Study on the Impact of Altitude on the Hitting Accuracy of Laser Terminal Guided Projectile and Its Improvement

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Abstract. Aiming at the phenomenon of low firing accuracy and low hit probability of guided projectiles in Plateau area, based on the differential equation of kinematics of guided projectiles, the variation and regularity of hit range at different altitudes are simulated and calculated. The measures to improve hitting accuracy are proposed and simulated.

1. Introduction
With the increase of altitude, the air density becomes thinner, which leads to the decrease of control force, the change of hitting range and the decrease of guidance efficiency under the same conditions. Under certain conditions of shooting error, it can not even hit the target. In this paper, under the condition of the mechanical differential equation model given in document (1), the methods and measures to improve the hitting accuracy are obtained by theoretical analysis and simulation calculation.

2. Hit Range and Its Variation with Altitude
According to the model of mechanical differential equation in reference (1), the hitting range of a guided projectile at different altitudes is simulated under the same initial condition at 0 M. The hitting range corresponding to the altitude of 0-5000 meters is shown in Figure 1.

Figure 1. Diagram of hitting range at different altitudes.
Figure 1 shows that with the increase of altitude, the hitting range decreases under the same shooting conditions. The hitting range corresponding to altitude 5000 meters is about 65% less than that corresponding to altitude 0 meters.

Further analysis shows that the data of hitting boundary points corresponding to the altitude of 0 meters are shown in Figure 2. The data of hitting boundary points corresponding to altitude 5000 meters are shown in Figure 3.

![Figure 2](image2.png) **Figure 2. Diagram of hit range boundary points at 0m altitude.**

![Figure 3](image3.png) **Figure 3. Diagram of hit range boundary points at 5000m altitude.**

Figures 1 and 2 show that the range difference corresponding to the hitting range of 0 meters above sea level is 1832 meters. When the altitude is 5000 meters above sea level, the range difference is 1154 meters, which decreases by about 37%. The maximum transverse range decreases by about 36% when the altitude is 5000 meters.

The main reason why the hitting range decreases with the increase of altitude is that the air density decreases with the increase of altitude, which leads to the decrease of the actual control efficiency of rudder wing. Although the deflection angle of rudder wing in plateau condition is not changed compared with that in plain condition, the control force provided is smaller than that in plain condition, resulting in a smaller hit range.
3. Ways and Measures to Improve Hitting Accuracy

According to the above simulation calculation and analysis, it can be seen that with the increase of altitude, the range of guided projectile hit is small under the same conditions, and under certain error conditions, it may lead to the constraints of corrected distance and direction and can not hit the target. The fundamental method and measure to solve this problem is to increase the rudder deflection or condition to allow the increase of laser irradiation time and guidance time.

3.1. Increase rudder deflection

Because the laser terminal guidance projectile uses the ping-pong rudder, the rudder only works when the rudder is in the horizontal or vertical position. When the steering gear is working, it provides fixed rudder deviation angle and pneumatic control force. After the missile body rotates horizontally or vertically, the rudder deflection angle returns to 0 degrees. The timing of steering in flight is mainly calculated by the missile-borne autopilot through the control loop. Therefore, the flight trajectory is simulated when the rudder deflection angle is increased at different altitudes.

According to the calculating conditions in section 1, the same shooting data are selected, the altitude is 4000 meters, the rudder deflection angle is 5 degrees, 6 degrees and 7 degrees respectively, and the hitting range is calculated. The hitting range varies with rudder deflection as shown in Figure 4.

As can be seen from the figure, with the increase of rudder deflection angle, the range of landing point increases, the number of left and right boundary increases, the number of the longest distance and the nearest distance of hitting increases, and the hitting range increases as a whole. The area of hitting range at 6 degree of rudder deviation is about 45% larger than that at 5 degree of rudder deviation, and that at 7 degree of rudder deviation is about 96% larger than that at 5 degree of rudder deviation. The corresponding hit range boundary points are shown in Figure 5 and Figure 6.
Increasing rudder deflection increases hitting range, which is beneficial to improving hitting accuracy. However, in terms of ballistic characteristics, the increase of rudder deflection angle will make the aerodynamic characteristics of the projectile change more, the angular motion of the projectile will intensify, the dynamic balance angle will increase, and the flight instability will easily occur. Therefore, the rudder deflection angle can only be moderately increased.

3.2. Increasing Laser Irradiation Time
Laser terminal guided projectile receives the reflected laser signal from the target in the terminal stage, and generates control signal through the missile-borne autopilot to control the steering gear deflection. The current laser target indicator can increase the laser irradiation time and make the laser terminal guided projectile enter the terminal guidance stage as soon as possible because of its fixed maximum working time, which is conducive to improving its guidance accuracy (range) at high altitude.

According to the calculation conditions in Section 1, the same firing elements are selected, the position elevation is 40 meters, the rudder deflection angle is 5 degrees, and the laser irradiation time is 15 seconds, 20 seconds and 25 seconds respectively. The hitting range varies with exposure time as shown in Figure 7.
Figure 7. Schematic chat of hit range of different rudder deviation angles at 4000m elevation.

It can be seen from the figure that the hitting range increases with the increase of laser irradiation time and the same shooting data. When the irradiation time is 20 seconds, the hitting range increases about 2.5 times than that when the irradiation time is 15 seconds. However, when the laser irradiation time increases to 25 seconds, the hitting range increases slightly compared with that when the irradiation time is 20 seconds.

4. Conclusion
The change of altitude results in the change of aerodynamic characteristics of projectile flight, and the change of ballistic elements and attitude of projectile body cannot be ignored, which ultimately leads to the decrease of hit accuracy. Although from the point of view of shooting, man-made amendments can be made, but does not cure the root cause. For the laser terminal guidance projectile, the simulation calculation shows that with the increase of altitude, the guidance ability decreases and the hit probability decreases, which an objective normal phenomenon is. The method of increasing rudder deflection angle and laser irradiation time proposed in this paper can effectively increase hitting range and improve hitting accuracy through simulation calculation. However, the factors such as rudder deflection angle and irradiation time increase are the best, and the projectile-target distance increase and laser intensity attenuation caused by irradiation time increase must be considered, which need further study.

References
[1] Jiang M. (2018) Study on Aerodynamic and Ballistic Characteristics of Rotating Projectile under Plateau Meteorological Conditions. Ph.D. Dissertation
[2] Liu Y.W., et al. (2018) Artillery and Air Defence Firing Meteorology Theory and Application. Weapons Industry Press, Beijing.
[3] Li C.M., et al. (2014) The Influence of High Altitude Graves on Ballistic Characteristics of Surface Artillery. Journal of Shooting.
[4] Wu Z.L., Liu Y.W. (2010) Artillery and Air Defense Forces Decisive Shooting Elements Theory and Method. Haichao Press, Beijing.