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# Sabot Design Optimization

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## Nomenclature

$I_m$ = absolute value of the perturbing pitching moment impulse produced by a sabot segment
$M_{p_a}$ = pitching moment on the projectile due to sabot/projectile aerodynamic interaction
$M_{p_m}$ = pitching moment on the projectile due to sabot/projectile mechanical interaction
$t_0$ = time duration of the sabot/projectile interaction
$X_{c.g.}, Y_{c.g.}$ = sabot center of gravity coordinates with respect to a frame of reference fixed on projectile
$X_{TL}, Y_{TL}$ = sabot trailing-edge coordinates with respect to a frame of reference fixed on projectile

## Abstract

SABOT discard aerodynamics are described using local shock/expansion procedures. Optimization was based upon a figure of merit for pitching moment impulse, precluding sabot impact on the projectile stabilizing fins. Optimum designs exhibit initial lateral motion with small rotation minimizing mechanical moments and facilitating fin clearance, followed by rapid pitch-up/deceleration minimizing interaction duration.

## Contents

Projectiles launched with sabots are subjected to asymmetric forces during discard which contribute significantly to dispersion. Aerodynamic interaction was found to be a major source of such transverse loads.[1,2] Based on experimental data,[3] a local shock/expansion aerodynamics model was developed and incorporated into a sabot-discard dynamic motion code.[4] This model was used to define optimized configurations that produce minimum dispersive pitching moments upon the projectile during discard.[5,6]

### Validation

Prior to conducting the optimization it was necessary to verify that the model was sufficiently accurate to provide worthwhile design guidelines. Test data taken from actual firings of a discarding sabot round were used for this purpose. Figure 1 presents a comparison of analytical results with measured data.

### Optimization

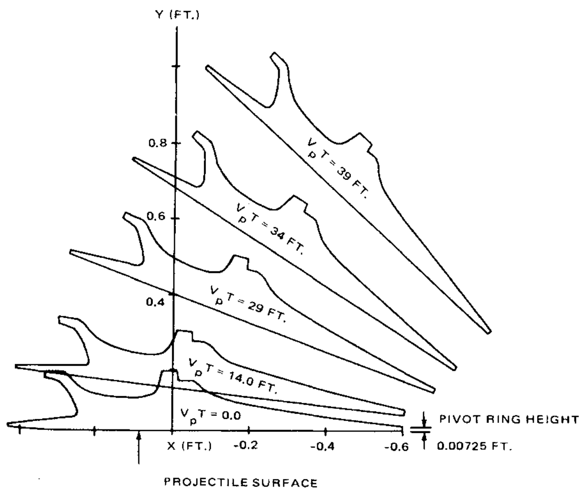
It was necessary to define a figure of merit for use in ranking the relative performance of various candidate configurations. The total possible perturbing impulsive pitching moment "potential" per sabot segment was selected

$$I_m = \int_0^{t_0} |M_p| \, dt \tag{1}$$

$$|M_p| = |M_{p_a}| + |M_{p_m}| \tag{2}$$

Optimum designs were identified as having minimum $I_m$ while simultaneously providing sabot segment trailing-edge trajectories which did not penetrate through the projectile stabilization fin exclusion zone.

Modification of a baseline design was performed to minimize $I_m$. The length and position of the bore rider were varied as shown in Table 1. Corresponding performance results are shown in Table 2 while Fig. 2 presents the sabot segment trailing-edge trajectories. Without pivot rings, designs D-0.00, D-0.08, and D-0.16 suffer from high fin impact probabilities. With pivot rings, these designs rotate more quickly into a high-drag configuration and decelerate rapidly off the projectile. This early rotation causes the mechanical interaction component to increase. Design MD-0.16 is "best" because it produces the lowest $I_m$ and also stays sufficiently clear of the fins to be used without a pivot ring.




| $V_{pt}$ (ft) | PITCH ANGLE | | SABOT TAIL LOCATION (ft) | | | |
|---|---|---|---|---|---|---|
| | Theory | Exp. | Theory | | Experiment | |
| | | | $-\Delta X_t$* | $Y_t$ | $-\Delta X_t$ | $Y_t$ |
| 14.0 | 4.5° | 5.5° | 0.0044 | 0.0411 | -- | -- |
| 29.0 | 25.3° | 25.0° | 0.067 | 0.1411 | 0.051 | 0.128 |
| 34.0 | 35.8° | 33.0° | 0.131 | 0.2067 | 0.120 | 0.203 |

* $\Delta X_t = X_t - X_t$ (t = 0) with corrections for projectile deceleration.

**Fig. 1 Comparison of measured and theoretical sabot-discard trajectories.**

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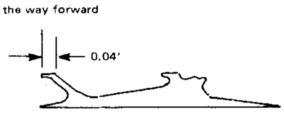
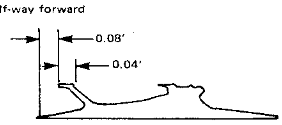
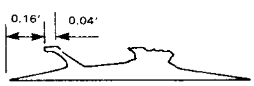
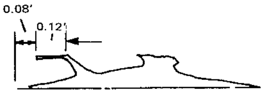
**Table 2 Summary of computed sabot discard performance**

| Configuration | | $I_m^a$ ($I_{m_{mech}}^a$) | $t_0$, s × $10^2$ | Pitch angle, deg | $V_p t_l = 10$ ft; $X_{c.g.}$; $Y_{c.g.}$, ft | $\int_0^{t_l} \lvert M_p \rvert dt^a$ ($(\int_0^{t_l} \lvert M_{p_m} \rvert dt)^a$) |
|---|---|---|---|---|---|---|
| D-0.00 | N/PVT | 0.74063 (0.1758) | 0.405 | 4.9 | 0.0825; 0.1473 | 0.58212 (0.1758) |
| | W/PVT | 0.785371 (0.2014) | 0.397 | 5.9 | 0.0361; 0.1526 | 0.6111 (0.2014) |
| D-0.08 | N/PVT | 0.811545 (0.0696) | 0.4340 | 2.7 | 0.0994; 0.1351 | 0.4205 (0.0696) |
| | W/PVT | 0.78862 (0.0914) | 0.4320 | 3.2 | 0.0483; 0.141 | 0.43671 (0.0914) |
| D-0.16 (baseline) | N/PVT | 0.87449 (0.047) | 0.4634 | 2.0 | 0.0942; 0.126 | 0.42519 (0.047) |
| | W/PVT | 0.78953 (0.080) | 0.500 | 2.5 | 0.0485; 0.132 | 0.4452 (0.080) |
| MD-0.16 | N/PVT | 0.70375 (0.096) | 0.364 | 4.6 | 0.0914; 0.163 | 0.41613 (0.096) |
| | W/PVT | 0.63427 (0.1032) | 0.363 | 6.7 | 0.0485; 0.164 | 0.4446 (0.1032) |

[a] lb-ft-s.

**Table 1 Cross sections of sabot configuration used in optimization study**

| Configuration | Remarks |
|---|---|
| D-0.00 | Bore rider all the way forward   |
| D-0.08 | Bore rider half-way forward   |
| D-0.16 | Original design   |
| MD-0.16 | Bore rider lengthened   |

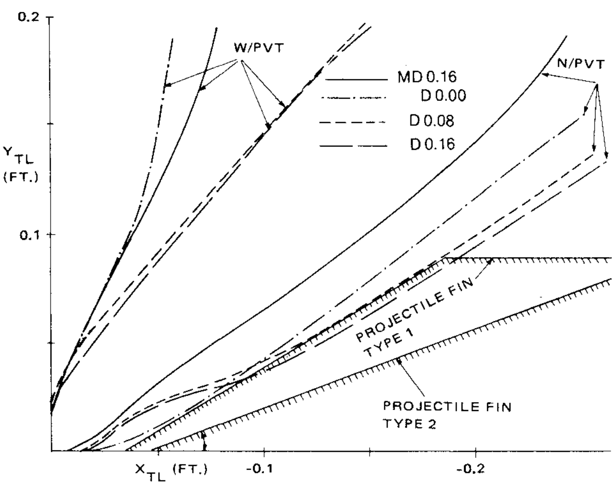



**Fig. 2 Sabot trailing-edge trajectories.**

### Sabot Design Practices

Design practices which result in minimum discard dynamic motion perturbations can be summarized as follows:

1) Aft c.g. location: locating the sabot c.g. as far aft as possible minimizes early time mechanical interactions.

2) Long/midpositioned bore rider: providing a relatively long bore rider and locating it about midway back to the obturator produces the most desirable pitching moment distribution.[5,6]

3) No pivot rings: the presence of pivot rings leads to enhanced mechanical interactions and projectile slowdown. Aft-mounted sabot winglets and the use of lightweight sabot materials show promise for achieving attractive pivot ringless designs.[5]

4) Maximum number of sabot segments: using more than three sabot segments has been shown to be beneficial.[5]

## References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[3] Schmidt, E., "Wind Tunnel Measurements of Sabot Discard Aerodynamics," *Journal of Spacecraft and Rockets,* Vol. 18, May-June 1981, pp. 235-240.

[4] Siegelman, D., Crimi, P., and Schmidt, E., "Projectile/Sabot Discard Aerodynamics," AIAA Paper 80-1588, Aug. 1980.

[5] Siegelman, D. and Wang, J., "Sabot Design Optimization," U.S. Army Ballistic Research Laboratory, Rept. ARBRL-CR-00450, March 1981.

[6] Siegelman, D., Wang, J., and Schmidt, E.M., "Sabot Design Optimization," AIAA Paper 81-1903, Aug. 1981.