Multiphysics Analysis of Electromagnetic Flow Valve

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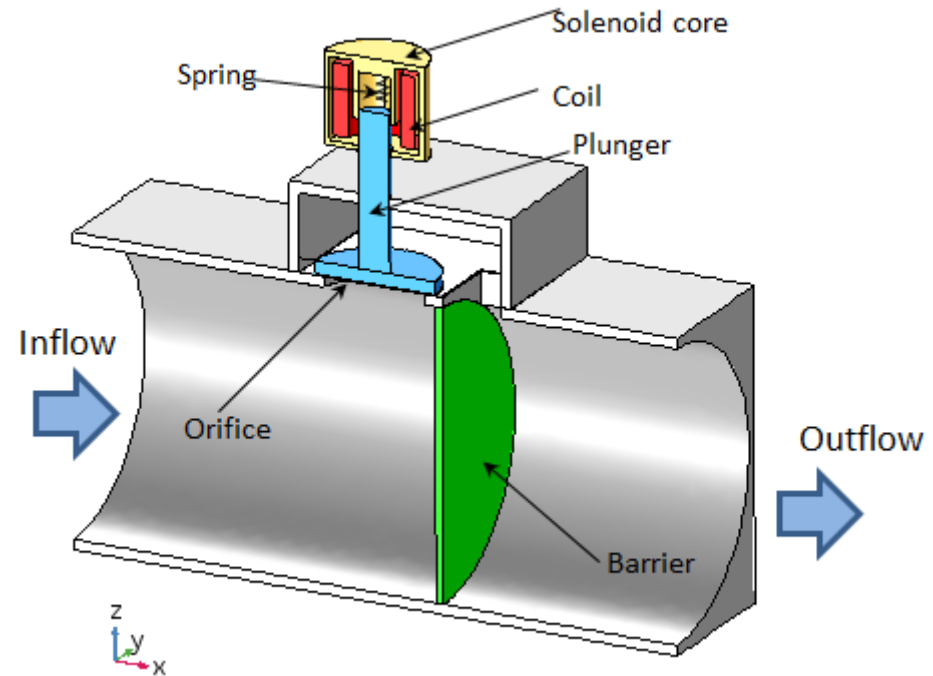**AltaSim Technologies**

Overview

- **Valve mechanics**

- **Modeling methodology**

- **Electromagnetics of coil / plunger**

- **Fluid flow in valve**

- **Design study for internal pressure**

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OVERVIEW OF VALVE MECHANICS

Schematic – Two-Port Valve

- **Three primary components**
  - **Coil / core**
  - **Plunger**
  - **Spring**
- **Normally closed valve**
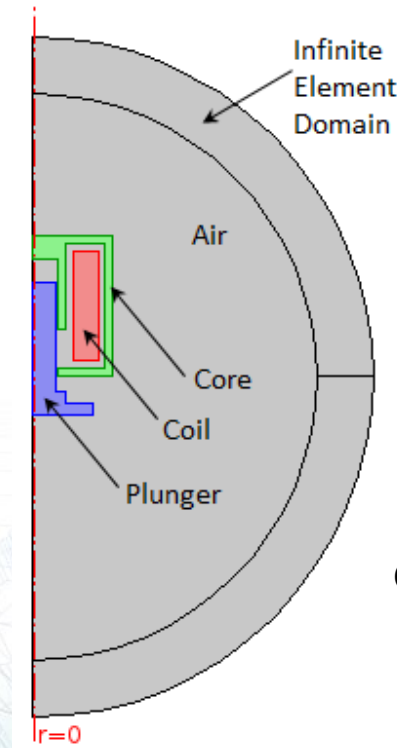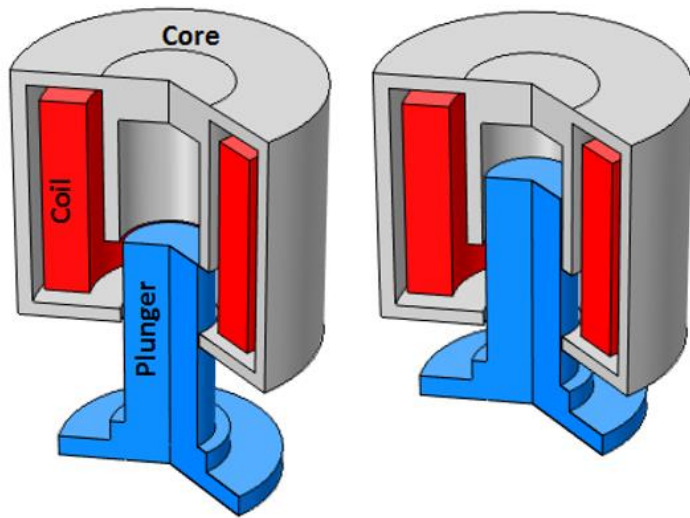 - **Spring closes valve**
  - **EM force opens**

MULTIPHYSICS

The Model Contains Four Physics

1. **Electromagnetic**
   - **Coil / core / plunger**
2. **Rigid body mechanics**
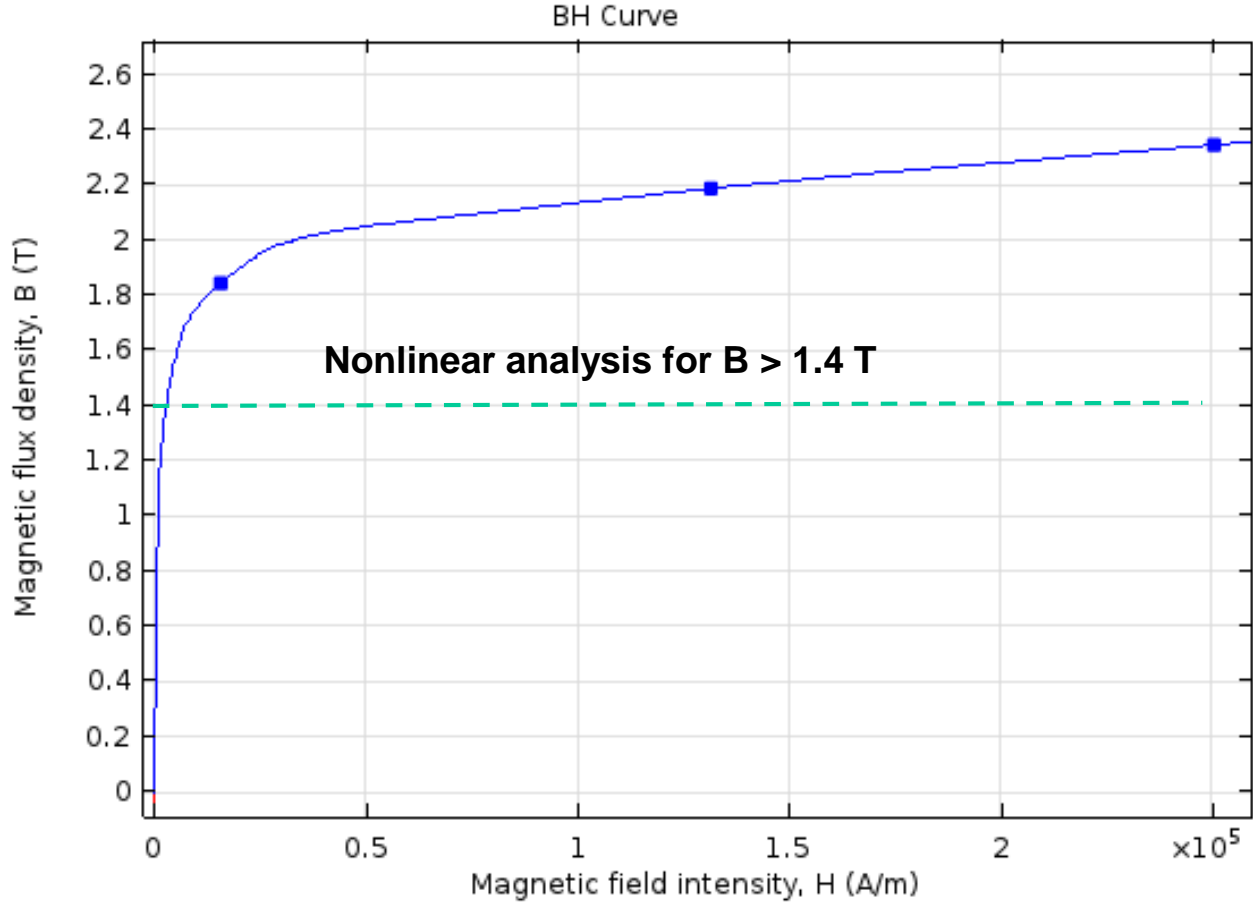   - **Plunger**
3. **Fluid dynamics**
4. **Moving mesh**

Electromagnetics

- **Solved using axisymmetric model**
- **Calculate electromagnetic force using magnetostatics**
- **Non-linear BH curve for plunger and core**

Coil: 500 turns

Electromagnetics – B-H Curve

Nonlinear analysis for B > 1.4 T

Plunger and Core constructed of ferromagnetic steel

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Rigid Body Mechanics

- **Plunger attached to spring and dashpot**
- **Solved using global ODE capabilities**
- **F_{EM} calculated from electromagnetic analysis**
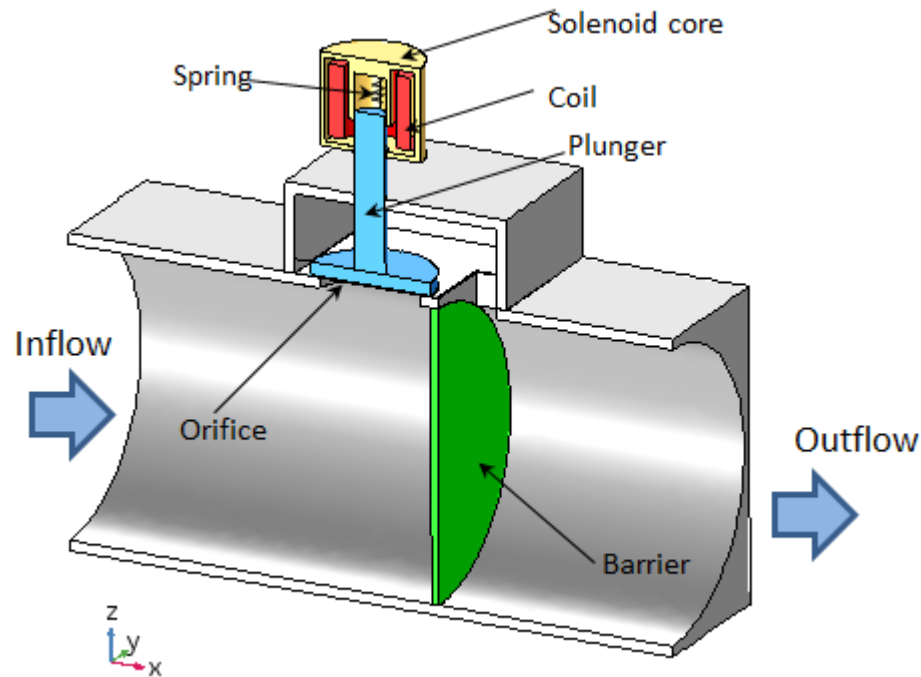- **F_{CFD} calculated from fluid dynamics analysis**

$$M_P \frac{d^2 U_0}{dt^2} + D \frac{dU_0}{dt} + kU_0 - \left(F_{CFD} + F_{EM} - F_{init} \right) = 0$$

$$M_P = 5 \ g \qquad D = 1 \ N \cdot s / m$$

$$k = 3.6 \ kN / m \qquad F_{init} = 3.6 \ N$$

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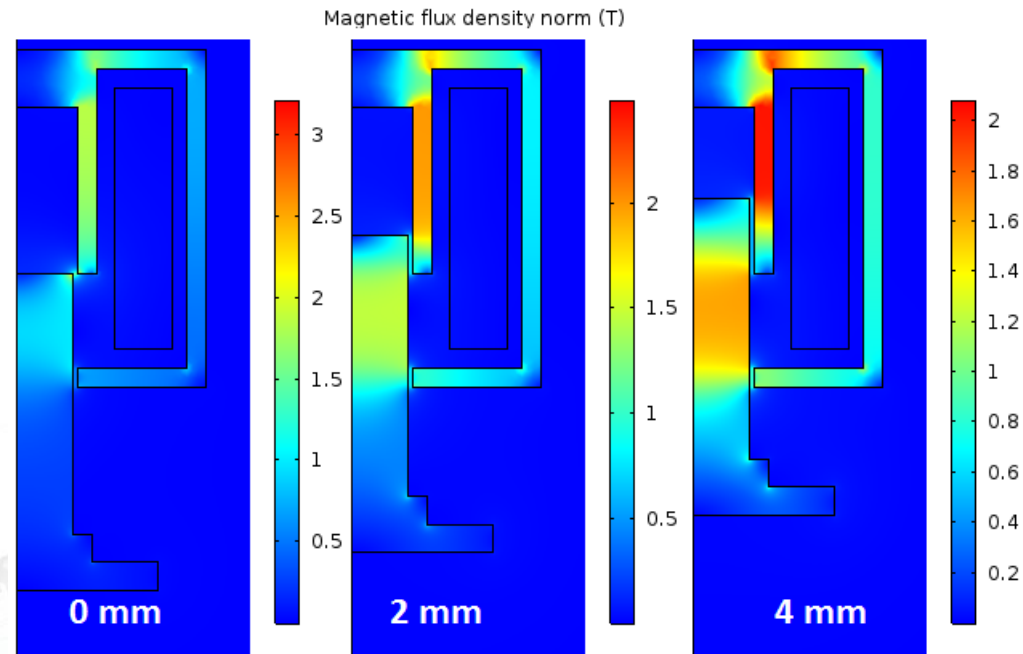
Fluid Dynamics

- **Laminar flow**

- **Pressure specified at inflow, zero gauge pressure at outflow**
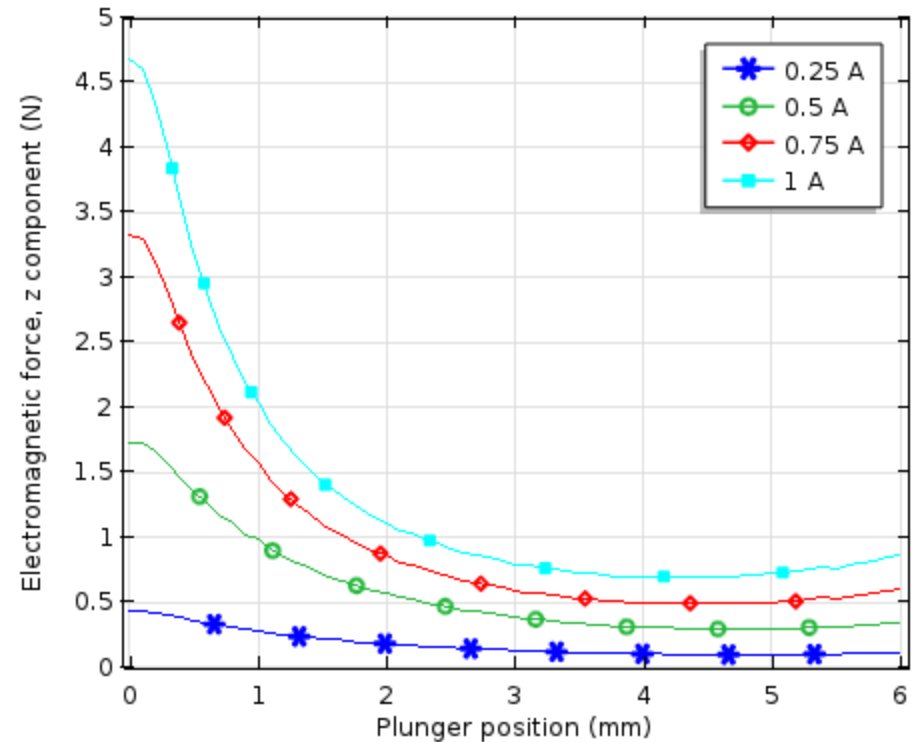
RESULTS

Electromagnetics– Magnetic Flux

- **Function of plunger position**

- **Exceeds 1.4 T over much of core**

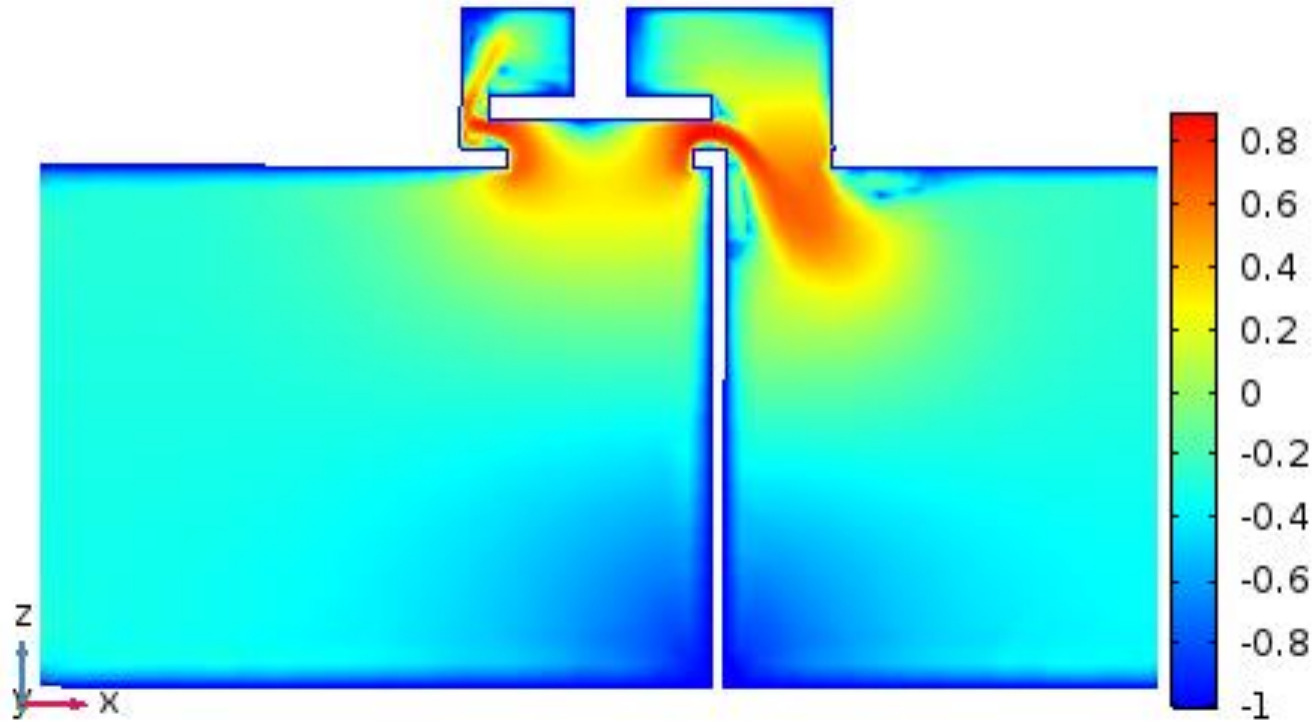- **Non-linear analysis necessary for accurate forces**

Magnetic flux density norm (T)

0 mm   2 mm   4 mm

Electromagnetics– Force on Plunger

$$\mathbf{F}_{EM} = \int_{\partial\Omega} \mathbf{n} \cdot \left[\mathbf{H}\mathbf{B}^{T} - \frac{1}{2}(\mathbf{H} \cdot \mathbf{B})\hat{\mathbf{I}} \right] dS$$
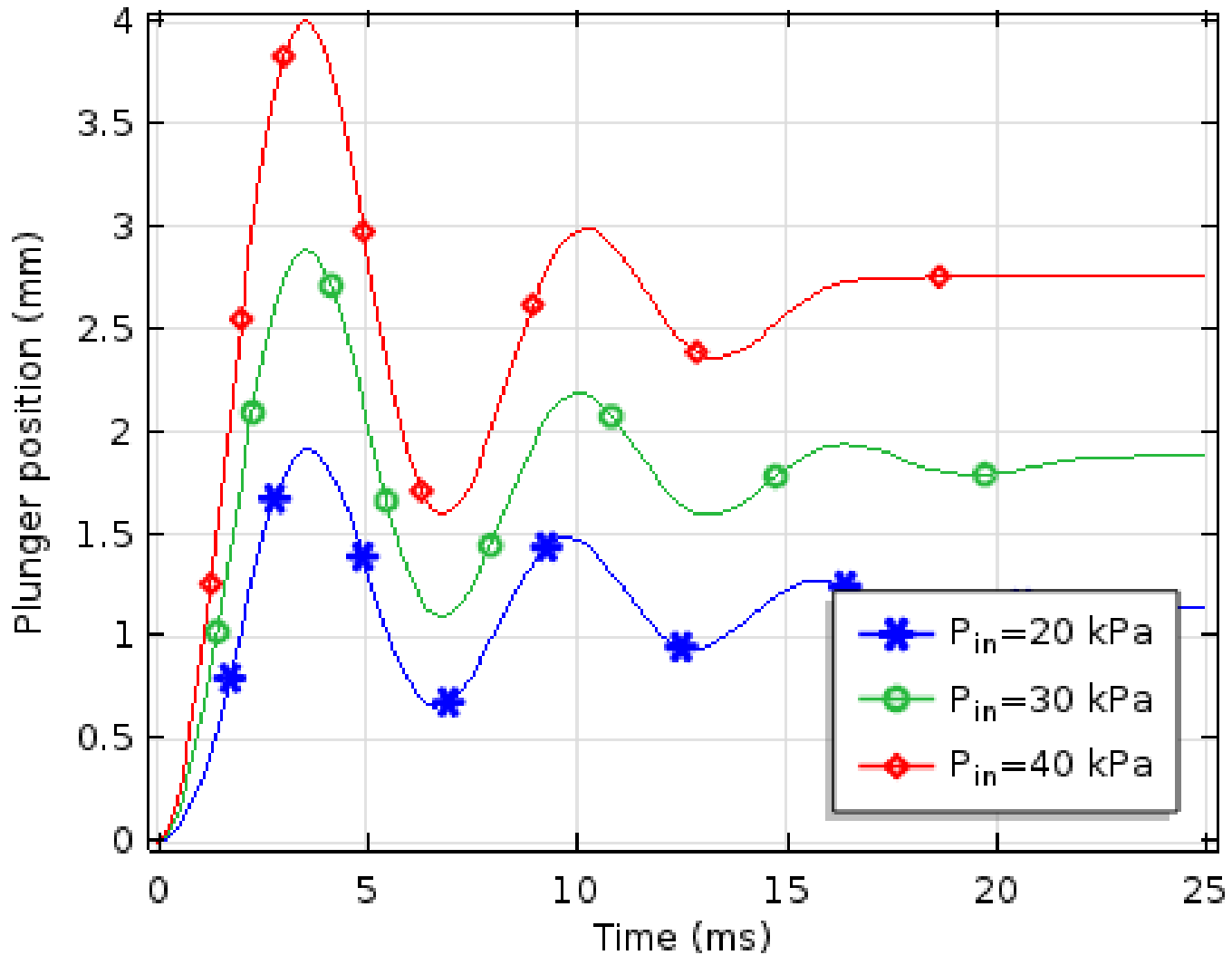
- **Calculated using Maxwell stress tensor**

- **Nonlinear function of position and current in coil**

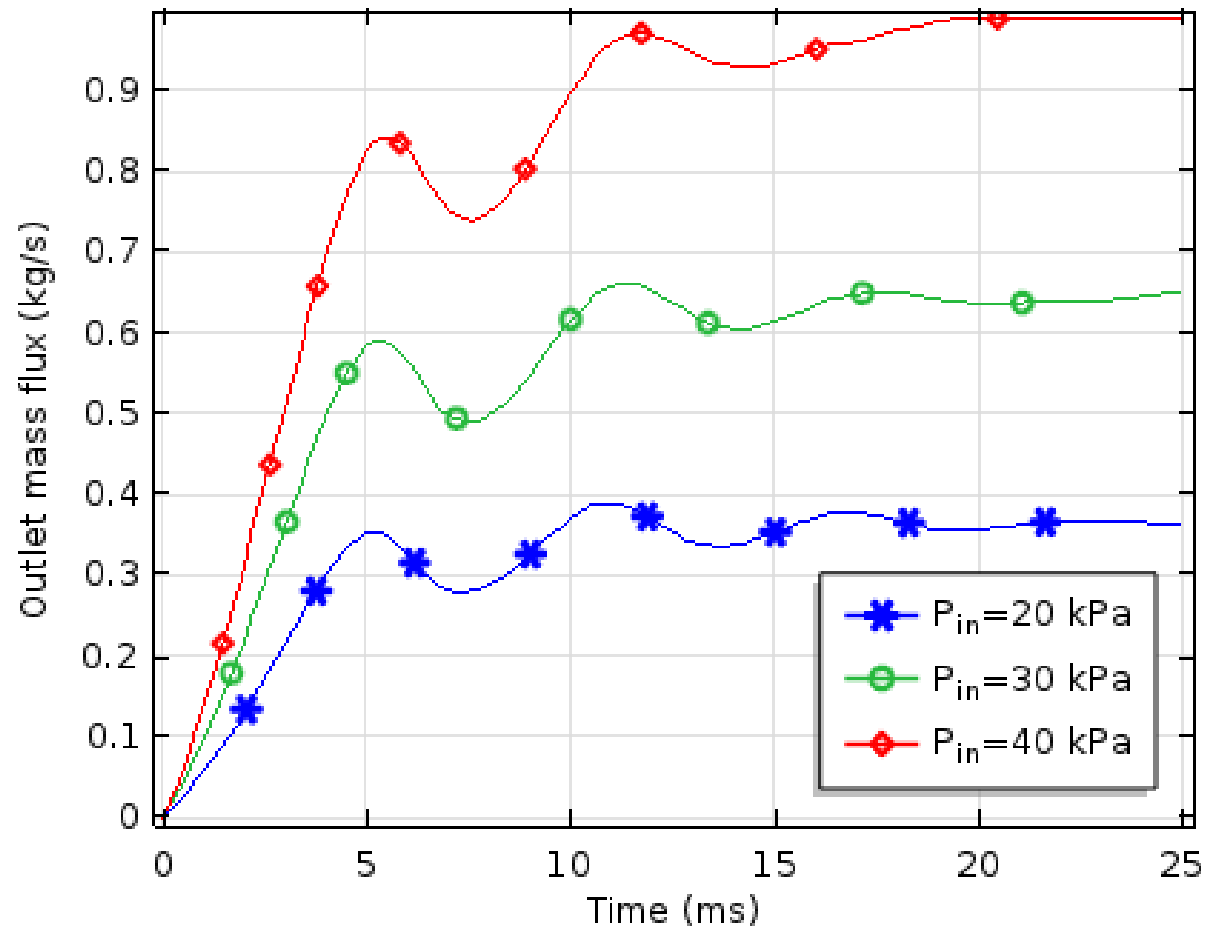# Fluid Velocity – Log10(u)

Time=0.01 s   Multislice: log10(spf.U+1e-1)

Inlet Pressure – Plunger Position

Inlet Pressure – Flow Rate

Summary

- **Multiphysics analysis developed for solenoid valve design**
  - **Electromagnetic analysis of solenoid**
  - **Fluid mechanics analysis**
  - **Rigid body motion for plunger**
- **Design study of inlet pressure**
  - **Plunger position/velocity**
  - **Flow rate**

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Thank You!