction

Formula SAE is an automobile design and manufacture competition organized by college students majoring in automobile engineering or related majors. Each team was given a year to design and build a small, one-seater recreational car with excellent acceleration, braking and handling, according to race rules and race car manufacturing standards.[1]

In order to limit the power of the engine, the organizing committee stipulated that a flow-limiting valve with a circular internal section and a maximum diameter of 20mm should be installed between the throttle of the intake system and the engine. It is required that the intake air of all engines should flow through this limiting valve.[2] The intake valve has a great influence on the overall performance and intake efficiency of the racing engine, which directly affects the result of the race.[3] In summary, the optimal design of intake valve is of great significance for

ISSN 2616-5767 Vol.3, Issue 4: 109-120, DOI: 10.25236/AJETS.2020.030411

the performance improvement of FSAE racing car.

2. Design parameters and modeling of flow limiting valve

2.1 Design parameters of valve

The main advantage of the venturi is its simplicity. The influence of inlet cone Angle on inlet efficiency is small, while that of outlet cone Angle is large, generally controlled within 10°.[1] Set the inlet diameter of the limiting valve at 50mm and keep it unchanged. The length of the valve is arranged in a reasonable extension of the premise as far as possible. In order to simplify the process, the length of the valve is set as 150mm.The main design parameters of the valve are shown in figure 1. α is Exit cone Angle, d is Valve wall thickness, R is Fillet radius.

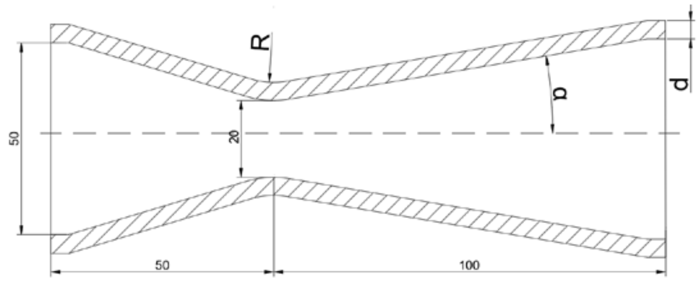

Figure. 1 main parameters of Valve

2.2 Valve modeling

The initial wall thickness is 5mm, the initial fillet radius is 5mm, and the outlet cone angles are 4°, 6°, 7°, 8° and 10° respectively. The flow-limiting valve model is built in UG. Taking 4° exit cone Angle as an example, its 3d model is shown in figure 2.

ISSN 2616-5767 Vol.3, Issue 4: 109-120, DOI: 10.25236/AJETS.2020.030411

Figure. 2 3D valve model

3. Determine the outlet cone angle of the limiting valve

3.1 Fluent meshing

Contrast outlet cone Angle for 4°, 6°, 7°, 8°, 10° valve. The flow-limiting valve data was imported into the MECH module in FLUENT for grid division. The intake system grid is divided by unstructured grid. The fluid domain adopts Sweep grid. The boundary layer is set as 5 layers, the first layer is 0.5mm, and the growth rate is 3.2. There were 87,598 nodes and 20,784 individuals. Since the fluid analyzed is air, the compressibility of the gas is much greater than that of the liquid, so it is treated as a compressible fluid. Furthermore, the fluid motion form is turbulence, and the modified k-epsilon model is adopted. The boundary conditions are set as follows：

inlet Pressure： 101325Pa.

Export pressure： 0Pa.

Residual set: 0.001.

3.2 Simulation comparative analysis

After the mesh is divided, the flow velocity and pressure cloud images of the outlet cone Angle limiting valves are obtained by fluid simulation as shown below：

ISSN 2616-5767 Vol.3, Issue 4: 109-120, DOI: 10.25236/AJETS.2020.030411

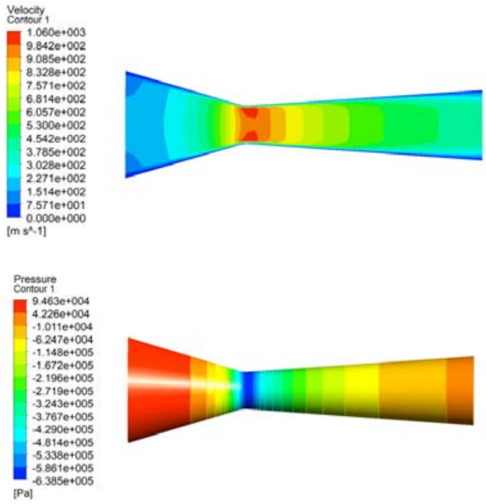

Figure. 3 4°Flow velocity and pressure cloud diagram of outlet cone Angle limiting valve

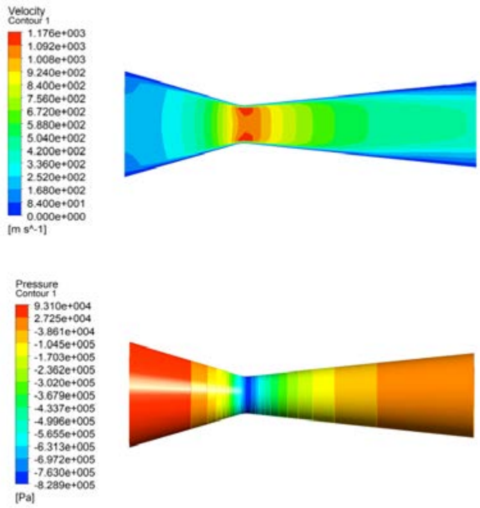

Figure. 4 6°Flow velocity and pressure cloud diagram of outlet cone Angle limiting valve

ISSN 2616-5767 Vol.3, Issue 4: 109-120, DOI: 10.25236/AJETS.2020.030411

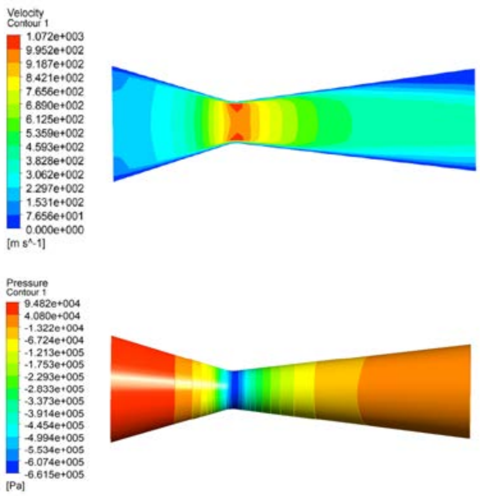

Figure. 5 7°Flow velocity and pressure cloud diagram of outlet cone Angle limiting valve

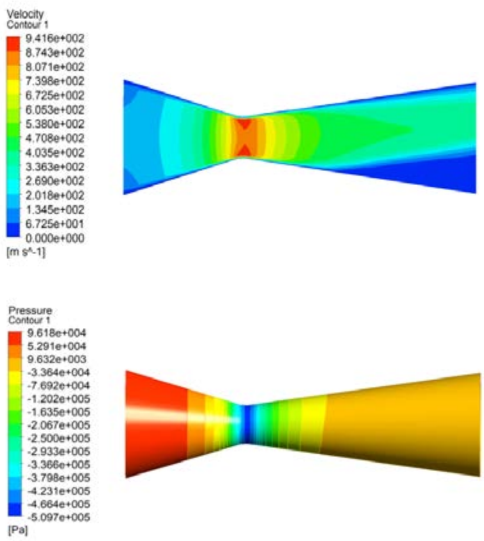

Figure. 6 8°Flow velocity and pressure cloud diagram of outlet cone Angle limiting valve

ISSN 2616-5767 Vol.3, Issue 4: 109-120, DOI: 10.25236/AJETS.2020.030411

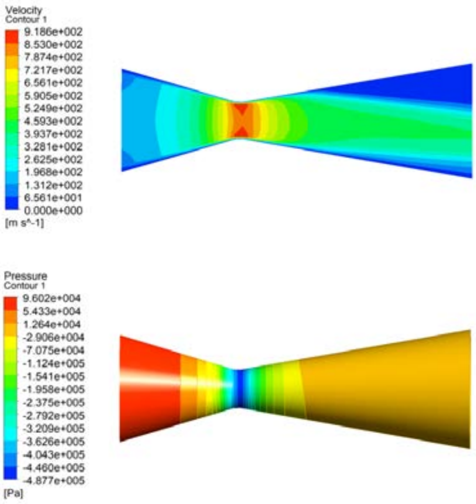

Figure. 7 10°Flow velocity and pressure cloud diagram of outlet cone Angle limiting valve

Among them, the three indexes of outlet flow rate, maximum flow rate and pressure loss have great influence on the engine inlet efficiency [4]. Data were sorted out, as shown in Table 1.

Table 1 Data contrast

Exit cone Angle	Outlet flow /(kg/s)	The highest velocity /(m/s)	The pressure loss /Pa
4°	0.26185	1.06E+03	5.24E+04
6°	0.29469	1.18E+03	5.33E+04
7°	0.26882	1.07E+03	5.40E+04
8°	0.24034	9.42E+02	8.52E+04
10°	0.23847	9.19E+02	8.34E+04

Table 1 shows that. The pressure loss increases with the increase of outlet cone Angle. When the outlet cone Angle is less than 7°, there is little difference in the pressure loss value, and when the outlet cone Angle is greater than 7°, the pressure loss value suddenly changes. Therefore, if the outlet cone Angle is too large in the design of flow limiting valve, it will lead to greater pressure loss and lower inlet efficiency. It can be seen that when the outlet cone Angle is 6°, the outlet flow rate

ISSN 2616-5767 Vol.3, Issue 4: 109-120, DOI: 10.25236/AJETS.2020.030411

and the maximum flow rate of the limiting valve are the largest. So, we determine the best outlet cone Angle of the valve is 6°.

4. Finite element force analysis of limiting valve

4.1 Meshing

After determining the outlet cone Angle of the valve, it is necessary to consider whether the force is reasonable. The stress concentration and the overall stress of the valve are analyzed, and the structural parameters of the valve are further optimized.

First, import the model into UG. The valve mesh is divided by 3D tetrahedral mesh. The boundary layer is set as 10 layers, the first layer is 0.5mm, and the growth rate is 1.2. Finally, there are 9,404 nodes and 4,607 individuals. The meshing diagram of the valve is shown below.

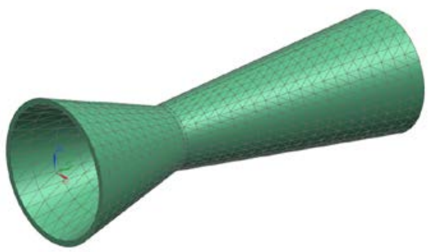

Figure. 8 Grid diagram of flow limiting valve

4.2 Stress analysis of flow limiting valve

4.2.1 Stress concentration

After grid division, the results show that the outlet cone Angle is 6°, the fillet radius is 5mm, and the wall thickness is 2mm.The structural stress diagram of the valve is shown below.

ISSN 2616-5767 Vol.3, Issue 4: 109-120, DOI: 10.25236/AJETS.2020.030411

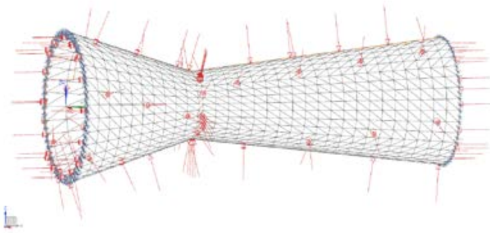

Figure. 9 The fillet radius is 5mm and the wall thickness is 2mm

The stress concentration can be seen at the inlet of the limiting valve. The influence of fillet radius and wall thickness on stress concentration is studied experimentally. Change the fillet radius of the limiting valve only. The results show that this has a great influence on stress concentration. The structure stress diagram when the fillet radius becomes 20mm is shown in Fig.10.

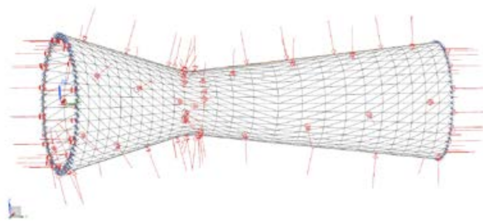

Figure. 10 The fillet radius is 20mm and the wall thickness is 2mm

Keep the fillet radius of the limiting valve unchanged, change its wall thickness, observe the change of the structure force. The results show that the wall thickness of the limiting valve has little effect on the structure stress. When the wall thickness of the flow limiting valve is 4mm, the obtained structure stress diagram is shown in Fig.11.

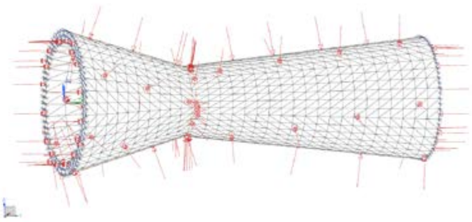

Figure. 11 The fillet radius is 5mm and the wall thickness is 4mm

4.2.2 Stress analysis of flow limiting valve

Further study when the valve normal operation, its overall stress. When the fillet radius of the limiting valve is 5mm and the wall thickness is 2mm, the stress cloud diagram is shown in the following Fig.12.

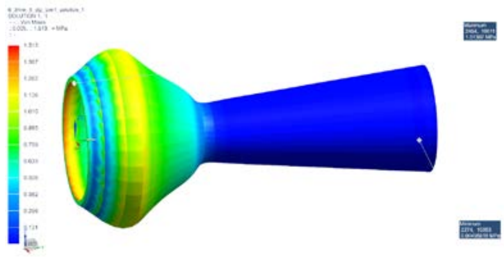

Figure. 12 The fillet radius is 5mm and the wall thickness is 2mm

As can be seen from Fig.12, the maximum stress on the valve wall is 1.51307MPa. Now keep its wall thickness unchanged, change its fillet radius. It can be found that the fillet radius has little effect on the finishing stress of the limiting valve. The stress cloud diagram of the limiting valve when the fillet radius is 20mm and the wall thickness is 2mm is shown in Fig.13.

ISSN 2616-5767 Vol.3, Issue 4: 109-120, DOI: 10.25236/AJETS.2020.030411

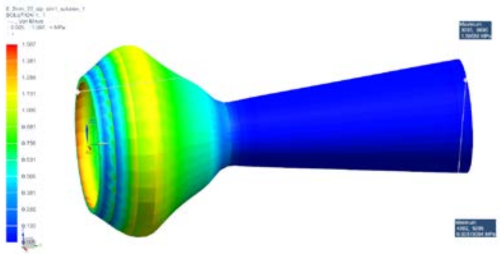

Figure. 13 Fillet radius 20mm, wall thickness 2mm

Keep the fillet radius of the limiting valve unchanged and change its wall thickness. The results show that the wall thickness has a great influence on the overall stress of the valve. The stress cloud diagram of the flow-limiting valve when the fillet radius is 5mm and the wall thickness is 4mm is shown in the following figure.

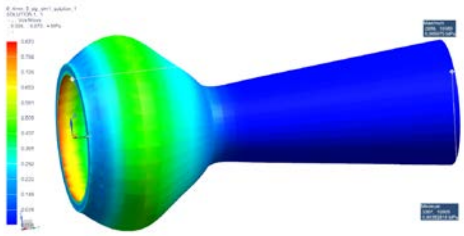

Figure. 14 The fillet radius is 5mm and the wall thickness is 4mm

As can be seen from Fig.14, the maximum stress of the flow limit valve wall decreases to 0.869975MPa. The overall stress cloud map is smoother than that in Fig.12.

4.2.3 Result

In summary, increasing the fillet radius of the limiting valve can solve the stress concentration. Thickening of the wall makes the pressure of the valve more uniform during normal operation. But the thicker the wall, the heavier the weight and the higher the cost. After comprehensive consideration, the chamfered Angle radius of the valve is determined to be 20mm and the wall thickness to be 4mm.The structure stress diagram and stress cloud diagram are shown below.

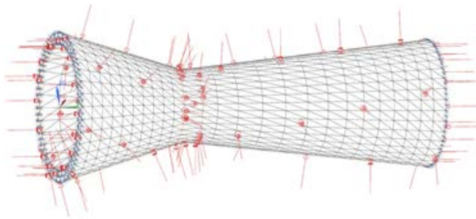

Figure. 15 The fillet radius is 20mm and the wall thickness is 4mm

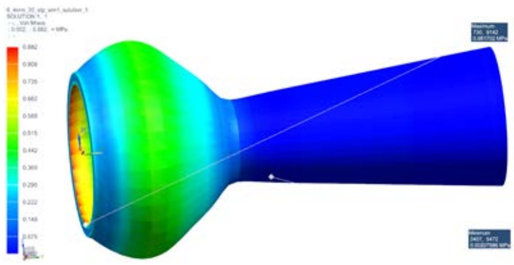

Figure. 16 The fillet radius is 20mm and the wall thickness is 4mm

5. Conclusion

In this paper, fluid simulation and force analysis are used to optimize the limiting valve of FSAE racing car so as to improve the intake efficiency of the engine. First of all, the flow limit valves with various outlet cone angles were simulated with FLUENT to compare the three indicators of outlet flow rate, maximum flow rate and pressure loss. Finally, the optimal outlet cone Angle of the valve was determined to be 6°.Then the finite element analysis of the limiting valve was carried out in UG, and it was found that the fillet radius of the limiting valve was 20mm and the wall thickness was 4mm.This paper provides a reference method for optimal design of FSAE racing valve.

ISSN 2616-5767 Vol.3, Issue 4: 109-120, DOI: 10.25236/AJETS.2020.030411

References

[1] Jian Wang, Lin Haiying, Liang Yinghua, Zhou Wenli. Formula racing design for college students[M]. 2017: 1-2,179-181.
[2] Organizing Committee of China University Student Formula Car Competition. Rules of Formula One Chinese University Student Competition[M]. 2018: 1-20.
[3] Xu Jun. The optimization and simulation of intake system for the FSAE racing based on intake limiting[D]. 2012: 66-70.
[4] Feng Yong，Yang Lin，Peng Renjie. Zhou Yongguang. Comparative Simulation Analysis of FSAE Racing Air Intake Restriction Valve [J]. 2013: 9-18.