The influence of different shape base cavity on aerodynamic drag of projectile

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Abstract. With numerical method, the effect of the shape of base cavity on the aerodynamic force of the projectile is investigated. The Navier-Stokes equations with k-ε turbulence model were used as governing equations. The distributions of the flow field parameters and the drag coefficient of projectile with different shape base cavity were obtained. Numerical results show that the shape of the base cavity has a remarkably effective on the aerodynamic drag of the projectile with base cavity. The base cavity with a decreasing diameter to the end of the projectile shape has the best efficiency reducing the aerodynamic drag.

1. Introduction

The correlative experiment results [1, 2] show that the base cavity configuration is an useful method to reduce the base drag of projectiles. Under the same condition, the field of fire for projectile with base cavity is farther than the projectile without base cavity 3~5% [3].

In a present paper, the projectile with different shape base cavity is investigated numerically. The influence of the cavity shape is discussed by the obtained flow field parameter distributions and the aerodynamic force coefficients.

2. Configuration of the Projectile with Base Cavity

In order to discuss the influence of the base cavity shape on flow field and aerodynamic force of the projectile, three kinds of cavity shape were set, as shown in Fig.1. The angle “α” is 15 degree.

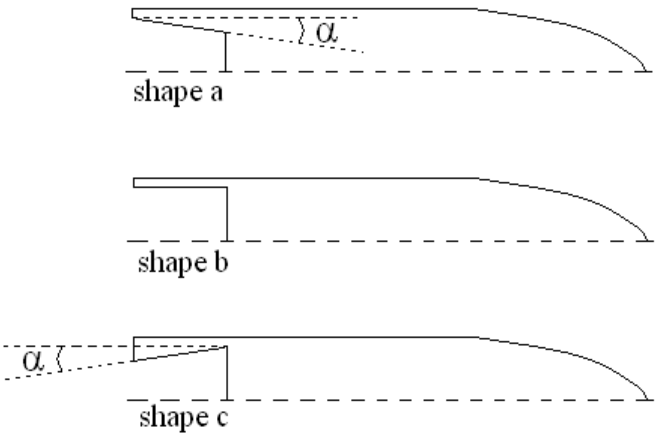


Fig.1: Schematic of the projectile with different shape base cavity

3. Computation Scheme

3.1 Governing Equation

For the axisymmetric character of the projectile flow field, the axisymmetric Navier-Stokes equation is used [4]:

$$\begin{aligned} &\partial U/\partial T + \partial F(U)/\partial x + \partial G(U)/\partial r + 1/r \cdot \partial H(U)/\partial r \\ &= 1/\mathrm{Re} \cdot \left(\partial F_v(U)/\partial x + \partial G_v(U)/\partial r + 1/r \cdot \partial H_v(U)/\partial r \right) \end{aligned} \tag{1}$$

where U is the conservation variable, F, G and H are the inviscid terms, F_v, G_v and H_v are the viscous terms. Equation (1), solved with the k-ε turbulence model [5], is used as the governing equation.

The convective terms are approximated using the Van Leer splitting method and the central difference method is used for the viscous terms. The LU-SSOR scheme is used for the time integration.

3.2 Grid and Boundary Conditions

The simulation grids of the projectile with base cavity (shape "a") are shown as Fig.2.

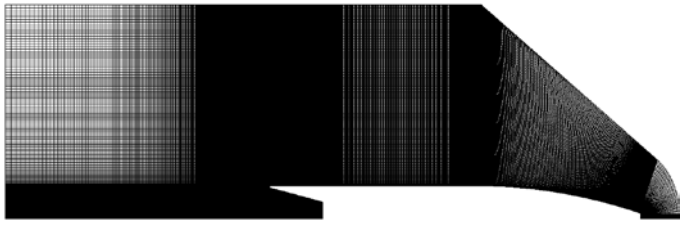


Fig.2: Grid of the simulation model (shape "a")

The boundary conditions are shown in Table 1. The wall boundary condition is assumed to a no-slip and adiabatic one.

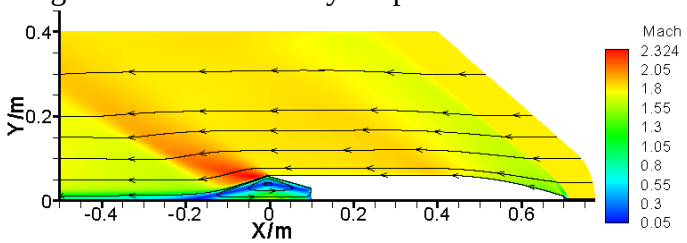
Table 1: Boundary conditions

Free stream parameter	Unit	Value
Mach Number (Ma)	----	1.97
Pressure (p_∞)	Pa	101325
Temperature (T_∞)	K	300

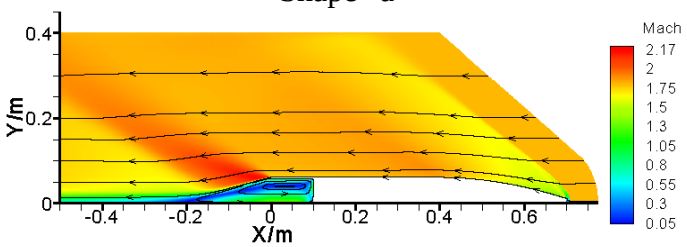
4. Results and discussion

4.1 Flow field

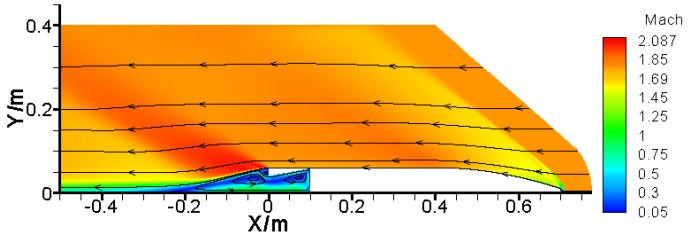
As shown in Fig.3, each shape has the same distribution of the Ma and streamlines in front of the projectile, but different backside. Because of the same flow condition and the nose form, there is a same classical bow shock in front of the projectile both of the three shapes. The different shapes of the base cavity cause the different shapes of the recirculation region. It is obviously that the recirculation region size and boundary are limited by the shape of the base cavity. Shape "c" even forms three recirculation region for its base cavity shape.



Shape "a"



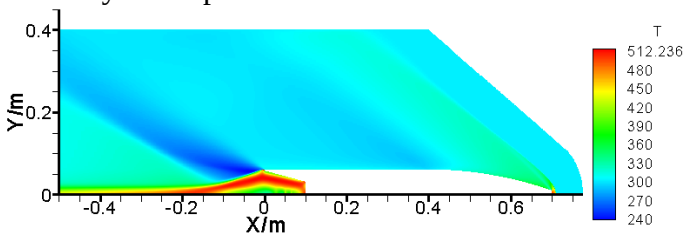
Shape "b"



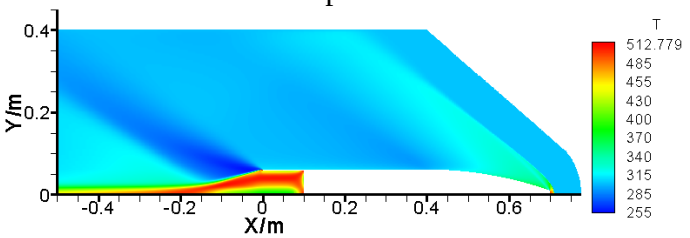
Shape “c”

Fig.3: *Ma* (streamlines) distributions

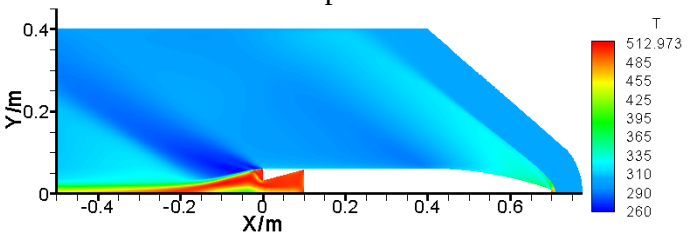
Fig.4 shows the temperature distribution of projectiles. High temperature area is formed in the cavity. Because the cavity diameter is decreasing at the end of the projectile, the high temperature area almost “fill” the base cavity of shape “c”.



Shape “a”



Shape “b”

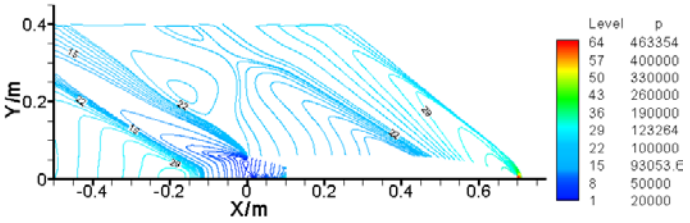


Shape “c”

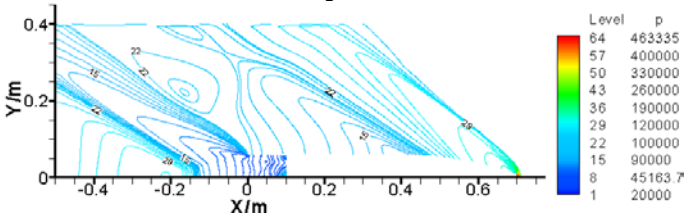
Fig.4: Temperature distributions

As shown in Fig.5, shape “a” and shape “b” have the similar pressure distribution, but shape “c”, for its more complicated flow behave, the distribution

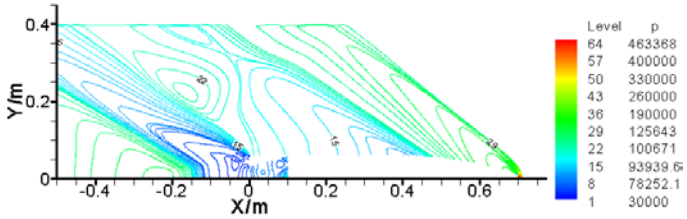
of the pressure is more complicated too.



Shape “a”



Shape “b”



Shape “c”

Fig.5: Pressure distributions

4.2 Aerodynamic drag

The drag coefficient (Cd) of the projectile is given by the expression:

$$C_d = F_d \Big/ \left(\frac{1}{2} \rho_\infty u_\infty^2 \cdot S_{ref} \right) \tag{2}$$

where F_d is the aerodynamic resistance, S_{ref} is the reference area which is the cross section of the projectile (diameter 122mm) .

The drag coefficients (Cd) of the projectile with different shape of the base cavity are shown in Table 2. It is obvious that the shape of the base cavity has an large effect on the aerodynamic drag of the projectile. Shape “a”, the cavity diameter increasing to the end of the projectile, this kind of cavity has the max drag within the three shapes. Shape “c”, the cavity diameter decreasing to the end of the projectile, this kind of cavity has the minimum drag in three shapes. To the shape “c”, the recirculation regions, which are formed behind and inside the cavity, increase the back pressure of the projectile effectively.

Table 2: Drag coefficient (C_d)

Cavity shape	a	b	c
Cd	0.3522	0.3267	0.3181

5. Conclusion

This paper focuses on the influence of the cavity shape on the flow field and aerodynamic drag of the projectile with base cavity. The numerical investigation shows that the shape of the base cavity has a remarkably effective on the reducing of the aerodynamic drag of the projectile. The base cavity with a decreasing diameter to the end of the projectile shape has the best efficiency reducing the aerodynamic drag. For the shape “c”, there are three recirculation region formed behind and inside the base cavity. These recirculation regions increasing the back pressure of the projectile well.

References

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