



Integrating Dynamic Systems Simulation into the Design process of a 105mm Gun's Recoil System

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Presented by:

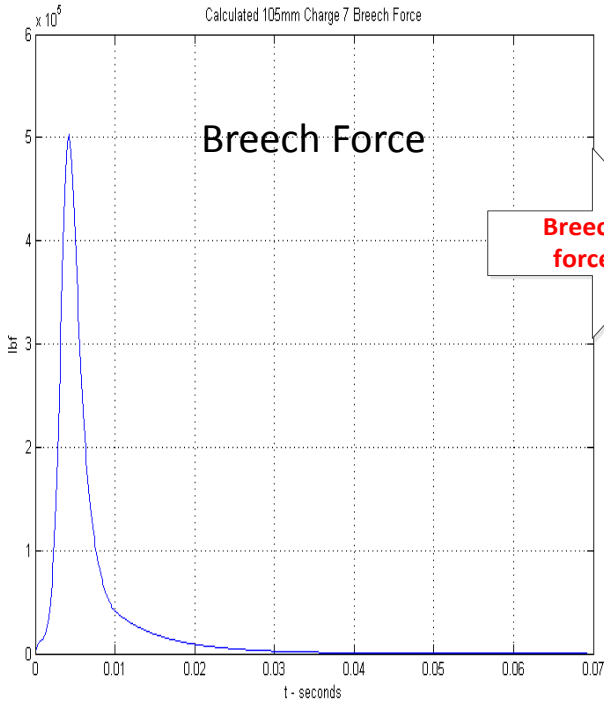
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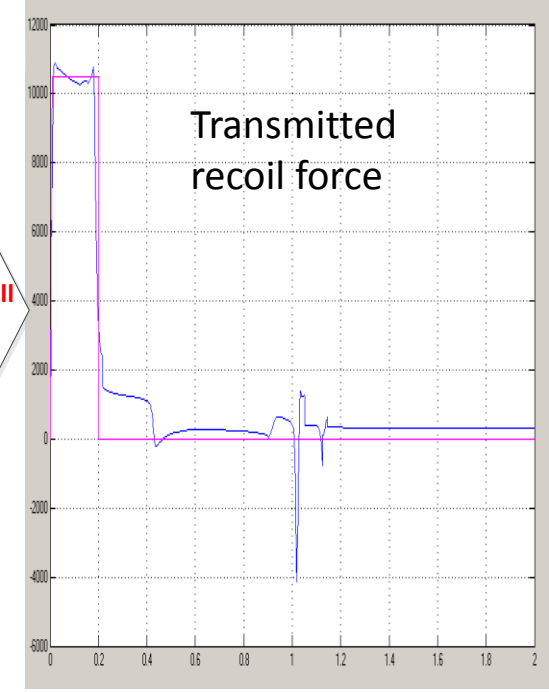
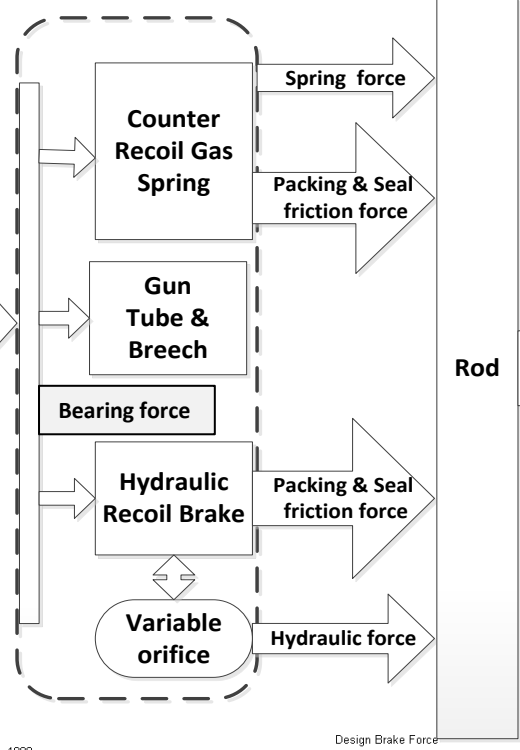
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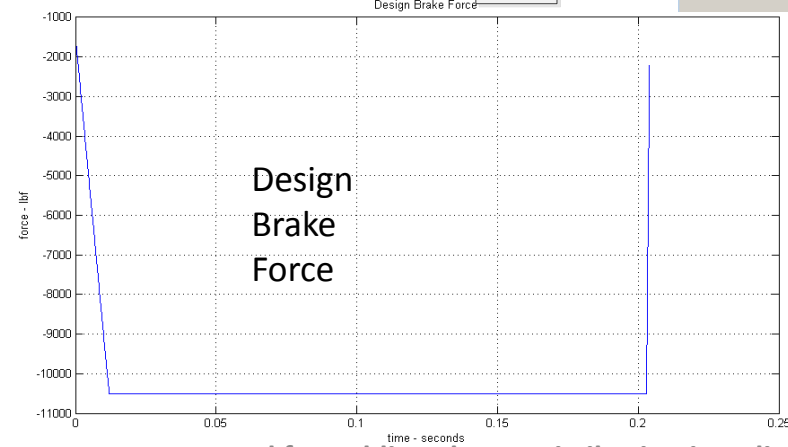
Problem Description: Recoil System



Breech force



Rod pull force

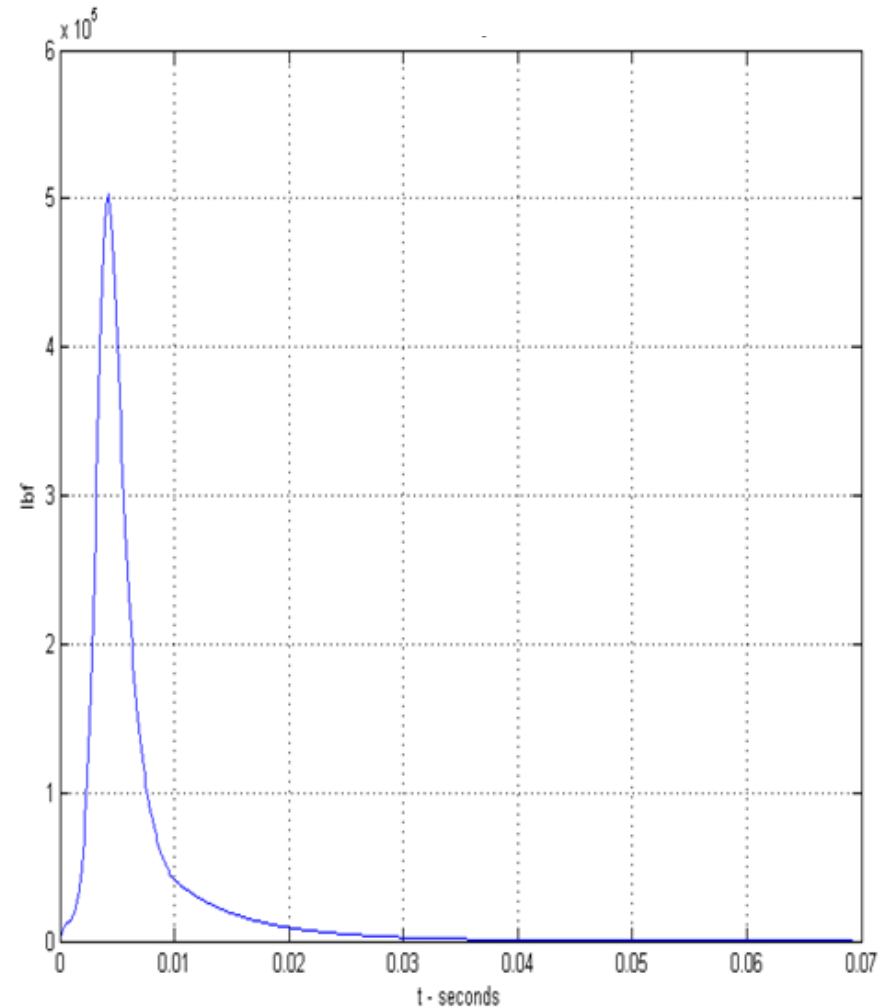


Objectives

- Develop and simulate models of recoil system functionality to:
 - Generate hydraulic orifice area design specifications,
 - Generate buffer area design specifications,
 - Generate hydraulic and pneumatic pressure and friction forces for cylinder packing, and seal design specifications,
 - Verify suitability of dimensional design specifications, and
 - Verify and predict system performance.
 - Target recoil and force requirements at nominal T&P, charge 7 based breech force at zero elevation
- Key References
 - DOD-HDBK-778(AR) RECOIL SYSTEMS (1988)
 - MIL-HDBK-785(AR) DESIGN OF TOWED ARTILLERY WEAPON SYSTEMS (1990)
 - RHEINMETALL Handbook on Weaponry (1982)

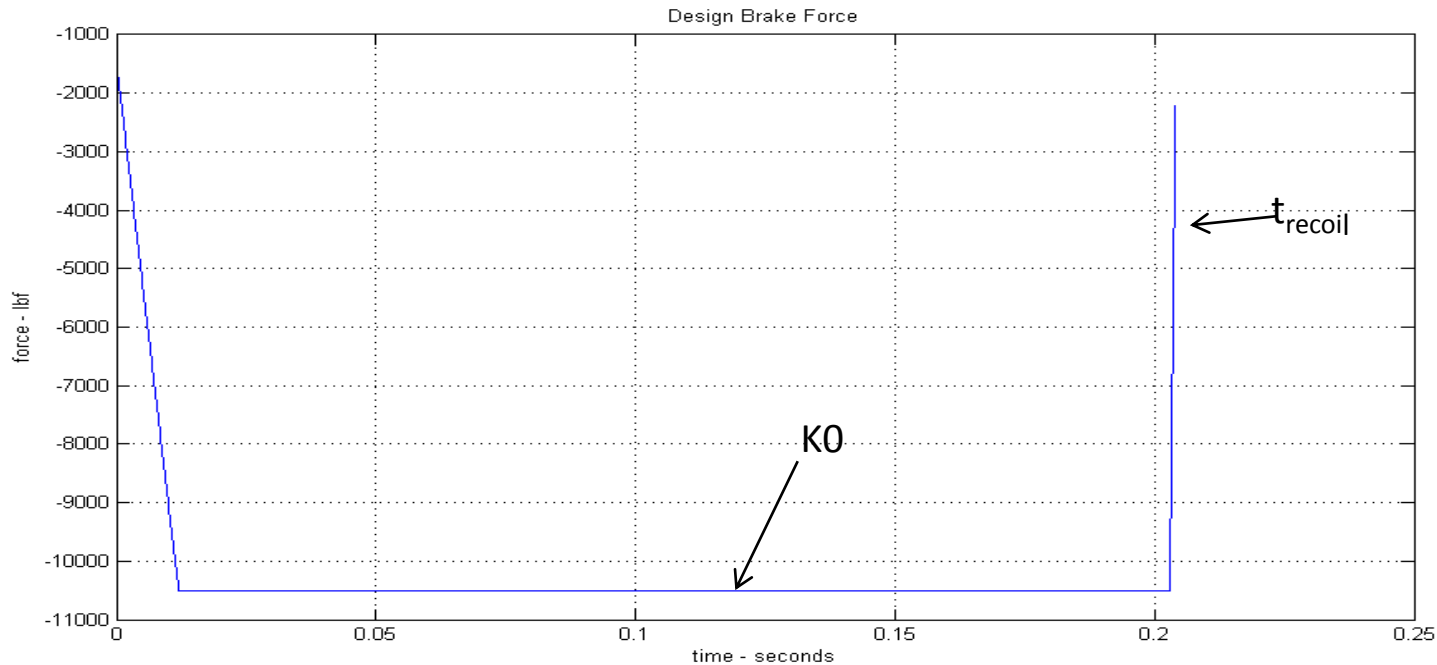
Breech Force

- Driving force for recoil system
- Impulse (I)
 - Integral of breech force curve
 - Used to design brake force function



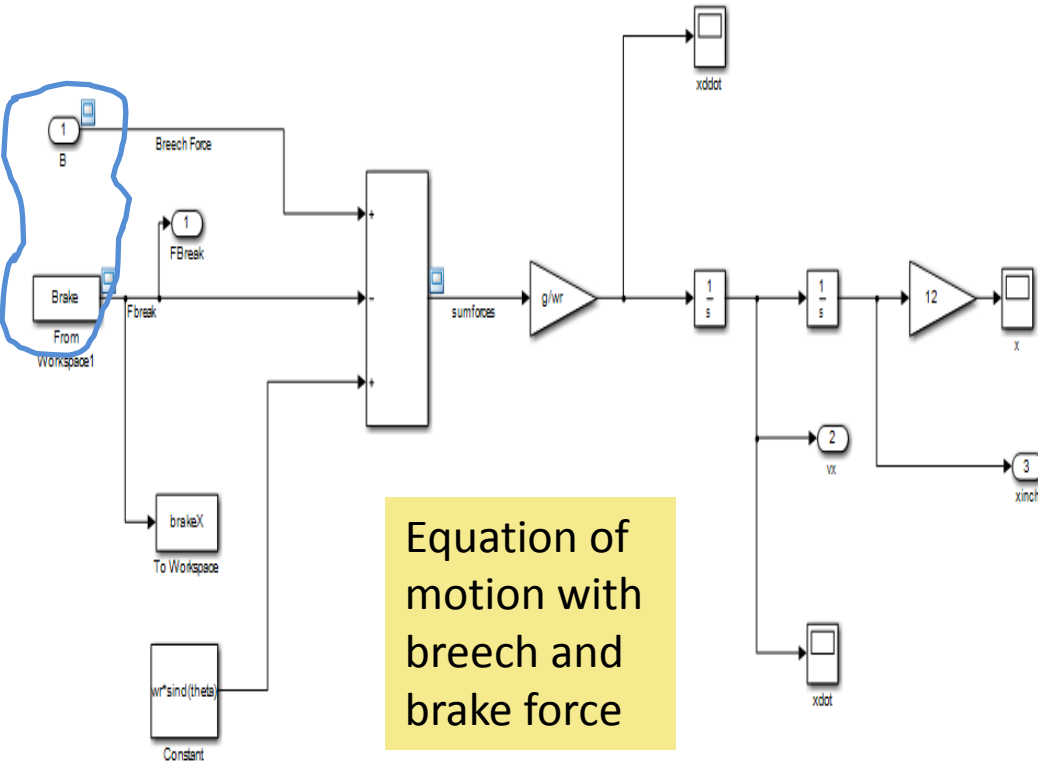
Brake Force Functions

- Brake force curve design
 - Average Brake Force: $K0 = I^2 / (2 * m_{recoil} * L_{recoil})$
 - Recoil time: $t_{recoil} = I / K0$
 - Estimate friction and gas spring forces
 - Design trapezoidal $F_{Brake}(t)$, over recoil duration

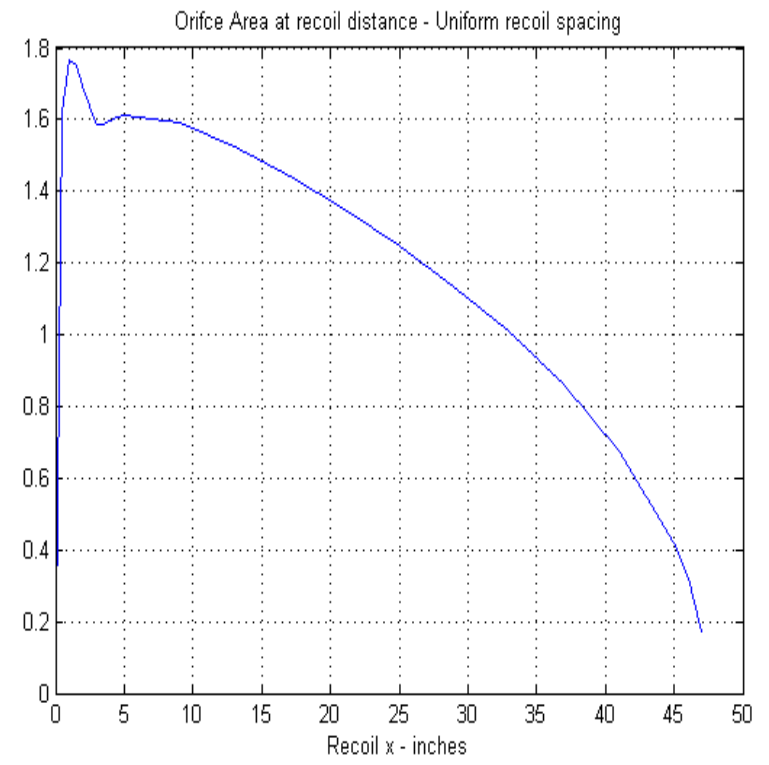


Designing Variable Orifice

- $ae(x) = ao(x) * Cd = A_{hyd} * v(x) * \sqrt{\frac{density * A_{piston}}{2 * F_{orifice}(x)}}$
- Simulate: $B(t)$ and $Brake(t) \rightarrow v(t), F_{orifice}(t), x(t) \rightarrow v(x), F_{orifice}(x)$



Equation of motion with breach and brake force



Simulink and Simscape

- Simulink
 - Graphical numerical programming
 - Numerically solve differential equations
 - Directional flow - evaluation order
- Simscape (and Simhydraulics)
 - Graphical **physical modeling**
 - Through and across variables bidirectional
 - Encapsulate equations for all behaviors of components

Simhydraulics Variable Orifice

Block Parameters: Variable Orifice

Variable Orifice

The block simulates a variable orifice of any type as a datasheet-based model. To parameterize the block, three options are available: (1) by maximum area and control member stroke, (2) by a table of orifice area vs. control member displacement, and (3) by the pressure-flow rate characteristics. The lookup table function is used in the second and third cases for interpolation and extrapolation. Three methods of interpolation and two methods of extrapolation are provided to choose from.

Connections A and B are hydraulic conserving ports associated with the orifice inlet and outlet, respectively. Connection S is a physical signal port. The block positive direction is from port A to port B. Positive signal at port S opens or closes the orifice, depending on the value of the Orifice orientation parameter.

Settings

Parameters

Model parameterization:	By maximum area and opening	
Orifice maximum area:	0.5e-4	m ²
Orifice maximum opening:	5e-3	m
Orifice orientation:	Opens in positive direction	
Flow discharge coefficient:	0.7	
Initial opening:	0	m
Critical Reynolds number:	12	
Leakage area:	1e-12	m ²

OK Cancel Help Apply

$$q = C_D \cdot A(h) \sqrt{\frac{2}{\rho}} \cdot \frac{p}{(p^2 + p_{cr}^2)^{1/4}}$$

$$p = p_A - p_B$$

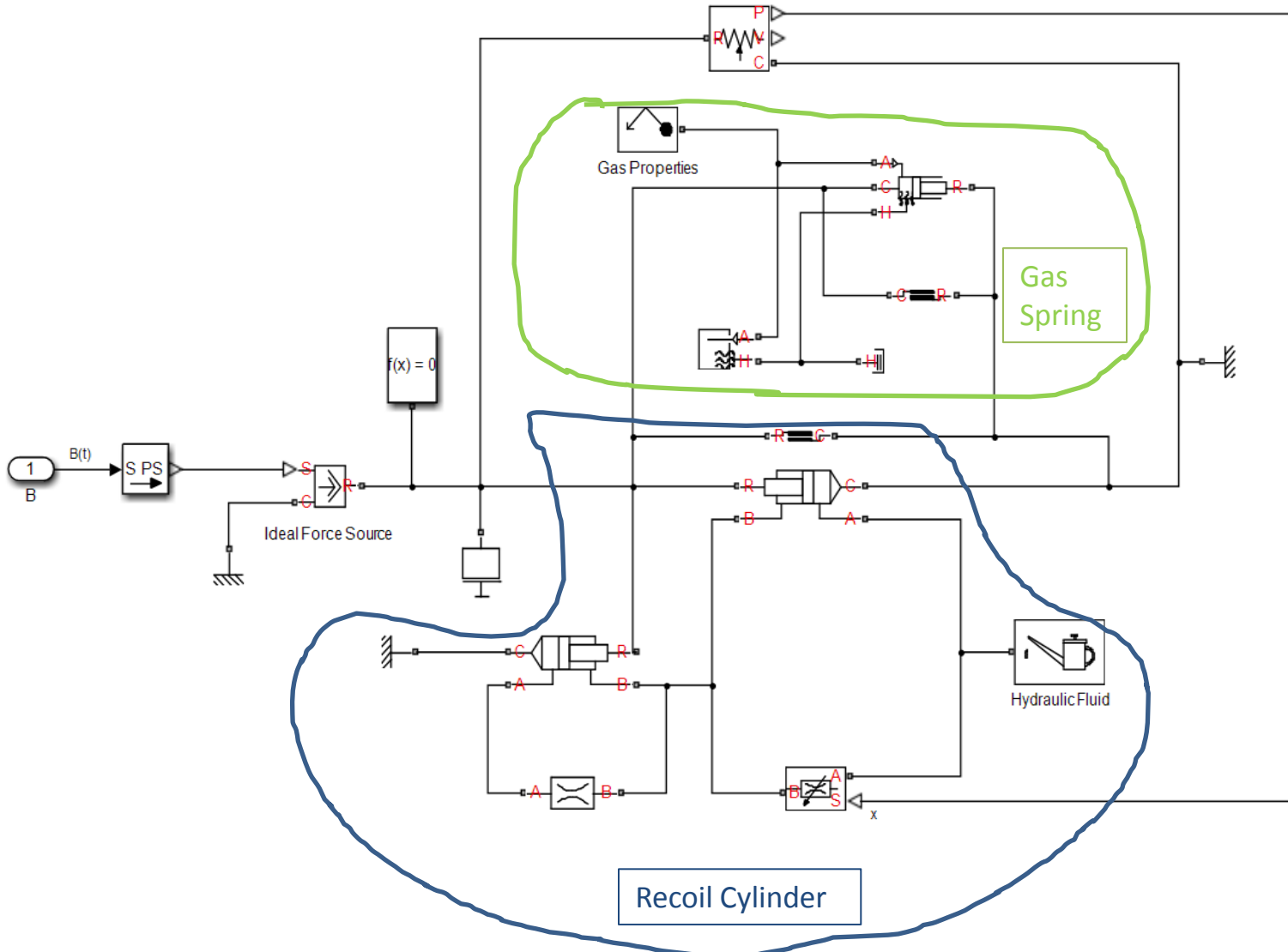
$$p_{cr} = \frac{\rho}{2} \left(\frac{Re_{cr} \cdot v}{C_D \cdot D_H} \right)^2$$

$$h = x_0 + x \cdot or$$

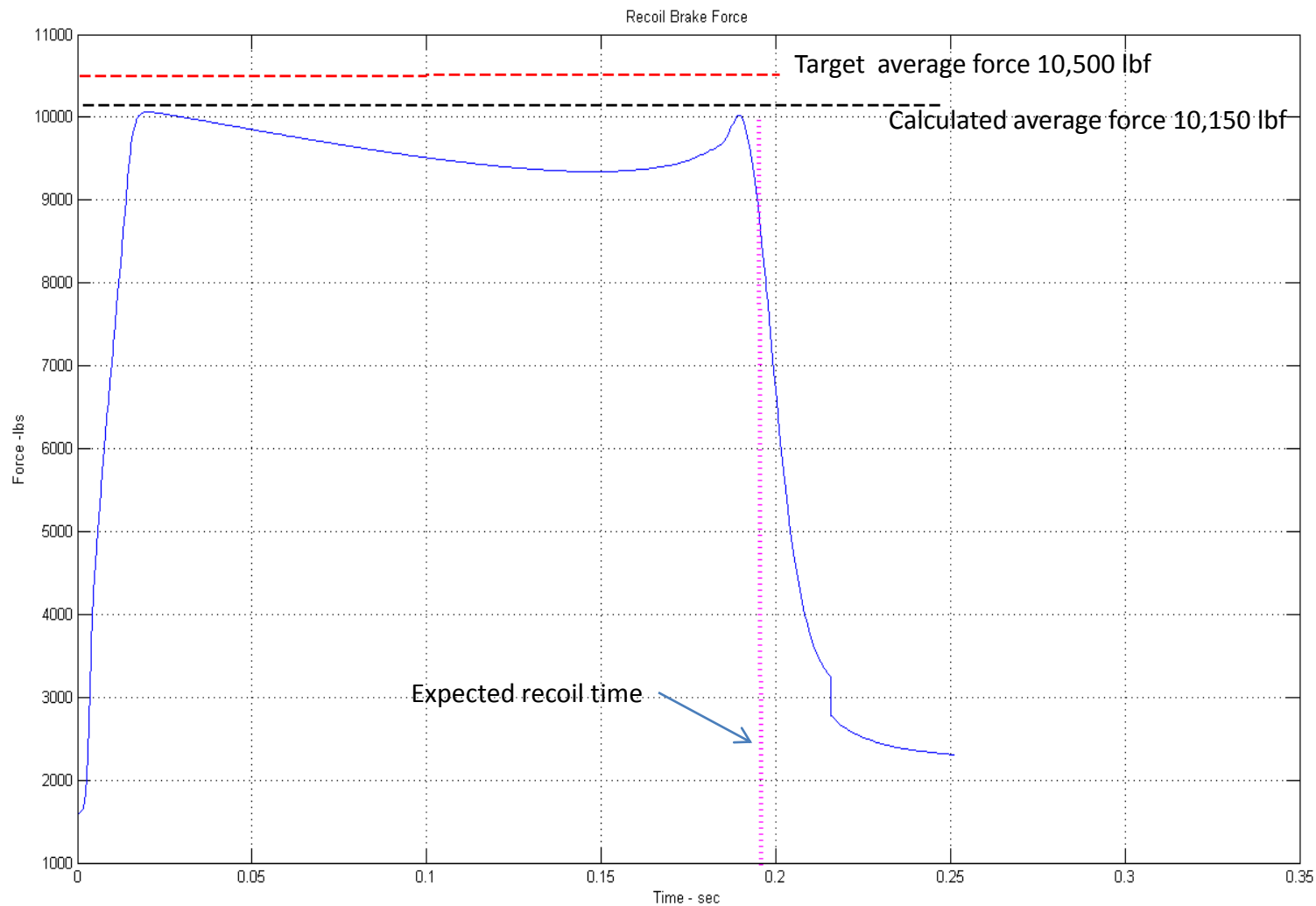
$$A(h) = \begin{cases} h \cdot A_{max} / h_{max} + A_{leak} & \text{for } h > 0 \\ A_{leak} & \text{for } h \leq 0 \end{cases}$$

$$D_H = \sqrt{\frac{4A(h)}{\pi}}$$

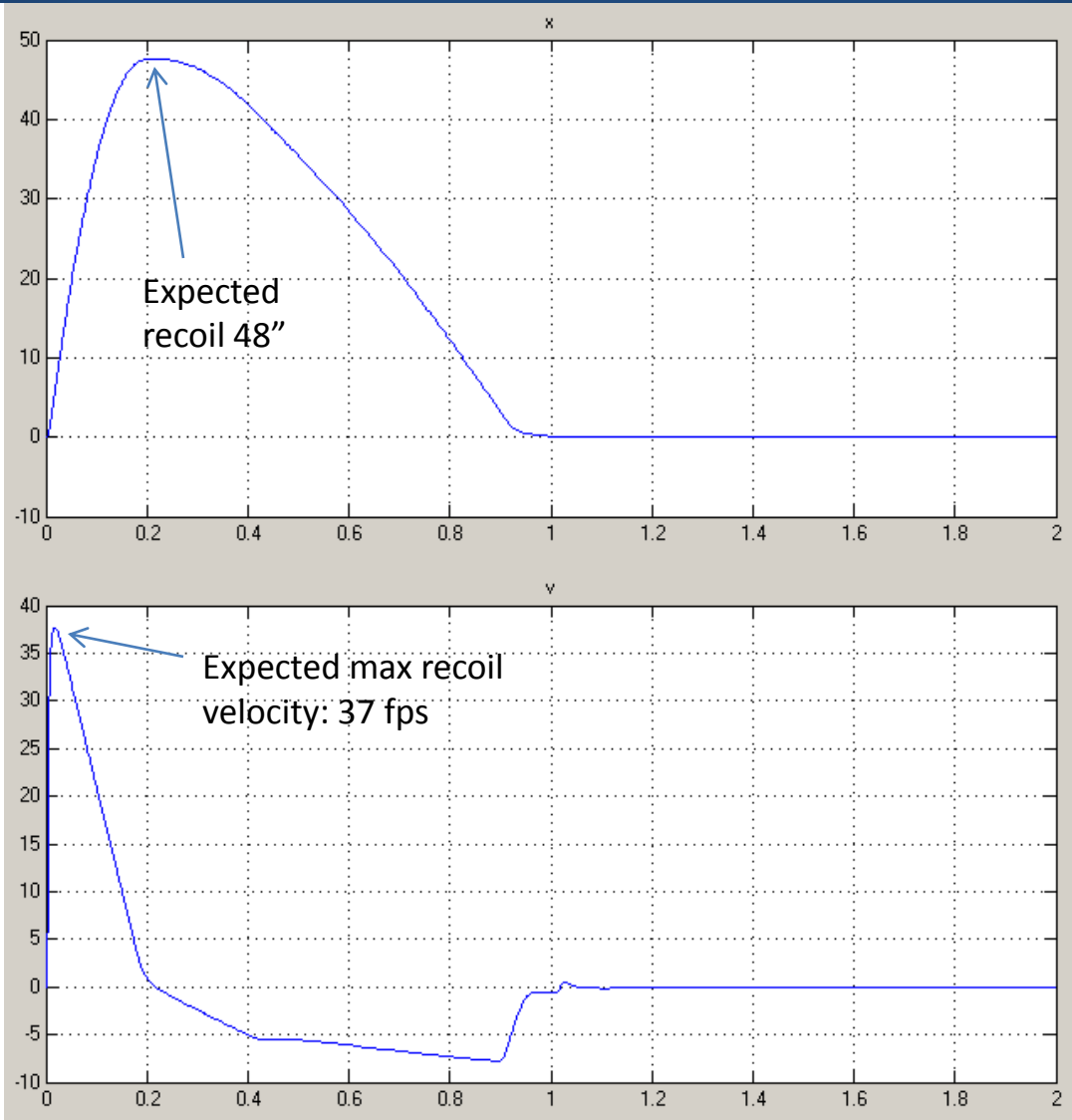
Recoil System Model



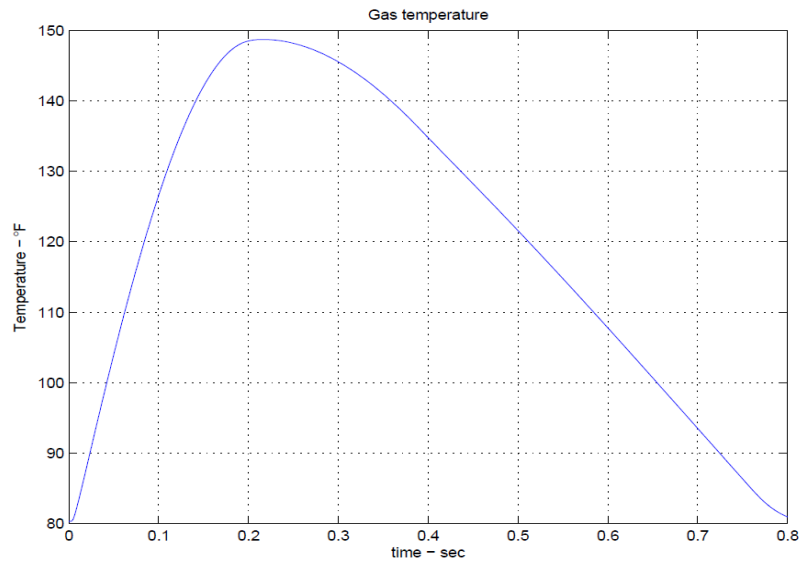
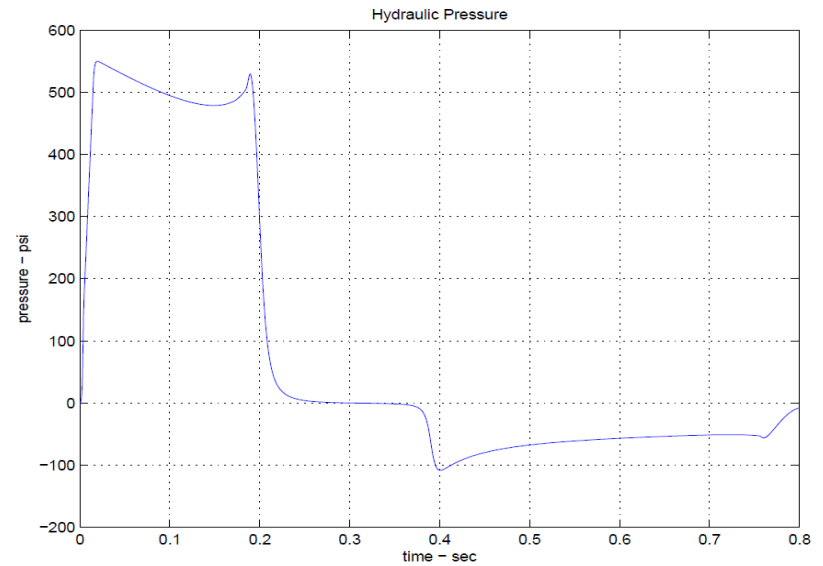
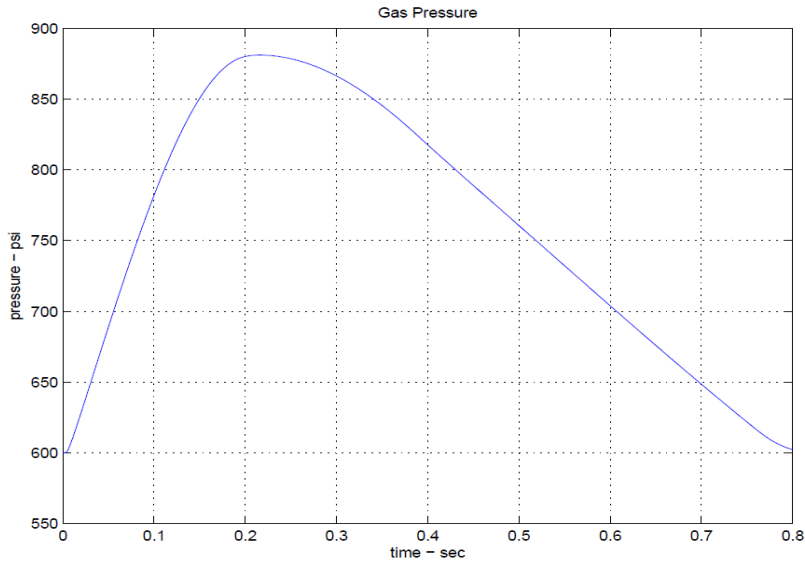
Simulation: Force



Validation: Recoil and Velocity



Design Information From Simulation



- Maximum hydraulic pressure: 550 psi
- Maximum gas pressure: 880 psi
- Maximum gas temperature: 150°F

- **Dynamic system simulation critical to design process**
 - Highly interdependent interacting subsystems
 - Exploration of design variables and trade studies
 - Actual dimensional design of subsystems (buffer, replenisher)
 - Sensitivity analysis
- **Continuing work**
 - Continue refining model detail
 - Explore and complete counter recoil buffer design
 - Conduct environment and operational mode sensitivity analysis
 - Validate model
 - Tests prototype subsystems
 - Range test development gun-recoil system
 - Iterative design adjustments using test and simulation results