Investigation of Ice-Cream processing machines: a numerical approach

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Ice-Cream processing is a complex series of operations that are typically driven by experience or by trial and error procedures. The complexity of the procedure is related to the nature of the product that has to be handled (mixture of liquid and air), that must undergo thermal cycles that determine phase changes.

This study is devoted to model the behavior of the fluid in the machinery that are typically used for the preparation of the ice-cream. The investigation has been carried out numerically, and a complete open source toolchain has been used for the analysis.

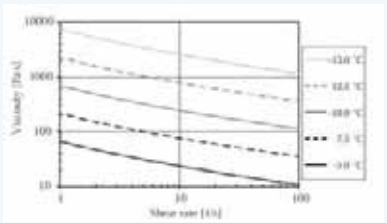
OpenSource Toolchain

- Geometry generation/conversion and defeaturing
- Cut-cell cartesian mesh generation – fully integrated with OpenFOAM
- CFD software suite for continuum mechanics solution
- Post-Process based on VTK libraries – fully integrated with OpenFOAM

Meshing & Computational Setup

- Cartesian cut-cell mesh generation based on dictionary (robust meshing of alternative designs)
- Steady-state and transient approach, different stator-rotor interface modeling (frozen rotor vs. sliding interface)
- Single phase and VOF approaches
- Effect of Ice-Cream head included

Ice-Cream Rheology[1,2]

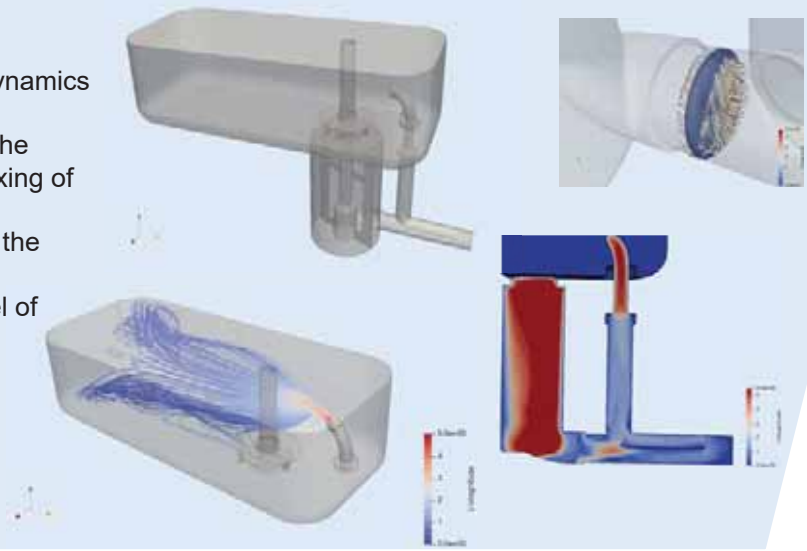


- Ice-cream exhibit shear-thinning behavior, and consistency index variable with temperature
- New model implemented: Hershel-Bulkley Model modified to account for temperature effects

$$\nu = \min\left(\nu_0, \frac{\tau_0}{\dot{\gamma}} + k_0\gamma^{n-1}\right)$$
$$\tau_0 = A_\tau + \exp(-b_\tau T)$$
$$k_0 = A_k + \exp(-b_k T)$$

CFD analysis of Pasteurizator

- Need to understand the fluid-dynamics in the tank
- Possible re-design of some of the components to optimize the mixing of the fluid
- Different behavior according to the thermal cycle that is imposed
- Study of squirts due to low level of mixture in tank



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[1]Shrivastav, A., & Goswami, T. K. (2017). Low Temperature Extrusion of Ice Cream: A Review. J. Food Nutr. Popul. Health, 1(2), 11.

[2]Martin, P. J., Odic, K. N., Russell, A. B., Burns, I. W., & Wilson, D. I. (2008). Rheology of commercial and model ice creams. Applied Rheology, 18(1), 12913-1.