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CENTRIFUGAL CASTING OF PARAFFIN WAX: NUMERICAL ANALYSIS OF THE INFLUENCE OF CASTING TUBE ASPECT RATIO

Abstract

Alternative hybrid rocket propellants like paraffin wax continue to gain attention from researchers because of their attractive characteristics such as being non-toxic, multi-purpose, and easy to store. The centrifugal casting process is a common method of efficiently fabricating paraffin wax into an industrially useful cylindrical annulus. In the centrifugal casting process, centrifugal force spins high-density fluid in a partially filled tube towards the walls whereas low-density fluid migrates towards the center of the tube forming a thin-walled hollow cast after solidification.

Casting tube geometrical parameters like length and diameter have a direct impact on the quality of the final cast product in the centrifugal casting process. To further understand, predict various heat and mass flow phenomena, and even optimize the centrifugal casting process, it is necessary to study, both through experiments and numerical simulations, fluid flow patterns in the centrifugal casting process. The present research focuses on understanding the impact that combined length and diameter, in the form of aspect ratio (a = l/d), has on the formation of cylindrical annulus during the centrifugal casting process of paraffin wax. Representing data in the form of on-dimensional parameters like aspect ratio ensures that findings are useful beyond a specific case. When rotation of fluid takes place inside a cylinder of finite length, inevitable end flow disturbance occurs (also known as Ekman flow phenomenon). These disturbances have a direct impact on how long it takes to form a complete cylindrical annulus, and thus quality of the final cast products.

The present numerical research work is the first phase of an extensive series of numerical work that is currently underway in the Space Enabled Research Group, MIT. The numerical work will facilitate further understanding of the fluid mechanics and heat transfer mechanism of centrifugal casting; the overarching aim being to better understand centrifugal casting to be able to produce better fuel grains both on Earth and in space.

The present research will leverage the commercial Computational Fluid Dynamics, CFD solver ANSYS Fluent to numerically investigate the effects that aspect ratio of the casting tube has on the centrifugal casting process. Three tube diameters, d (12.5 mm, 25.4 mm, and 50.8 mm) have been studied previously by the present authors, each investigated at three different lengths, l (50.8 mm, 101.6 mm, and 203.2 mm). This corresponds to aspect ratio, a of: 4, 8, and 16 (for d = 12.5 mm), 2, 4, and 8 (for d = 25.4 mm), and 1, 2, and 4 (for d = 50.8 mm). It is expected that the casting tube with the highest aspect ratio will be expected to experience relatively less disturbances from the end flows, thus forming an annulus in less time compared to its counterparts with a smaller aspect ratio.