Researches on plateau flight trajectory characteristics of Non-controlled rotating projectile

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Abstract: The projectile dispersion in the plateau area has increased in various degree and decreased of the fire precision. The analysis shows that it has a considerably relations with altitude and the changes of trajectory characteristics associated with altitude. In order to reflect the change law of external ballistics trajectory characteristic in the plateau area clearly. Simulate compute the trajectory data and changes of projectile attitude in different altitude accord to trajectory model. These research findings will lay a foundation for further research on projectile precision in the plateau.

1. Introduction

The motion of projectile includes mass center motion and around mass center motion. The characteristic of mass center motion includes parameters variation characteristics such as firing range, high of ballistic, speed, and trajectory inclination angle. The characteristic of around mass center motion includes parameters variation characteristics such as azimuth of shell axis, elevation angle of shell axis, attack angle, dynamic equilibrium angle, and rotate speed.

2. Mass center motion trajectory characteristics of Non-controlled rotating projectile in the plateau

2.1 Change law of ballistic trajectory with ground elevation change

To simplify the analysis, it must be considered separately with mass center motion of Non-controlled rotating projectile. The projectile mass center motion follows

\[
\begin{align*}
\frac{dv}{dt} &= -\frac{\rho v^2 S_a C_D}{2m} g \sin \theta \\
\frac{d\theta}{dt} &= -\frac{g \cos \theta}{v}
\end{align*}
\]

(1)

It is the same that the meaning of parameters in this formula with ballistics theory textbook (It is the same with the follows).

The formula showed that, because of the decrease of air density in the plateau, the degree of speed attenuation with trajectory in the plateau, which leads projectile speed decreases become small compared to it in the plain. So that the rate of change with inclination angle will reduce at the same angle of fire and the ballistic trajectory will become flat relatively.
Take a certain type of artillery, a charge, and a firing angle as an example, the simulation curve of X~Y, X~Z, T~θ, T~V like figure 1 to 4.

It can be found by comparing the calculated results that the firing range and sideslip range will be bigger as the increase of ground elevation. In addition, we can see that as the ground elevation increases, the change speed of trajectory inclination angle become smoothly. It shows that the ballistic trajectory become flat.

2.2 Change law of firing range and drift with ground elevation change

According to external ballistics, the projectile mass center motion follows:

\[
\begin{align*}
\frac{dx}{dt} &= -\frac{1}{2} \rho Sv^2 C_D - g \sin \theta \\
\frac{d^2 z}{dt^2} &= \frac{1}{2} \rho Sv^2 C_D \delta_p
\end{align*}
\]

The formula (1), (2) show us that force of friction of projectile will decrease because air density is low in the plateau. With the same muzzle velocity, firing range and drift will increase. With the same firing range, flight time and drift will decrease.

Take a certain type of artillery, a charge, and different firing angles as an example, the deviations of firing range and drift with ground elevation change like figure 5, 6.
It can be found by calculating, with the same charge, the range deviation increase with ground elevation increase. Although sideslip range is also increasing, the drift is less obvious because of increasing with firing range.

3. Around mass center motion trajectory characteristics of Non-controlled rotating projectile in the plateau

Take the change of ground coordinate and attack angle relative to shell axis direction as an example, research on around mass center motion trajectory characteristics (Limited by paper length, rigid body trajectory model will not be given here). The change of ground coordinate relative to shell axis direction include elevation angle and azimuth of shell axis, attack angle can break up into high-low and direction attack angle, both describe the pitching motion characteristics of projectile. Furthermore, rolling movement of projectile is one aspect of around mass center motion.

3.1 Change law of Shell axis direction with ground elevation change

Take a certain type of artillery, a charge, and a firing angle as an example, the change law of azimuth and elevation angle with ground elevation change like figure 7, 8.

Through the analysis of the calculation results, the azimuth of shell axis increase with ground elevation increase. And the elevation angle change trend of shell axis has slowed with ground elevation increase, the change law is the same as the change of trajectory inclination angle with ground elevation increase.
3.2 Change law of attack angle with ground elevation change

Attack angle is an important parameter of artillery projectiles, and an important indicator to inspect projectile flight stability. Taking the low fire arc as an example, the change law of attack angle with ground elevation change like figure 9.

![Figure 9. Change law of attack angle](image)

It shows us that the attack angle becomes bigger with ground elevation increase.

3.3 Change law of rotate speed with ground elevation change

For rotating stabilized projectiles, the rotate speed will gradually decay after projectile out of the muzzle. Take a certain type of artillery, a charge, and a firing angle as an example, the change law of rotate speed with ground elevation change like figure 10.

![Figure 10. Change law of rotate speed](image)

The result of simulation proves that there are two inflection points in attenuation curve with the angle of firing increase. It explains that rotate speed decay faster at the initial segment, rate of decay will slow down, and rate of decay will aggravate in the end piece.

4. Conclusion

According to the ballistic model, trajectory characteristics of Non-controlled rotating projectile in the plateau were studied with different elevations. Analyses a number of parameters reflect the motion characteristic of mass center motion, such as ballistic trajectory, firing range, drift and trajectory inclination angle. And a number of parameters reflect the change law of around mass center motion characteristic with ground elevation change, such as azimuth of shell axis, elevation angle of shell axis, attack angle, attack angle, rotate speed and so on. The result reflects firing range and sideslip range will be bigger, drift is less obvious, projectile angle motions aggravate, attenuation of speed and rotate speed will be slow as the increase of ground elevation. All these change of ballistic characteristic have an effect on firing diffusion and firing precision.
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