INTERNATIONAL JOURNAL OF RESEARCH IN AERONAUTICAL AND MECHANICAL ENGINEERING

ISSN (ONLINE): 2321-3051

Vol.4 Issue 7, July 2016

Pgs: 10-18

Internal flow field and noise analysis of two-step throttle valve of natural gas wellhead

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Abstract

Throttle valve is the main equipment of natural gas wellhead throttling and pressure reducing. The natural gas will be throttled and pressure reduced by two-step throttle valve after come out of christmas tree. Two-step throttle valve is the sound source of the noise in natural gas well. In this paper, the numerical simulation of the two types of throttle valve and the internal flow field and noise were analyzed. The results show that: there are vortexes in the fluid flow in the outlet section of the throttle valve, and decreases with the increase of the distance from the throttle hole; the average outlet speed of 4 1/16 "throttle valve is 58.88% less than the average outlet speed of 3 1/16" throttle valve, thus the generated noise of 4 1/16 "throttle valve is much smaller theoretically.

Keywords: natural gas, throttle valve, numerical simulation, noise pollution

1. Introduction

Throttle valve is the main equipment of natural gas wellhead throttling and pressure reducing. The natural gas will be throttled and pressure reduced by two-step throttle valve after come out of christmas tree. Two-step throttle valve is the sound source of the noise in natural gas well. In two-step throttling, the role of the first throttling is to regulate the flow, the second throttle is used for regulating the pressure of the starting point. Therefore, this paper aims at the second throttle valve and analysis its internal velocity.

2. Pneumatic theory of throttle valve

The throttle and pressure reduction process of natural gas through the throttle valve is an irreversible gas expansion process, and its principle is shown in Figure 1.

Figure 1 Throttle process principle

When the absolute pressure of the inlet of the throttle valve P1 and the absolute pressure of the outlet of the throttle valve P2 are equal, the natural gas is in a static state; In the case of P1 and throttle valve opening degree stay constant, if the throttle valve outlet pressure P2 is gradually decreased, then the natural gas flow

through the throttle valve will be gradually increased, the gas begins to flow in the subsonic flow state, and can reach the supersonic state through the throttle orifice; When absolute pressure ratio of the inlet and outlet reaches the critical pressure ratio[1], the flow will reach the maximum value, even lowered the throttle valve outlet pressure P2 will not improve the transient flow through the throttle valve, this effect is called blocking flow[2].

3. Noise generation mechanism of throttle valve

Throttle valve noise mainly includes two categories[3]: mechanical vibration noise and hydrodynamic noise. Mechanical vibration noise is the noise generated by the mechanical vibration, natural frequency vibration and fluid pressure fluctuation caused by the displacement of the throttle valve core, the reason of its production concern with the design of the throttle valve, parts manufacturing, processing technology[4], they are determined by the throttle valve itself. Fluid dynamic noise is generated by the turbulence and vortex which is produced by the flow of the fluid through the throttle valve, which also is the noise generated by the interaction between the turbulent fluid and the throttle valve or the inner surface of the pipe.

When the natural gas is going through the throttle valve sleeve cage and throttle valve outlet diameter expanding parts, vortex flow and turbulent will be generated due to changes in velocity and pressure, and vortex and turbulence due to its own characteristics and impact will change the fluid mechanical energy into sound energy, and the noise generated with that is called fluid dynamics noise[5]. The frequency of the noise is generally 1000~8000Hz, and there is no special sharp peak of the peak frequency. When the natural gas flows through the throttle valve is in a critical state at the throttle orifice, the natural gas flow rate will reach the speed of sound or even more than the speed of sound; But in the downstream of the throttle valve, due to the increase of space, the natural gas flow speed will be decreased, when the flow speed decreased from supersonic to subsonic, air pressure will be increased and generates shock wave in different direction. The shock wave is produced by the sudden change of the physical state (pressure, velocity, temperature) of the moving fluid, which is a special phenomenon of supersonic flow[6]. That pressure wave spreads at a speed close to the sound wave, in the spreading process, part of its energy will be transformed into heat energy, another part will be transformed into high frequency sound energy, which is the main source of throttle valve noise.

4. Internal flow field analysis of two-step throttle valve

4.1 Flow field analysis of 3 1/16 "10000Psi throttle valve

According to the actual working conditions in natural gas wellhead, there are basic parameters: two-step throttle inlet pressure is 29.8MPa, temperature is 89.93 ℃; outlet pressure is 7.13MPa, temperature is 65.19℃.When the throttle opening degree is 65%, the relative position of the plunger and the cage is shown in Figure 2.

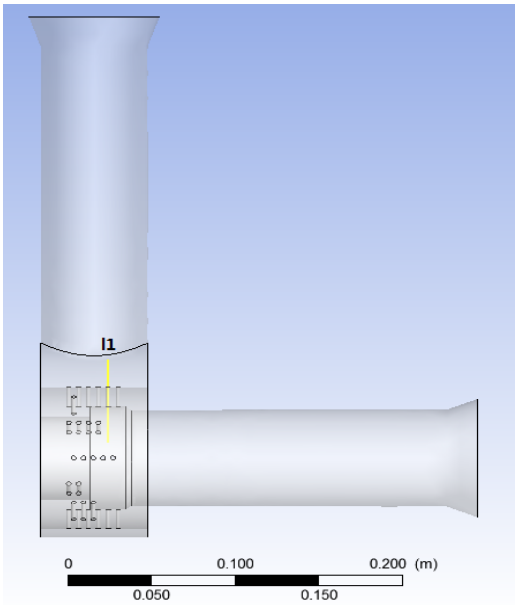

Figure 2 Plunger and cage position when the opening degree is 65%

According to the condition of opening degree 65%, the velocity contour was established as shown in Figure 3.

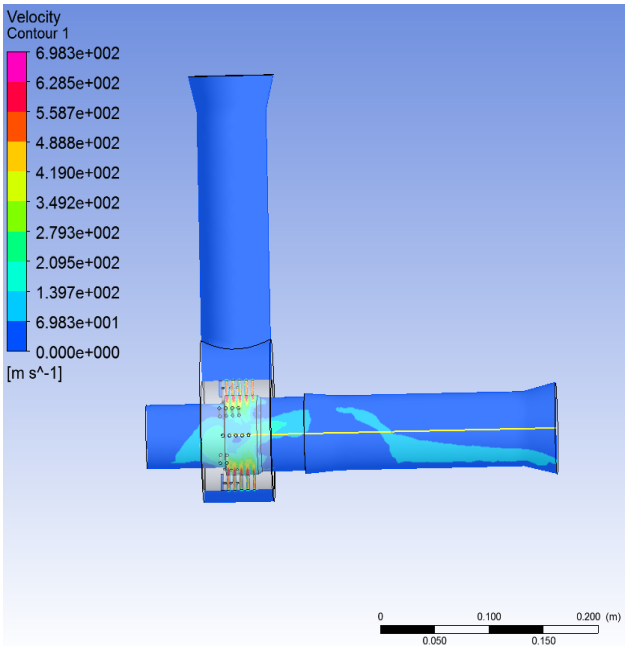

Figure 3 Velocity contour of two-step throttle valve

Make a straight line (l_1) in the throttle orifice, partially amplify the line, and equally divide the straight line l_1 into 10 points, as shown in Figure 4.

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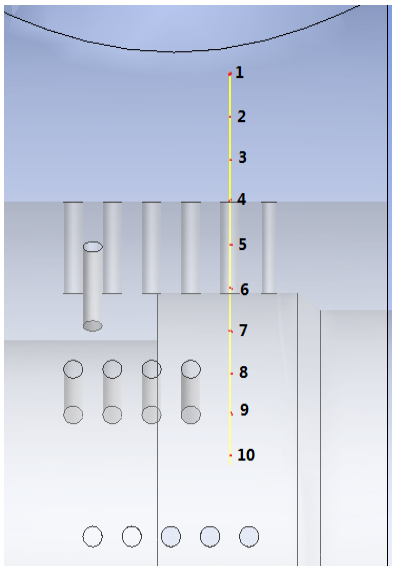

Figure 4 local amplification of the orifice line l_1

The velocity of each point on the line is shown in Figure 5.

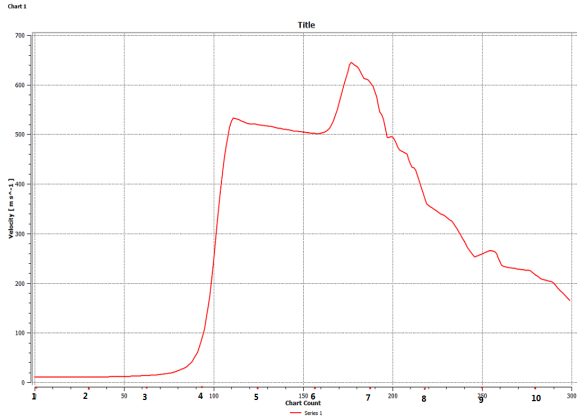

Figure 5 The velocity of each point on the line l_1

A straight line l_2 (axis) which is throttle valve outlet was also made to display the velocity change along the exit of the trend, as shown in Figure 6:

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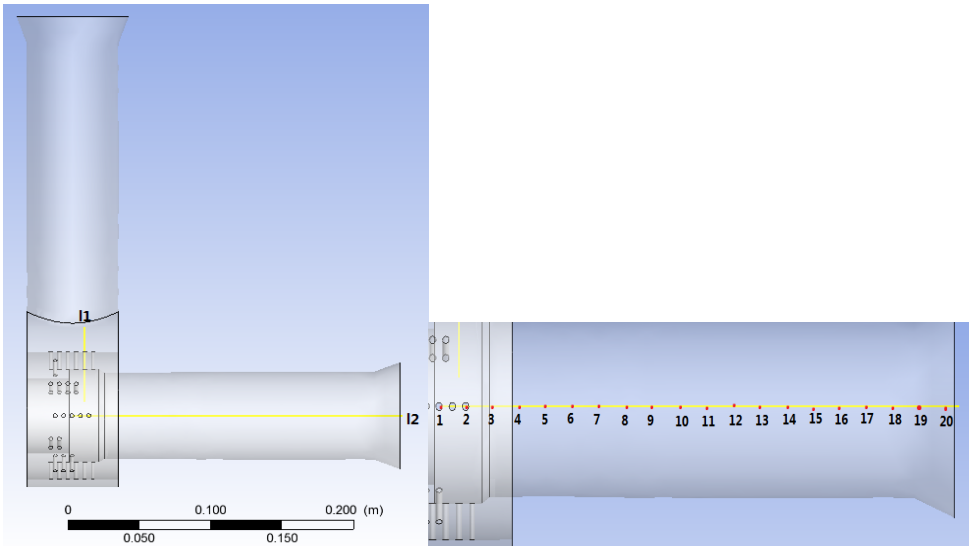


Figure 6 Straight line l_2 along the valve outlet

The velocity of each point on the line is shown in Figure 7.

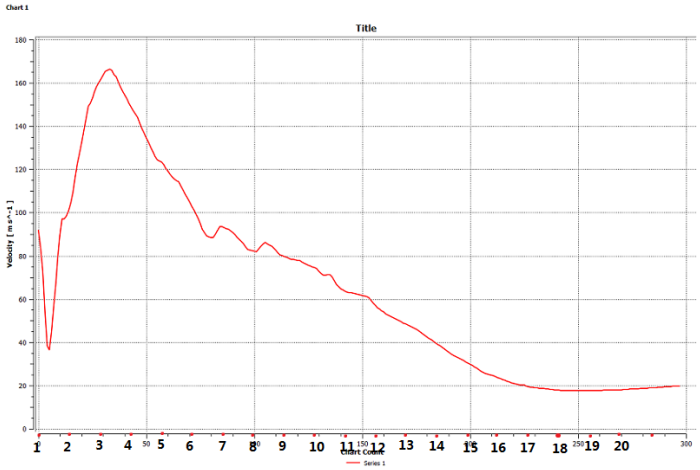


Figure 7 The velocity of each point on the line l_2

In the two-step throttle valve outlet, make 3 planes (plane2,plane3 and plane4) while X=-0.15, -0.1, -0.05, as shown in Figure 8.

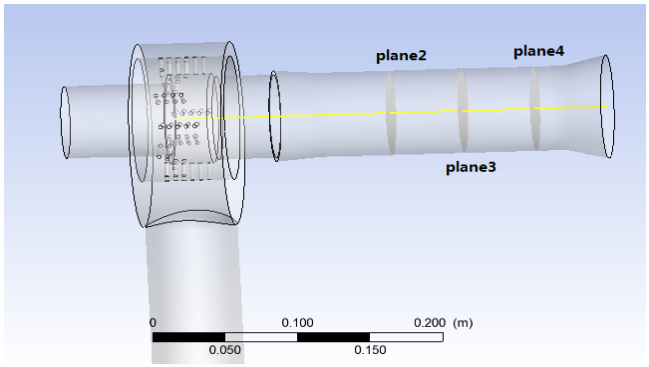
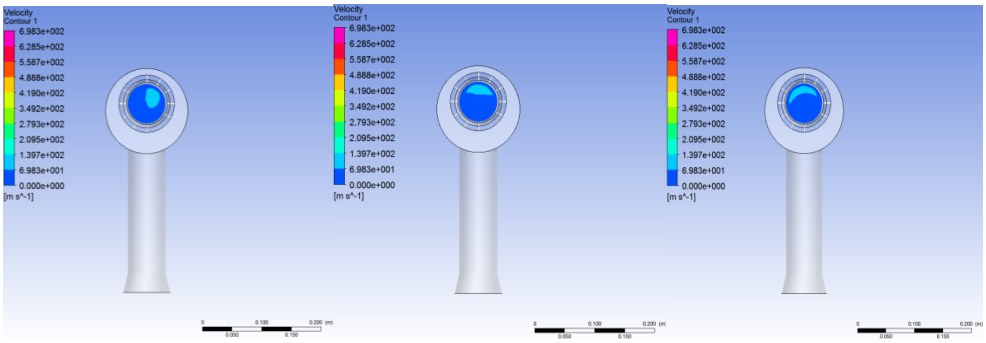


Figure 8 3 planes of two-step throttle valve outlet

Their velocity change are shown in Figure 9.



a.plane2 b.plane3 c.plane4

Figure 9 Velocity distribution of different planes

Through the above analysis of the two-step throttle valve outlet velocity, and the throttle valve in the actual conditions, there is such a phenomenon:

a. In the axis line, the speed changes a lot in the beginning of the middle point of the outlet section the speed changes a lot.

b. In different plane, the velocity distribution is uneven, and the maximum velocity point varies with the change of the distance in axis.

Internal fluid speed of throttle valve can reach the supersonic speed (602m/s), and the fluid in the outlet section of the throttle valve is in a spiral rotating movement, and the rotation axis is coincident with the axis of the pipeline, that is, the turbulence and vortex are generated, and the vortex decreases with the distance away from the throttle orifice.

c. The noise mechanism of the throttle valve shows that the speed change is the main cause of noise, it can be considered to reduce the speed change so that the noise can be reduced, and select the type of larger throttle valve can achieve this purpose.

4.2 Flow field analysis of 4 1/16"1000Psi throttle valve

The simulation of the internal flow field was made while chose the throttle valve 4 1/16" 1000Psi model as the research object, as shown in Figure 10.

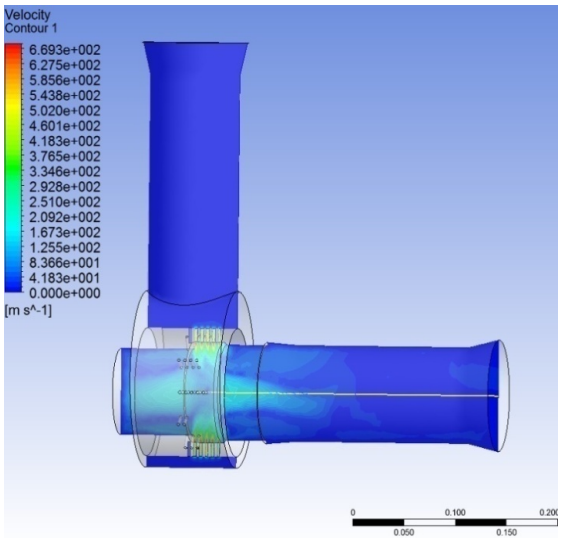


Figure 10 4 1/16" Throttle valve velocity contours

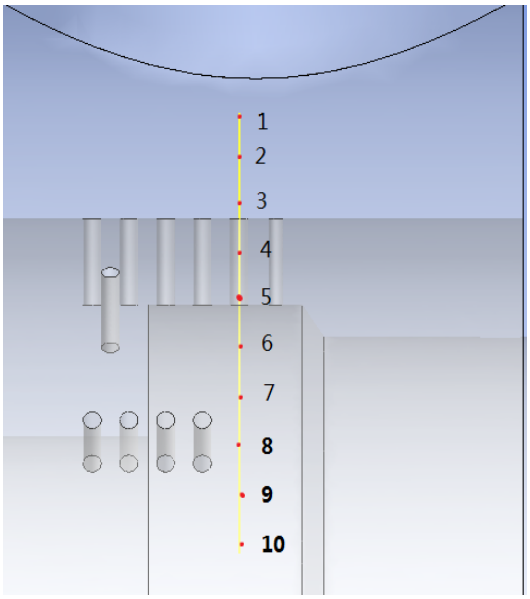


Figure 11 local amplification of the orifice line l_3

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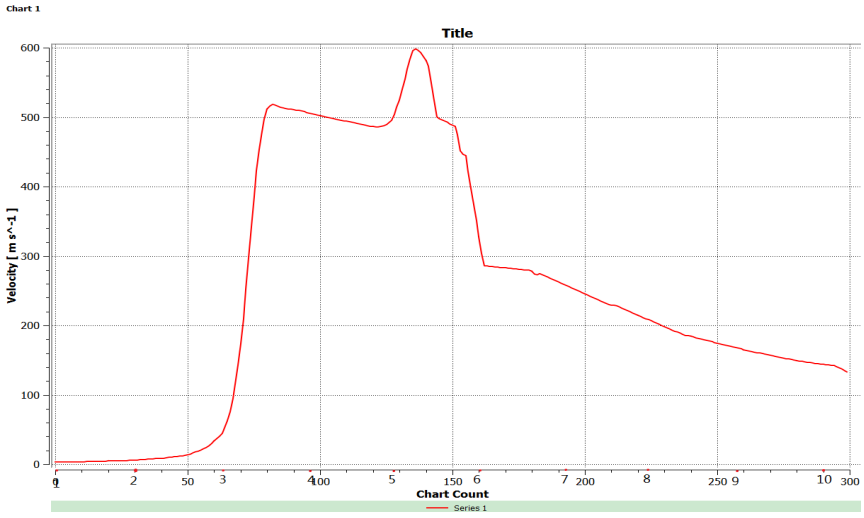


Figure 12 The velocity of each point on the line l_3

A straight line l_4 (axis) which is throttle valve outlet was also made to display the velocity change along the exit of the trend, as shown in Figure 13, and the velocity of l_4 is shown in Figure 14.

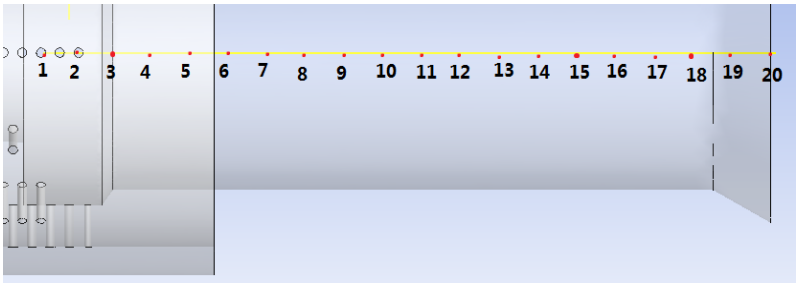


Figure 13 Straight line l_4 along the valve outlet

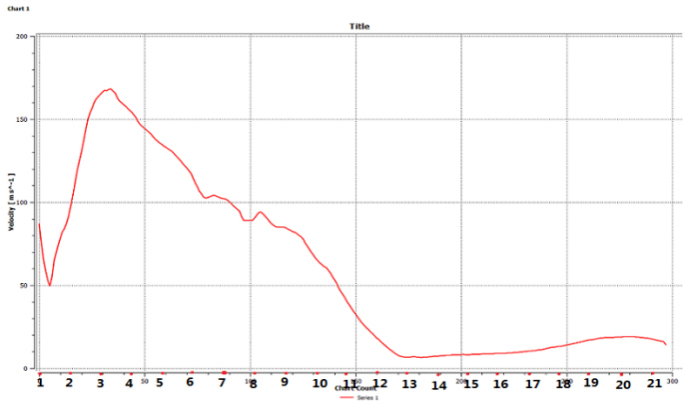
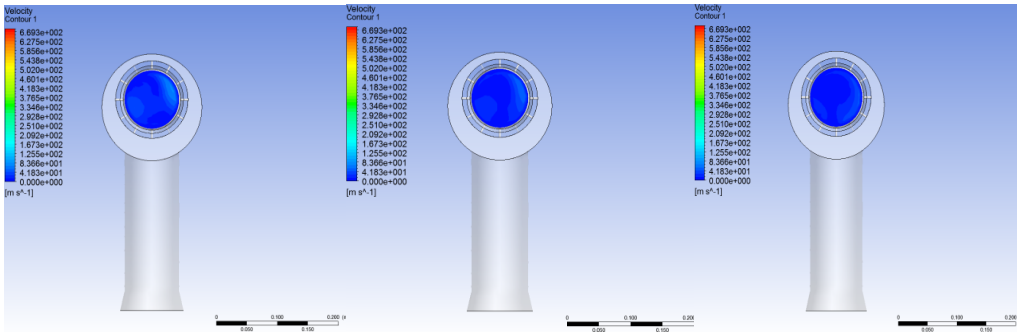


Figure 14 The velocity of each point on the line l_4

3 planes were taken in the same way as the last section in the outlet section of the throttle valve, the velocity contour is shown in Figure 15.



a.plane2 b.plane3 c.plane4

Figure 15 Velocity distribution of 3 different planes

5. Conclusion

In this paper, the numerical simulation of the two types of throttle valve and the internal flow field and noise were analyzed. The throttle valve outlet section of the fluid in the pipeline is a spiral rotation, the axis of rotation and the axis of the pipe line are coincident. That spiral rotation is the vortex, which decreases with the distance from the throttle hole; The speed change rate of 2 different valve from the throttle hole to the outlet position: 3 1/16 "=3.05, 4 1/16" = 1.9; 4 1/16 "throttle valve outlet average velocity is 39.983m/s; The average speed of 4 1/16" throttle valve outlet is 16.44m/s, decreased 58.88%;From the above conclusions, it can be found that the two-step throttle valve 4 1/16 " can reduce the noise.

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