World Academy of Science, Engineering and Technology
International Journal of Aerospace and Mechanical Engineering
Vol:15, No:06, 2021

Spin Rate Decaying Law of Projectile with Hemispherical Head in Exterior Trajectory

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Abstract : As a kind of working environment of the fuze, the spin rate decaying law of projectile in exterior trajectory is of great value in the design of the rotation count fixed distance fuze. In addition, it is significant in the field of devices for simulation tests of fuze exterior ballistic environment, flight stability, and dispersion accuracy of gun projectile and opening and scattering design of submunition and illuminating cartridges. Besides, the self-destroying mechanism of the fuze in small-caliber projectile often works by utilizing the attenuation of centrifugal force. In the theory of projectile aerodynamics and fuze design, there are many formulas describing the change law of projectile angular velocity in external ballistic such as Roggla formula, exponential function formula, and power function formula. However, these formulas are mostly semi-empirical due to the poor test conditions and insufficient test data at that time. These formulas are difficult to meet the design requirements of modern fuze because they are not accurate enough and have a narrow range of applications now. In order to provide more accurate ballistic environment parameters for the design of a hemispherical head projectile fuze, the projectile's spin rate decaying law in exterior trajectory under the effect of air resistance was studied. In the analysis, the projectile shape was simplified as hemisphere head, cylindrical part, rotating band part, and anti-truncated conical tail. The main assumptions are as follows: a) The shape and mass are symmetrical about the longitudinal axis, b) There is a smooth transition between the ball hea, c) The air flow on the outer surface is set as a flat plate flow with the same area as the expanded outer surface of the projectile, and the boundary layer is turbulent, d) The polar damping moment attributed to the wrench hole and rifling mark on the projectile is not considered, e) The groove of the rifle on the rotating band is uniform, smooth and regular. The impacts of the four parts on aerodynamic moment of the projectile rotation were obtained by aerodynamic theory. The surface friction stress of the projectile, the polar damping moment formed by the head of the projectile, the surface friction moment formed by the cylindrical part, the rotating band, and the anti-truncated conical tail were obtained by mathematical derivation. After that, the mathematical model of angular spin rate attenuation was established. In the whole trajectory with the maximum range angle (38°), the absolute error of the polar damping torque coefficient obtained by simulation and the coefficient calculated by the mathematical model established in this paper is not more than 7%. Therefore, the credibility of the mathematical model was verified. The mathematical model can be described as a first-order nonlinear differential equation, which has no analytical solution. The solution can be only gained as a numerical solution by connecting the model with projectile mass motion equations in exterior ballistics.

Keywords : ammunition engineering, fuze technology, spin rate, numerical simulation
Conference Title : ICBSET 2021 : International Conference on Ballistics Systems Engineering and Technology
Conference Location : Montreal, Canada
Conference Dates : June 14-15, 2021