

Plume Flow Field Analysis of Solid Rocket Motor

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Abstract. The distribution characteristics of plume field structure of solid rocket motor could great influence on overall design of rocket, design of launch vehicle, materials selection and so on. Therefore, it is necessary to study structure characteristic of plume field of solid rocket engine. In this paper, the numerical simulation of the nozzle and plume flow field rocket motor from air performed using FLUENT software the influence of flying altitude and Ma number on plume flow was analyzed.

Introduction

Plume flow field of solid rocket motor is influenced by many factors, such as the Maher flight number, flight altitude and flight factors, working pressure. Under angle of attack, the pure gas effect and gas-solid two-phase flow the effect, numerical simulation using FLUENT software. Based on two dimensional axisymmetric model , N-S equation and turbulence model^[1,2,3], the plume flow field of solid rocket motor is compared with different flight altitude and flight Maher number under the condition of constant attack angle.

Calculation Model

Solid rocket engine nozzle and plume flow was calculated in this paper. It is simplified because the computational domain is a two-dimensional axisymmetric the computational domain and plume field for solid rocket motor nozzle is as shown in Figure 1.

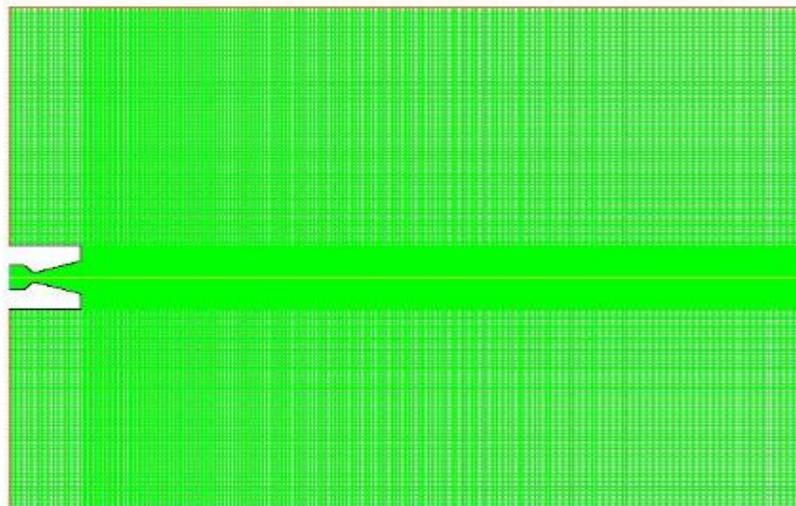


Figure 1. nozzle and plume flow field of solid rocket motor.

Simulation Results and Analysis of High Altitude Flow Field

Numerical Simulation of the Flow Field at High Altitude under the Same Maher Number

When the number of Maher is less than 1, the simulated flight altitude is ten km, fifteen km and twenty km in the case of the flow field.

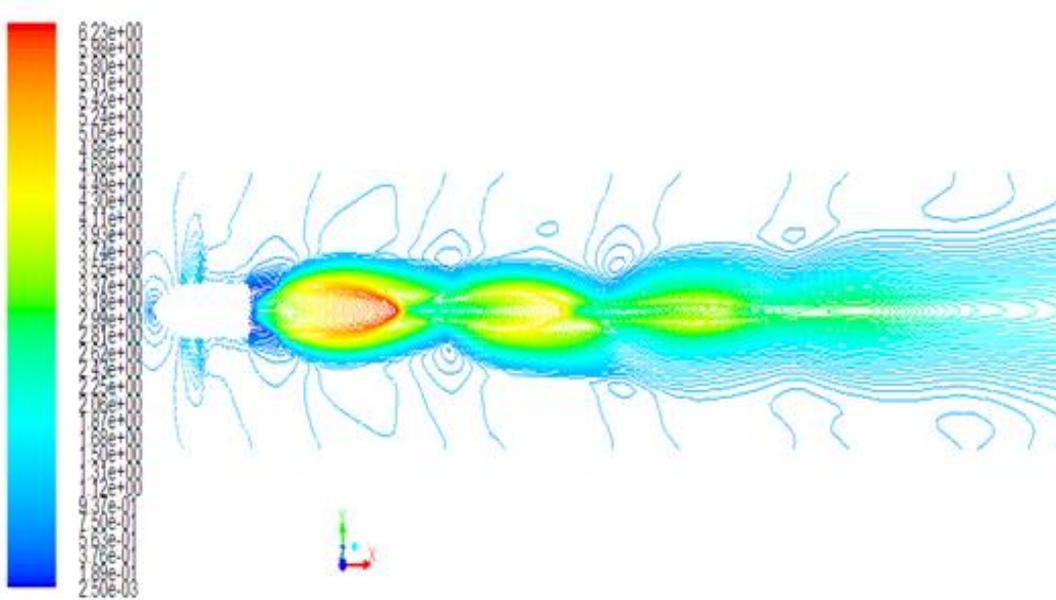


Figure 2. H=10km height of the flow field

From the figure 2, when the flight altitude is ten km, the flow field has four expansion compression wave, the first three the expansion compression wave development is complete, the fourth expansion compression wave is spread, once three complete expansion compression wave can be seen farther away from the nozzle, expansion compression wave intensity is low away from the nozzle. where expansion compression wave intensity is higher, is close from the nozzle, the more quickly the farther away from the nozzle, flow rate decreased gradually.

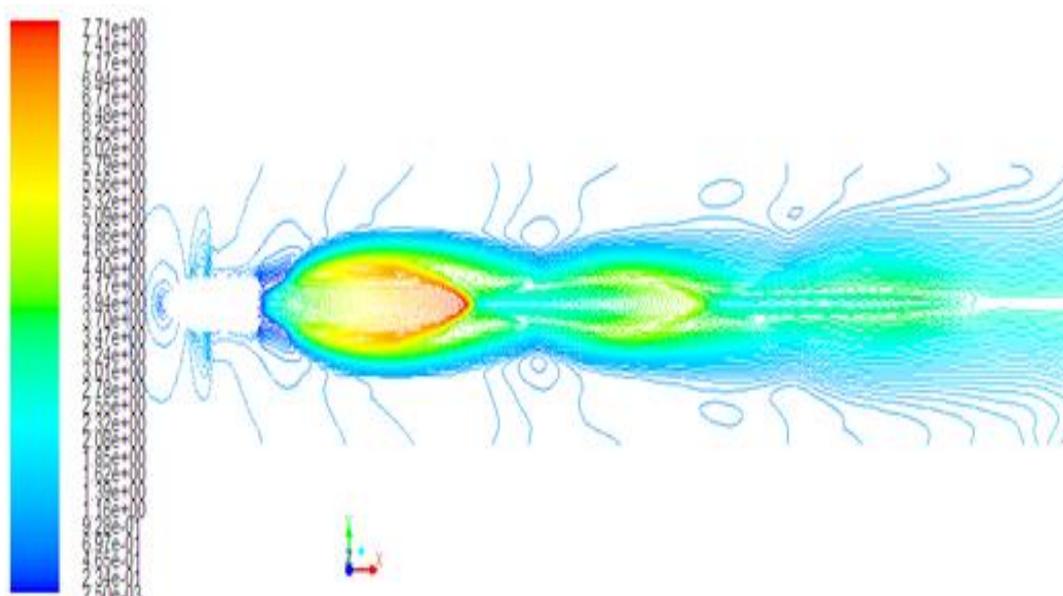


Figure 3. H=15km height of the flow field

From figure3 know when the flight altitude is fifteen kilometers, field has three expansion compression wave, one of the first compression expansion wave development is complete, the second expansion compression wave diffusion sign ,the third expansion compression wave has been completely diffusion. the nozzle expansion compression wave intensity is low.

From the figure 2- Figure 3 shows that when the flight height increases, the flow field of the expansion compression wave is gradual decrease, in the case of a difference of five thousand meters . With the increase of height, the radius of the expansion compression wave in the wake field is increasing, and the core part of the flow field is also increased. With the increase of the height,

the intensity of the expansion compression wave is also reduced.

At Km Altitude, the Numerical Simulation of the Flow Field At High Altitude under Different Flight Maher Numbers

In the ten thousand meters under the same height of solid rocket engine in different Maher number structure of field simulation.

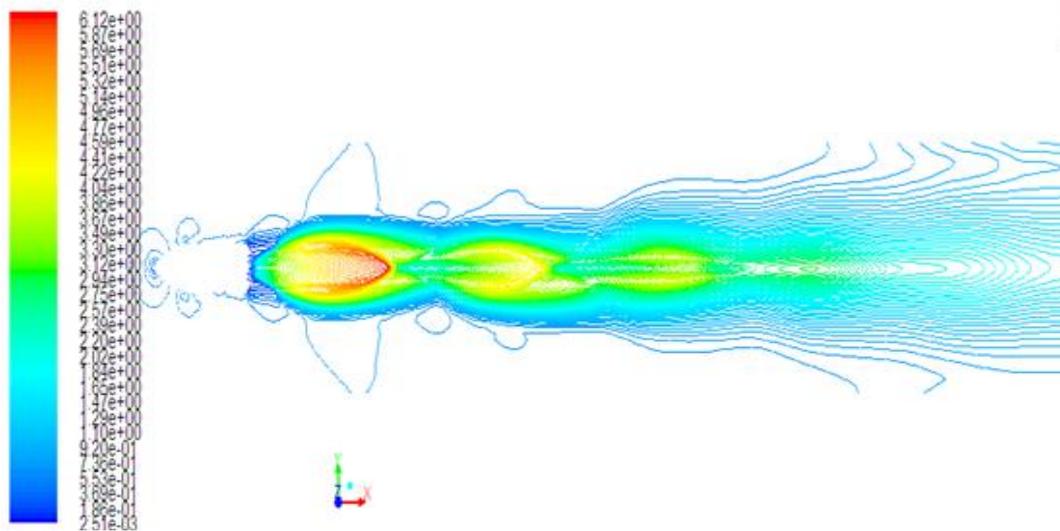


Figure 4. Ma=0.6 flow field

Figure 4 shows that Mach number 0.6 in the same height, it formed four obvious expansion compression wave, which the former two expansion compression wave is complete, third expansion compression diffusion, the fourth expansion compression wave diffusion is stronger than expansion along the axis to the right intensity of compression .

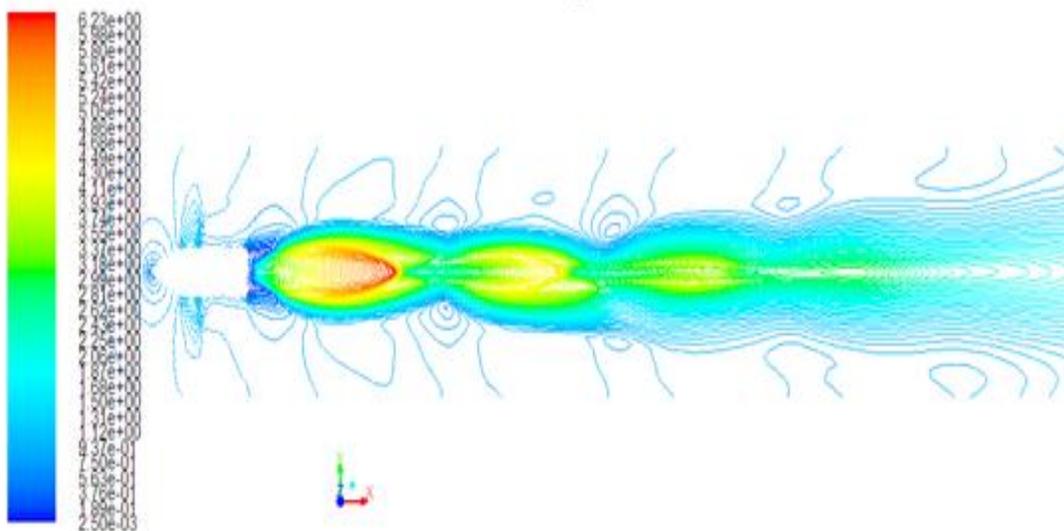


Figure 5. Ma=0.9 flow field

Figure 5 shows that Mach number as 0.9in the same height, it formed four obvious expansion compression wave, which the former two expansion compression wave is complete, the third expansion compression diffusion, the fourth compression waves completely diffusion, expansion of the compression wave along the axis line to the right intensity gradually to reduce the flow velocity

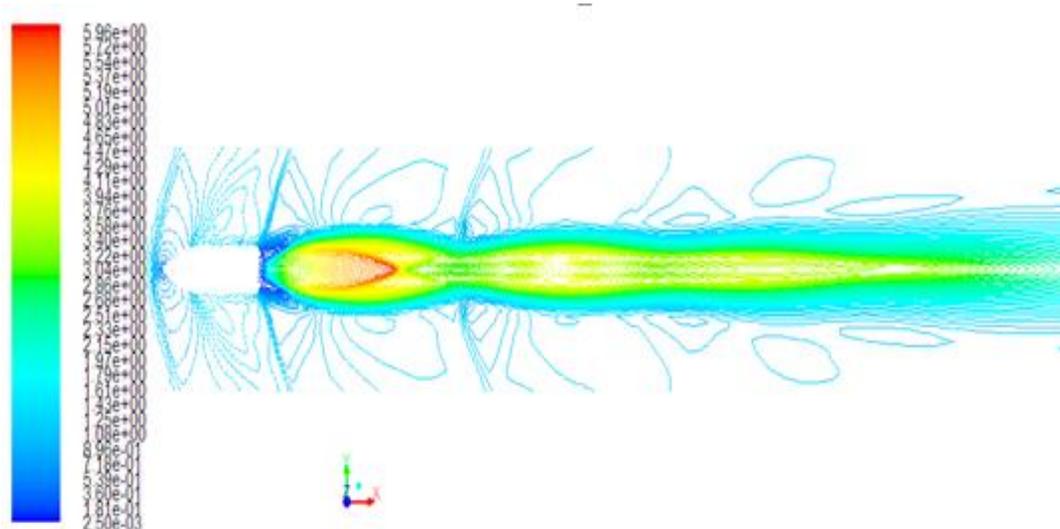


Figure 6. Ma=1.2 flow field

Figure 6 shows that Mach number 1.2 in the same height, formed 3 obvious expansion compression wave, one of the first compression wave expansion is complete, the second expansion compression and the third compression waves were completely diffused, expansion compression wave gradually decreases along the axis to the right the flow velocity.

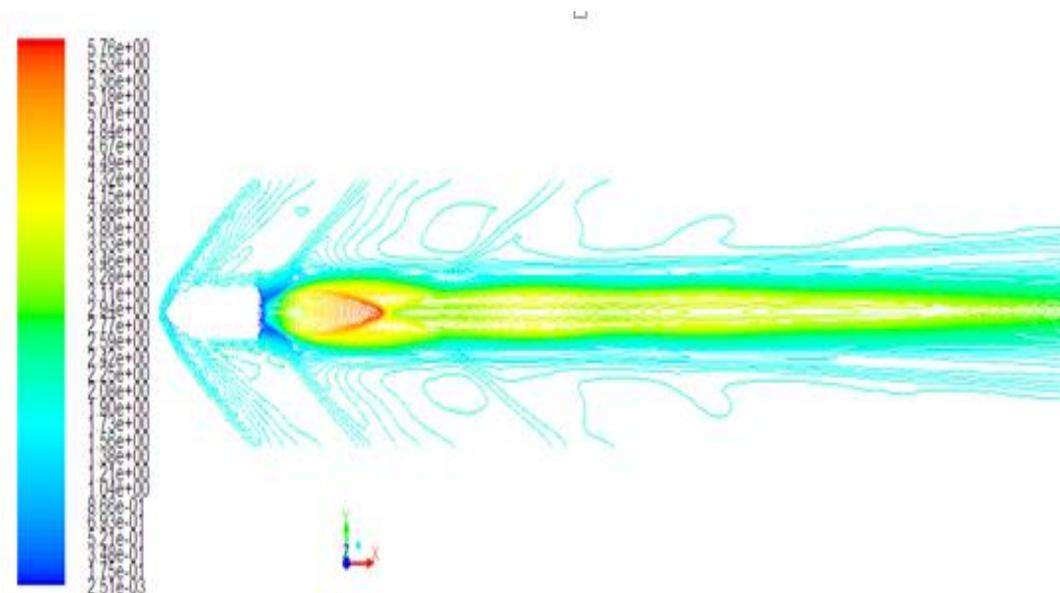


Figure 7. Ma=2 flow field

Figure 7 shows that Mach number as 2 in the same height, formed two obvious expansion compression wave, the first expansion of the compression waves slightly spreading, the second expansion compression wave completely diffusion, expansion of the compression wave gradually decreases along the axis to the right intensity, flow velocity along the axis to the right core area was obviously prolonged.

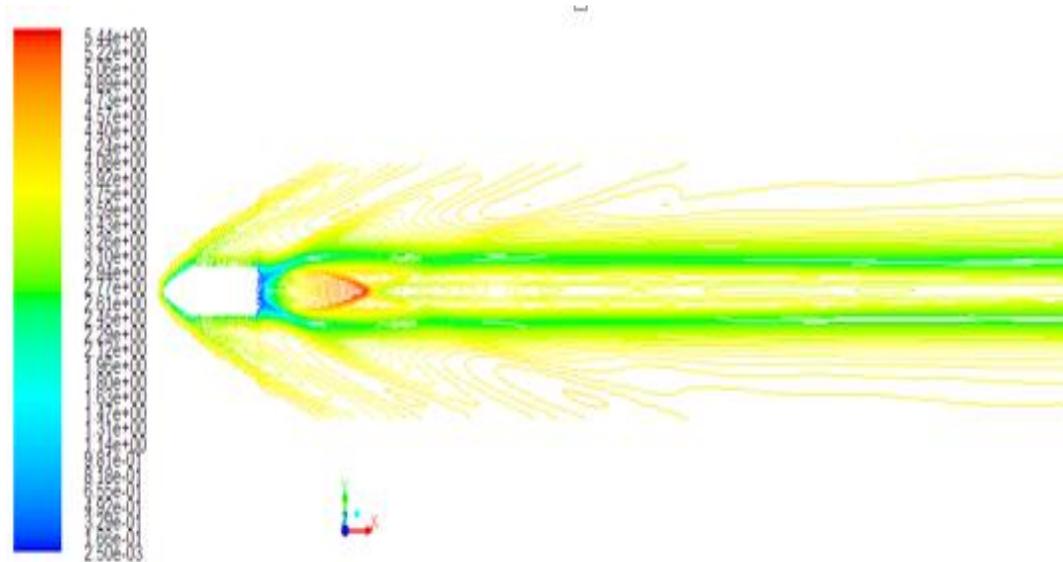


Fig 8. Ma=4 flow field

Figure 8 shows that Mach number is 4 in the same height, it formed one obvious expansion and the expansion compression wave compression has spread, the expansion compression wave gradually decreases along the axis to the right intensity, flow velocity along the axis to the right lower and the core area of the field obviously lengthened.

From Figure 4 to figure 8 shows that when the number of flight Mach increased, the wake flow field after the formation of the expansion compression waves in the gradual decrease. With the increase of Mach number, the core part of the flow field and the wake field is also increased. With the increase of the number of Mach, the intensity of the expansion compression wave at the same stage is also enhanced. With the increase of the Mach number, expansion wake reduce radius, Mach flight number is less than 1, the compression expansion wave of change is not obvious, but when Mach flight number is greater than 1, the expansion compression wave spread rapidly.

Summary

This paper was used to simulate the wake flow structure of solid rocket engine in different flight number, flight altitude, Mach under the conditions of the simulation using the FLUENT software, carries on the comparative analysis of the wake structure in pure gas, get the following conclusion:

1) when the flying height increases, field in the expansion compression to reduce the number of wave radius expansion compression waves but the increased strength of field in the same stage of compression waves is also reduced, single expansion compression wave length extension wake field of the core region also increased.

2) when the Mach number increases, the end of the flow field in the expansion compression to reduce the number of wave radius expansion compression waves but in reduced intensity of field in the same stage of compression waves is also reduced, wake field core area also increasing.

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