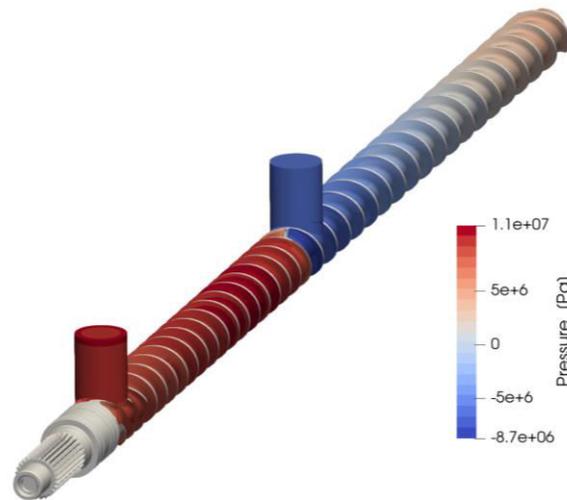**CHASE**
Chemical Systems Engineering

Programme: COMET – Competence Centers for Excellent Technologies

Programme line: COMET-Zentrum (K1)

multi-firm project MFP 2.1 "*Simulation-based Continuous Production System Monitoring and Control*", 10/23– 09/27,

Pressure field in single screw extruder (© CHASE/Pourhosseinian, Haddadi)

NUMERICAL INVESTIGATION OF ELASTOMER EXTRUSION

APPLYING PHYSICS BASED SIMULATION FOR THE BETTER UNDERSTANDING AND OPTIMIZATION OF ELASTOMER EXTRUDER

Extrusion is an essential process in the rubber industry, used to manufacture a wide range of products with complex shapes and demanding performance requirements. In this process, rubber is forced through a die under pressure and temperature, and its flow behaviour plays a key role in determining the quality and efficiency of production.

Rubber exhibits non-Newtonian behavior, meaning its viscosity changes depending on shear rate and on the temperature. This makes the flow inside an extruder highly complex, with strong interactions between heat transfer, pressure, and material deformation. Understanding these interactions is vital for optimizing production, improving material use, and increasing energy efficiency.

In the past, most simulation approaches for rubber extrusion were based on simplified one-dimensional models. These models could estimate average pressure and flow along the extruder but often ignored important effects such as temperature variation, wall slip, and three-dimensional flow behavior. As a result, they provided only limited insight into the detailed physical processes inside the extruder.

To address these challenges, CHASE and its partners developed a comprehensive simulation framework using the open-source CFD software OpenFOAM®. A specialized solver was created to model different types of extrusion processes, incorporating the coupling between temperature, shear rate, and viscosity. Experimental measurements were carried out to describe the material's viscosity behavior, and suitable viscosity and wall-slip models were implemented for accurate representation of rubber flow.

A key innovation in this project is a new implicit viscosity model for shear-thinning, non-Newtonian materials. This model improves numerical stability and greatly

reduces computational cost, enabling faster and more efficient simulations without sacrificing accuracy. The framework allows the entire extrusion process, from material feed to die outlet, to be simulated, providing detailed insight into pressure, temperature, and flow distribution at every stage.

By minimizing assumptions and representing the process more realistically, this new framework leverages OpenFOAM's flexible, library-based architecture to provide a powerful digital tool for analysing and optimizing extrusion processes. It supports virtual

testing and design improvements, helping to increase efficiency, reduce waste, and enhance product quality. Future developments will focus on further refining the model and reducing remaining assumptions to make simulations even more accurate and practical for industrial use.
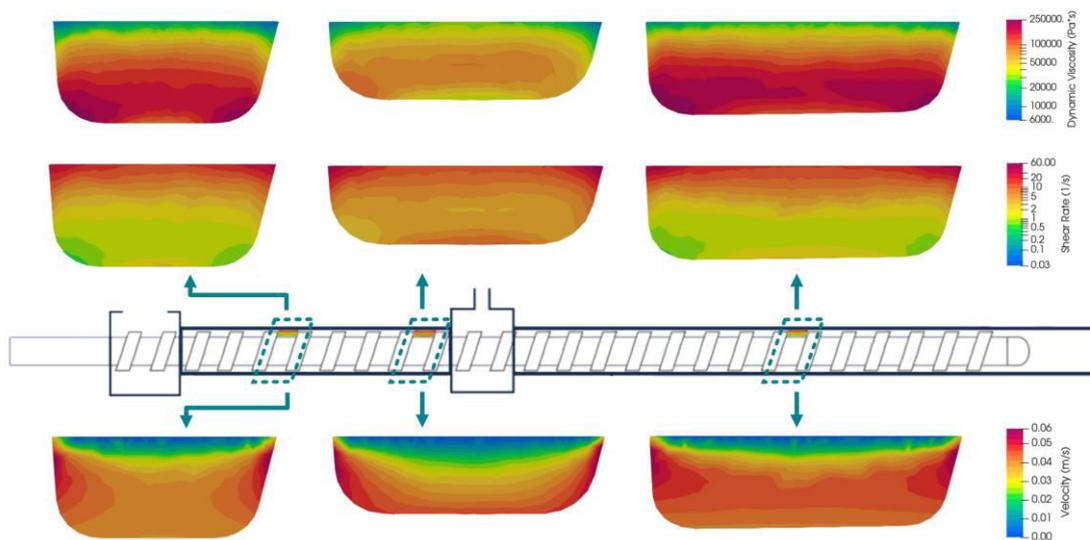
Figure 1: Velocity, Viscosity and Shear Rate distribution in the different zones

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