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CENTRIFUGAL CASTING OF PARAFFIN WAX: NUMERICAL SIMULATION - INFLUENCE OF ROTATIONAL SPEED, FLUID VISCOSITY, TUBE DIAMETER, AND VOLUME FILL FRACTION.

Abstract

The centrifugal casting process is an effective method of producing hollow casts including rocket fuel grains. 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.

Fluid properties, as well as 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. This research paper numerically investigates the influence of rotational speed, fluid viscosity, tube diameter, and volume fill fraction in the centrifugal casting process of paraffin wax.

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, aside from validating the experiments that have been conducted by the group, 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.

Commercial CFD solver ANSYS Fluent was employed in the numerical simulations. In the present simulations the following four parameters were considered: 1. liquids viscosity (water, SAE 5W-30 motor oil, paraffin wax dotriacontane C32H66) 2. rotational speeds, RPM (1000 RPM, 2220 RPM, and 3000 RPM) 3. centrifugal casting tube diameter, d (12.5 mm, 25.4 mm and 50.8 mm) 4. Liquid volume fill fraction, (50%, 86.5% and 95%). In all these simulations, a 2D cross-sectional slice of the centrifugal casting tube was considered.

It was found, as it was expected, that viscosity played a major role in the centrifugal casting process - with high viscosity liquids like SAE 5W-30 motor oil forming a smooth reliable annulus much faster, even at relatively lower rotational speeds, unlike low viscosity liquids like water. In addition, it was noted that an annulus was formed faster at higher RPM, for larger casting tube diameter, and lower volume fill fraction.