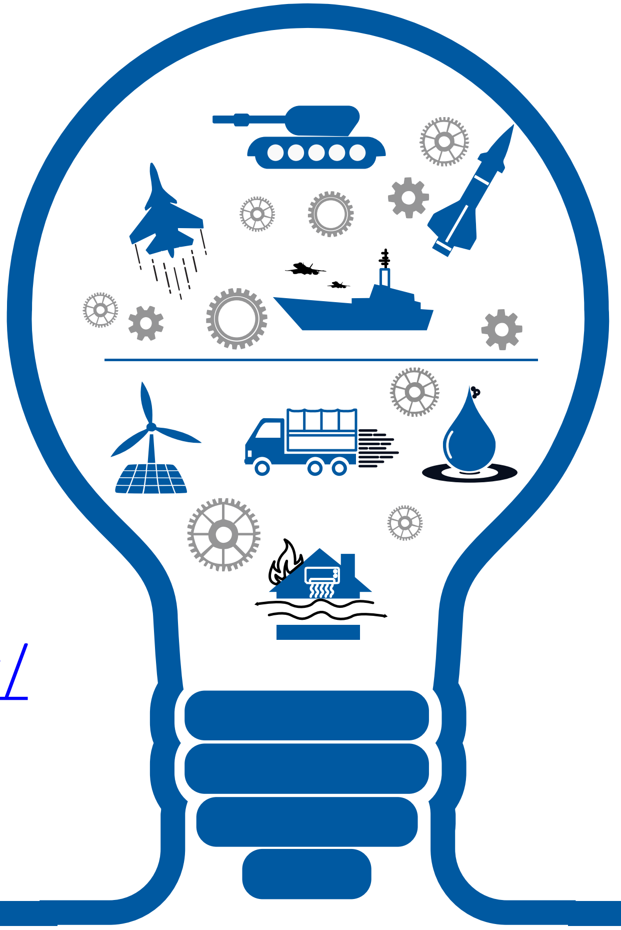
Inbore Ammunition Balloting

REFERENCE MANUAL

http://labs.zeusnumerix.com/inbore-ammunition-balloting/



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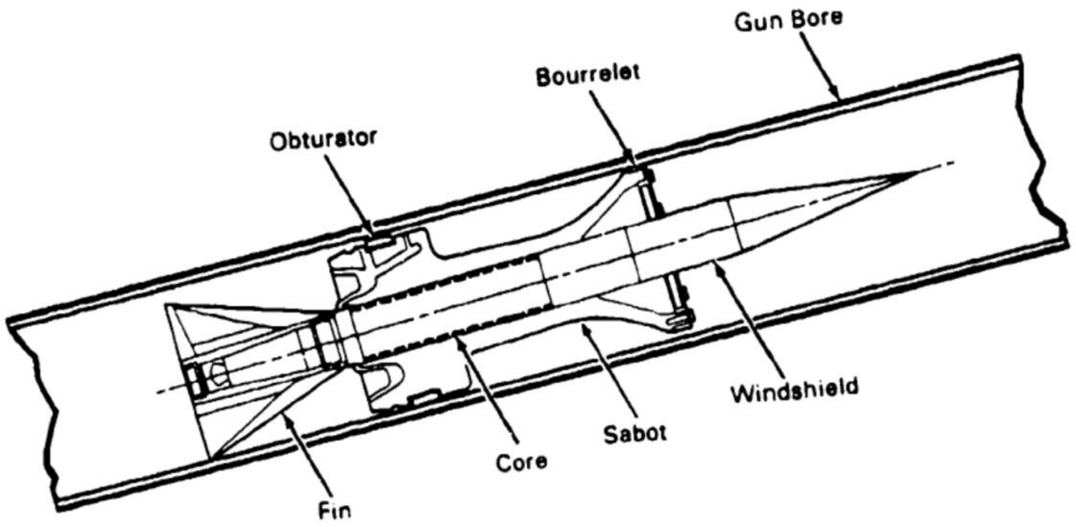
Introduction

- In order to obtain desired accuracy & consistency in ammunition trajectory, one needs to minimize the disturbances developed during its in-bore travel
- These in-bore disturbances are generally known as ‘balloting’ & results in significant ‘yaw-rate’ for the projectile as it exits barrel
- The source of in-bore disturbances are ‘out-of-control’ conditions such as shot eccentricity, barrel wear / bend, lateral gas pressure & initial shot concentricity / start angle of shot
- The extent of effect that balloting ‘sources’ has on ammunition yaw rate is governed by ammunition’s inertial properties, Obturator-Bourrelet distance, choice of material & Bourrelet-barrel tolerance



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Governing Equations

- Longitudinal motion:

$$P_b = \frac{P_c}{\left(1 + \frac{c}{2m_p}\right)} \qquad P_a = \frac{\gamma M_p}{4}\left[(\gamma+1)M_p + \sqrt{(\gamma+1)^2 M_p^2 + 16}\right] P_0 \qquad F_x^c = -\mu_{DB} A_{DB} k \delta_0$$

- Driving band stiffness: $\mathrm{k} = E \frac{\left[(1+v)r_0^2 + (1-v)r_i^2\right]}{(1-v^2)r_0\left(r_0^2 - r_i^2\right)}$

- Bourrelet-barrel impacts:

$$\Delta\dot{y}_{cg} = -(1+e)\dot{y}_{cg}^- \qquad \Delta\dot{\psi}_{cg} = -(1+e)\dot{\psi}_{cg}^- \qquad \hat{R} = m_p \Delta\dot{y}_{cg} \qquad \hat{R} = I_{zz}\Delta\dot{\psi}_{cg}/l_{CB-CG}$$

- Lateral motion – pitch coupling

$$F_y^c = k'\left[(l_{DB-CG})\psi - y_{cg}\right] \qquad M_z^c = -F_y^c(l_{DB-CG}) - \mathrm{k}'\left[\frac{l_{DB}^2\psi}{12} + \mu r_0\left(y_{cg} - l_{DB-CG}\psi\right)\right]$$

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Web App - Usage

- User needs to upload input file containing details of projectile design, barrel & firing parameters. Each parameter is described in next slide.
- 2nd upload contains pressure time profile within the barrel. 1st column is time instant in millisecond, while second column is breech pressure in MPa

- Upon execution, following output is generated:
  1. Time history plot of y & z motion (translational & angular) & rates
  2. Time history plot of y & z acceleration & CB-barrel impacts
  3. Time history plot of resultant lateral motion parameters
  4. Summary presenting lateral motions of the ammunition as it exits the barrel
- User can download the raw output data (textual format) for future reference

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Input File Description

Parameter	Default	Unit	Description
diameter_barrel	40.0	mm	Diameter of the barrel bore
rifling_twist	20	-	Number of bore diameters per turn of rifling
Inbore_travel_length	2000	mm	Length of barrel minus chamber length
propellant_mass	0.50	Kg	Mass of propellant grains inside cartridge case
mass_projectile	0.50	Kg	Mass of ammunition shot that travels within the barrel
inertia_Ixx_projectile	0.001	Kg.m2	Moment of inertia about longitudinal axis passing though C.G
inertia_Izz_projectile	0.050	Kg.m2	Moment of inertia about transverse axis passing though C.G
diameter_sabot_DB	35.0	mm	Diameter of driving band seat on the sabot
thickness_DB	2.51	mm	Thickness of the driving band. It should have some precompression with barrel
diameter_bourrelet	39.8	mm	Diameter of centering band of sabot or bourrelet
length_DB	10.0	mm	Length of driving band inside its seat
distance_rear_DB_CG	15.0	mm	Distance of rear end of driving band from shot CG
distance_rear_CB_CG	30.0	mm	Distance of rear end of centering band from shot CG
distance_rear_sabot_CG	25.0	mm	Distance of rear end of sabot from shot CG
projected_area_sabot_rear	400.0	mm2	Projected area of sabot on the longitudinal plane

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Input File Description (Contd.)

young_modulus_DB	3.0	GPa	Young modulus for the driving band material (i.e. brass or nylon)
poisson_ratio_DB	0.40	-	Poisson ratio for the driving band material
coeff_friction_DB	0.005	-	Coefficient of friction between driving band & barrel
coeff_friction_CB	0.1	-	Coefficient of friction between centering band & barrel
coeff_restitution_CB	1.0	-	Coefficient to define the bounce of centering band on impacting barrel
band_slip_parameter	0.1	-	Transfer of RPM from rilfing grooves to the shot.
barrel_elevation_angle	0.00	Degrees	Elevation angle of barrel
eccentricity_CG_magnitude	0.2	Degrees	Eccentricity in the CG location of ammunition due to manufacturing process
eccentricity_CG_orientation	90.0	mm	Angular orientation of C.G. eccentricity of ammunition
shot_start_angle_magnitude	0.01	Degrees	Misalignment of shot after engraving in terms of angle
shot_start_angle_orientation	90.0	Degrees	Angular orientation of misalignment of shot
shot_start_concentricity_magnitude	0.01	mm	Misalignment of shot after engraving in terms of its concentricity with barrel axis
shot_start_concentricity_orientation	90.0	Degrees	Angular orientation of misalignment of shot concentricity
gas_pressure_eccentricity_magnitude	0.01	-	Eccentricity in application of gas pressure on the base of ammunition during travel
gas_pressure_eccentricity_orientation	90.0	Degrees	Angular orientation in misalignment of gas pressure application
wear_depth_barrel	0.0	mm	Wear of the barrel bore
droop_barrel	0.0	mm	Magnitude of lateral deflection of muzzle end of barrel
droop_orientation	90.0	Degrees	Angular orientation of the barrel droop

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Summary File Description

- Summary shows following data (with units) about the ammunition’s inbore motion:

Output Parameter	Description
Shot Muzzle Velocity	Muzzle velocity of the ammunition
Max Y Velocity	Maximum during inbore travel
Max Z Velocity	Maximum during inbore travel
Max Pitch Rate	Maximum during inbore travel
Max Yaw Rate	Maximum during inbore travel
Avg Exit Y Velocity	Average of of last 10% inbore travel
Avg Exit Z Velocity	Average of of last 10% inbore travel
Avg Exit Pitch Rate	Average of of last 10% inbore travel
Avg Exit Yaw Rate	Average of of last 10% inbore travel
No. of CB-Bore Impacts	Number of impacts & rebounds
Max Impact Impulse	Maximum from all impacts
Avg Impact Impulse	Average impulse of all impacts

Output Parameter	Description
Max Y Acceleration	Maximum during inbore travel
Max Z Acceleration	Maximum during inbore travel
Max Pitch Acceleration	Maximum during inbore travel
Max Yaw Acceleration	Maximum during inbore travel
Max Lateral Velocity	Max resultant of Y & Z motion
Max Angular Rate	Max resultant of Y & Z motion
Avg Exit Lateral Velocity	Average of last 10% inbore travel
Avg Exit Angular Rate	Average of last 10% inbore travel
Max Lateral Acceleration	Max resultant of Y & Z motion
Max Angular Acceleration	Max resultant of Y & Z motion
Max DB Reaction	Due to compression of DB

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Output File Description

- The simulation output file presents detailed time varying data (time in milliseconds) of ammunition motion in terms of parameters such as:
  - barrel CB gap (mm), x travel(mm), x velocity(m/s), y travel(mm), y velocity(m/s),
  - z_travel(mm), z velocity(m/s), pitch angle(deg), pitch rate(deg/s),
  - yaw angle(deg), yaw rate(deg/s), shot RPM, rotation angle(deg),
  - y acceleration(m/s^2), z_acceleration(m/s^2), impact impulse(Ns), impact angle (deg),
  - lateral travel(mm), lateral travel angle(deg), lateral velocity(m/s), lateral velocity angle(deg)
  - lateral acceleration(m/s^2), lateral acceleration angle(deg),
  - lateral angular_rate(deg/s), lateral angular rate angle(deg),
  - lateral angular acceleration(deg/s^2), lateral angular acceleration angle(deg)
- All above parameters are also shown through plotter on the webapp

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References

- Ansari, Baugh, “Dynamics of a Balloting Projectile in Moving Gun Tube”, BRL-CR-605, Dec., 1988

WebApp is restricted; Applicable for projectile diameters less 50 mm

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Thank You !

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