MULTIPHYSICS ANALYSIS OF ELECTROMAGNETIC FLOW VALVE

Sergei Yushanov, Jeffrey Crompton and Kyle Koppenhoefer

AltaSim Technologies, Columbus, Ohio

KEYWORDS

Electromagnetics, Fluid Structure interaction, Coupled analysis

ABSTRACT

Solenoid valves are used in a variety of applications to control fluid flow and are actuated by the passage of an electric current that develops a magnetic field that controls the displacement of a plunger. With increasing electric current the plunger is moved progressively up, thus controlling the flow of fluid through an orifice, Figure 1.

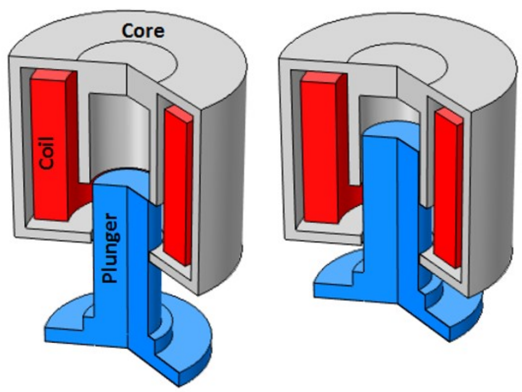


Figure 1: Schematic representation of a solenoid valve with increasing applied current.

The nature of the operation of a solenoid valve is inherently multiphysics, relying on electromagnetically induced forces to impart structural changes that control fluid flow thus creating a coupled electromagnetic-fluid-structure interaction.

In the current work the operation of a solenoid valve is analyzed as a fully coupled electromagnetic-fluid-structure problem in which the motion of a plunger operates against a spring to allow flow of pressurized fluid through an orifice. Initially the spring holds the plunger closed against the force due to the pressurized fluid. The plunger is constructed from material having non-linear magnetic B-H behavior such that current passing through an electromagnetic coil surrounding the plunger generates an electromagnetic force on the plunger. Motion of the plunger is resisted by a spring to allow controllable motion of the plunger; an increase in the current flowing through the coil is required to increase plunger displacement, increase the size of the opening and allow more fluid flow.

Analysis of the behavior of the solenoid valve is conducted as a single, integrated, fully coupled multiphysics analysis using COMSOL Multiphysics in which the electromagnetic response, structural response and fluid flow are solved simultaneously. Electromagnetic analysis is performed to determine the Lorentz force induced in the plunger that is represented as material having non-linear magnetic B-H behavior, the fluid is modeled as high Reynolds number incompressible viscous fluid flow.

The analyses show how applied current through the coil generates electromagnetic forces that control plunger position and subsequently mass flow through the orifice, Figures 1 and 2.

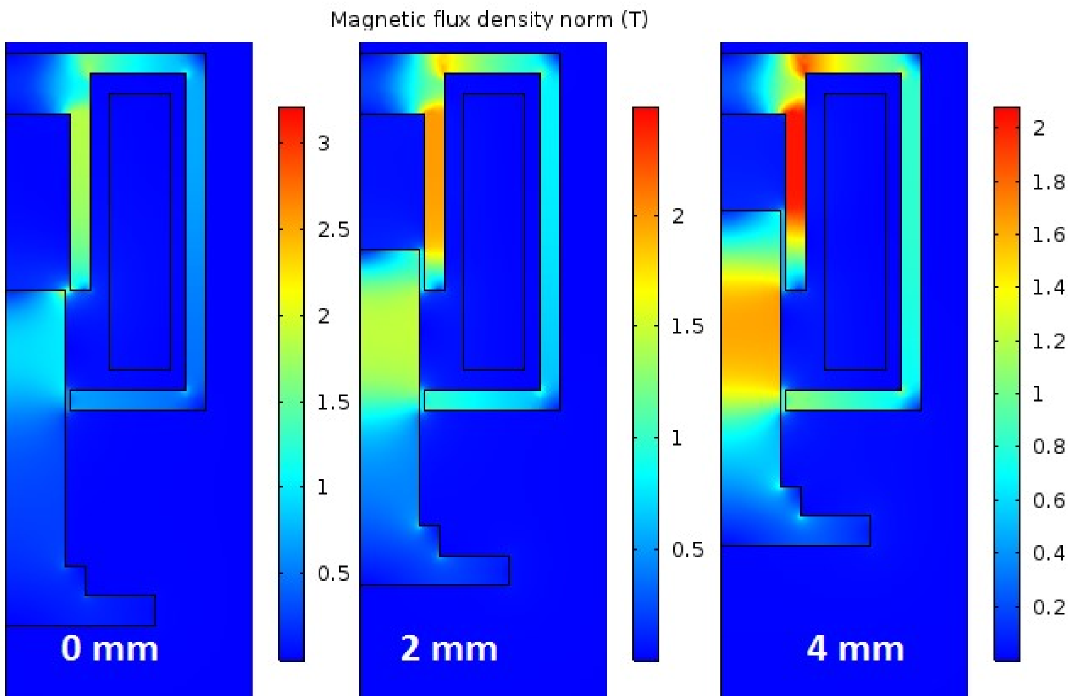
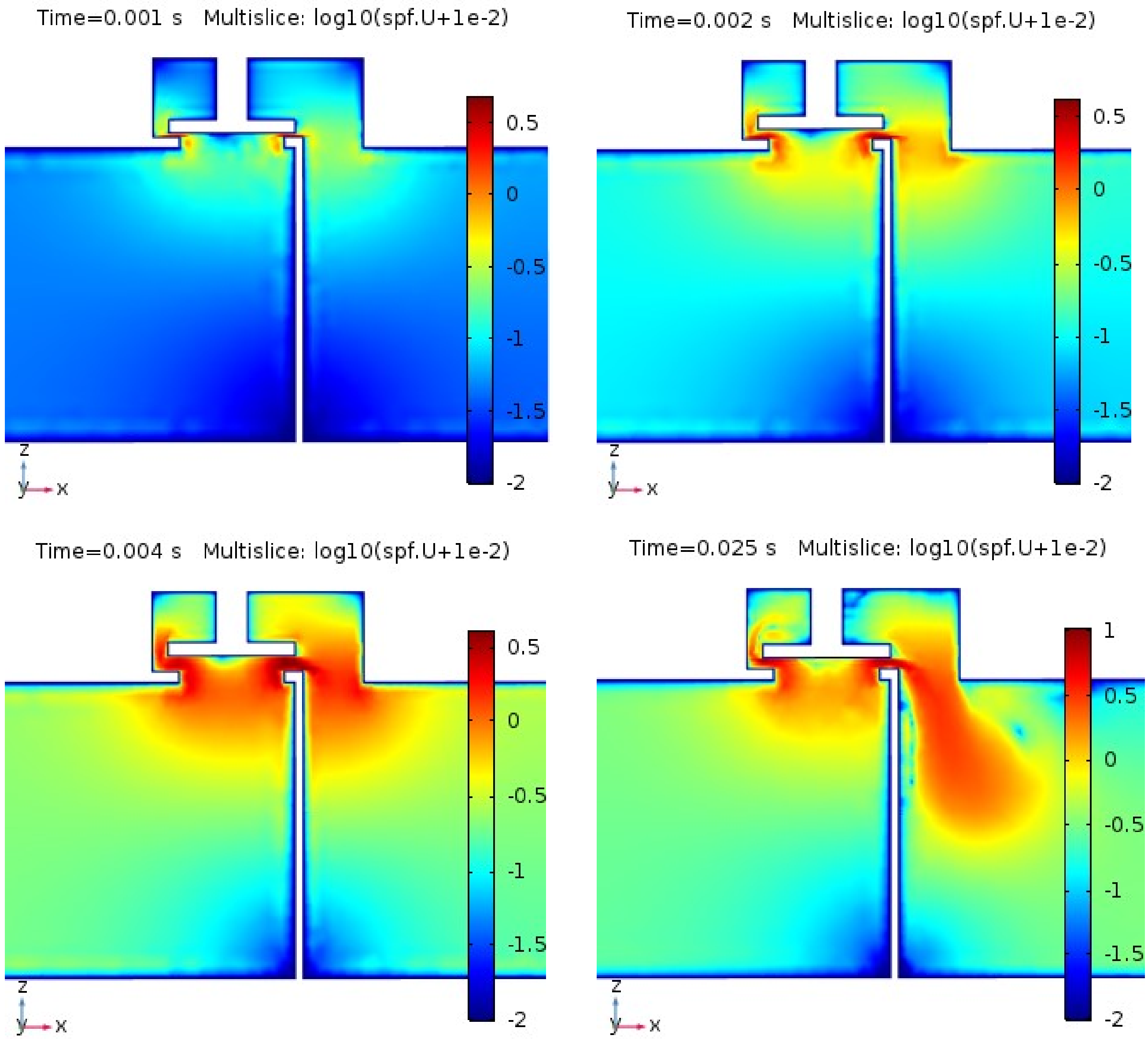


Figure 1: Magnetic flux density

10


Time=0.001 s Multislice: log10(spf.U+1e-2)
0.5
0
-0.5
-1
-1.5
-2
z
y
x
Time=0.002 s Multislice: log10(spf.U+1e-2)
0.5
0
-0.5
-1
-1.5
-2
z
y
x
Time=0.004 s Multislice: log10(spf.U+1e-2)
0.5
0
-0.5
-1
-1.5
-2
z
y
x
Time=0.025 s Multislice: log10(spf.U+1e-2)
1
0.5
0
-0.5
-1
-1.5
-2
z
y
x

COMPUTATIONAL ANALYSIS OF ADDITIVE MANUFACTURING

Figure 2: Fluid velocity distribution during valve opening