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A Quick Approach to Correct Range Prediction of A Surface to Surface Rocket Fitted with a Nonstandard Fuze

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Abstract

Equipping a nonstandard fuze to an unguided artillery rocket could affect the rocket characteristics and hence different flight trajectory. Consequently, the firing tables provided by the rocket manufacturer are no longer accurate. This paper investigates a quick and low cost approach that can mitigate this problem. The approach was applied to a case study of a 122 mm artillery rockets fitted with a fuze whose shape and mass are different from the original design. Available data from live fire tests were utilized to evaluate the accuracy of the prediction. The results suggested that the error was higher at greater quadrant elevation and the error of one sample point near the maximum range was up to 7.8%.

***Keywords**:* firing tables, artillery rockets, trajectory simulation, external ballistics.

Nomenclature

A_{ref}	Reference area (m^2)
a_x, a_y, a_z	Translations in the launching axes (m/s)
ac_x, ac_y, ac_z	Acceleration due to Earth's rotation in the launching axes (m/s^2)
C_A	Axial force coefficient
C_l	Rolling moment coefficient
C_{lp}	Rolling moment coefficient derivative with roll rate (1/rad)
$C_{m\alpha}$	Pitching moment coefficient derivative with angle of attack (1/rad)
C_{mq}	Pitching moment coefficient derivative with pitch rate (1/rad)
$C_{n\beta}$	Yawing moment coefficient derivative with side slip angle (1/rad)
$C_{N\alpha}$	Normal force coefficient derivative with angle of attack (1/rad)
$C_{Y\beta}$	Side force coefficient derivative with side slip angle (1/rad)
$Drift_{Nominal}$	Drift in nominal case (m)
$Drift_{Aero\ Var}$	Drift in aerodynamic coefficient variation case (m)
F_{dx}, F_{dy}, F_{dz}	Force due to disturbance in the launching axes (N)
F_{px}, F_{py}, F_{pz}	Force due to propulsion in the launching axes (N)
F_{rx}, F_{ry}, F_{rz}	Force due to aerodynamics in the launching axes (N)
F_{rbx}, F_{rby}, F_{rbz}	Force due to aerodynamics in the rocket body axes (N)
g_x, g_y, g_z	Acceleration due to Earth's gravity in the launching axes (m/s^2)
I_{bx}, I_{by}, I_{bz}	Moments of inertia of the rocket in the rocket body axes ($kg.m^2$)
L_{ref}	Reference length (m)
m	Total mass of the rocket (kg)
M_{rbx}, M_{rby}, M_{rbz}	Moment due to aerodynamics in the rocket body axes (N.m)
M_{dbx}, M_{dby}, M_{dbz}	Moment due to disturbances in the rocket body axes (N.m)
p, q, r	Angular rate of rocket body in the rocket body axes (rad/s)
QE	Quadrant elevation (mil, deg)
R_{Nom}	Range in nominal case (m)
$R_{Aero\ Var}$	Range in aerodynamic coefficient variation case (m)
V	Total velocity (m/s)
X_{cg}	Center of gravity position (m, caliber)
$X_{cg,ref}$	Reference center of gravity position when calculating aerodynamics (m, caliber)
α, β	Angle of attack and side slip (rad)
ρ	Atmospheric air density (kg/m^3)
σ	Standard deviation of range (m)
Δ_{Range}	Difference in range between nominal case and modified case (m)

1. Introduction

Computing firing data for unguided artillery rockets is a classic gunnery problem. The primary objective is to determine the azimuth and quadrant elevation for delivering an effective fire on the target under given conditions. The azimuth is the angle in the horizontal plane that determines the direction of fire. The quadrant elevation is the angle in the vertical plane that determines the range of impact point. To compute these two angles, artillerymen can follow standard