# Natural Convection Effects on the Solidification in Cylinders at Different Filling Percentages

R. Bourisli[1], A. Alshayji[1]

[1]Kuwait University, Kuwait City, Kuwait

## Abstract

The solidification of a fluid in a partially-filled circular cylinder is encountered in a number of industrial processes and in the oil and gas sector. The characteristics of the process depends on various fluid and geometrical parameters. In the current study, a fluid with temperature-dependent density in a partially-filled circular cylinder solidifies because of a sudden drop in pipe surface temperature. The phase-change process depends on the characteristics of the heat transfer process which, in turn, depends on the behavior of the buoyancy-driven flow.

The transient, 2D problem is investigated numerically for different levels of cylinder filling. The interface between the water and the air above it is tracked. The finite element method was used to solve the mass, momentum, energy and phase equations through COMSOL Multiphysics®. The analysis considers different combinations of Rayleigh and Prandtl numbers.

Initial results indicate that the dependence of the time to full solidification on the filling percentage as well as Rayleigh number is pronounced but not linear. The progress of liquid-solid mass fraction with time was also found to depend slightly on the filling level. This is due to the varying surface area in contact with the pipe surface. The effect is attenuated with decreasing Prandtl number. Figure 1 shows sample air circulation, temperature variations, and fluid solidification phase in the computational domain at a 25% filling percentages, a Prandtl number of 0.7 and a Rayleigh number of 3×〖10〗^6. Understanding of the filling percentage effects could be beneficial in applications where the phenomenon is critical for the operation of systems, such as in food processing, underground sewage water pipes and crude oil pipes.

# Figures used in the abstract

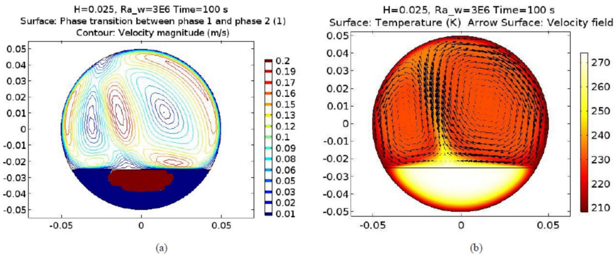


**Figure 1**: (a) Phase contours (blue: solid, red: liquid) and air circulation above it, and (b) velocity arrow and temperature contours at Ra = 3×106, filled percentage = 25% and time = 100 s.