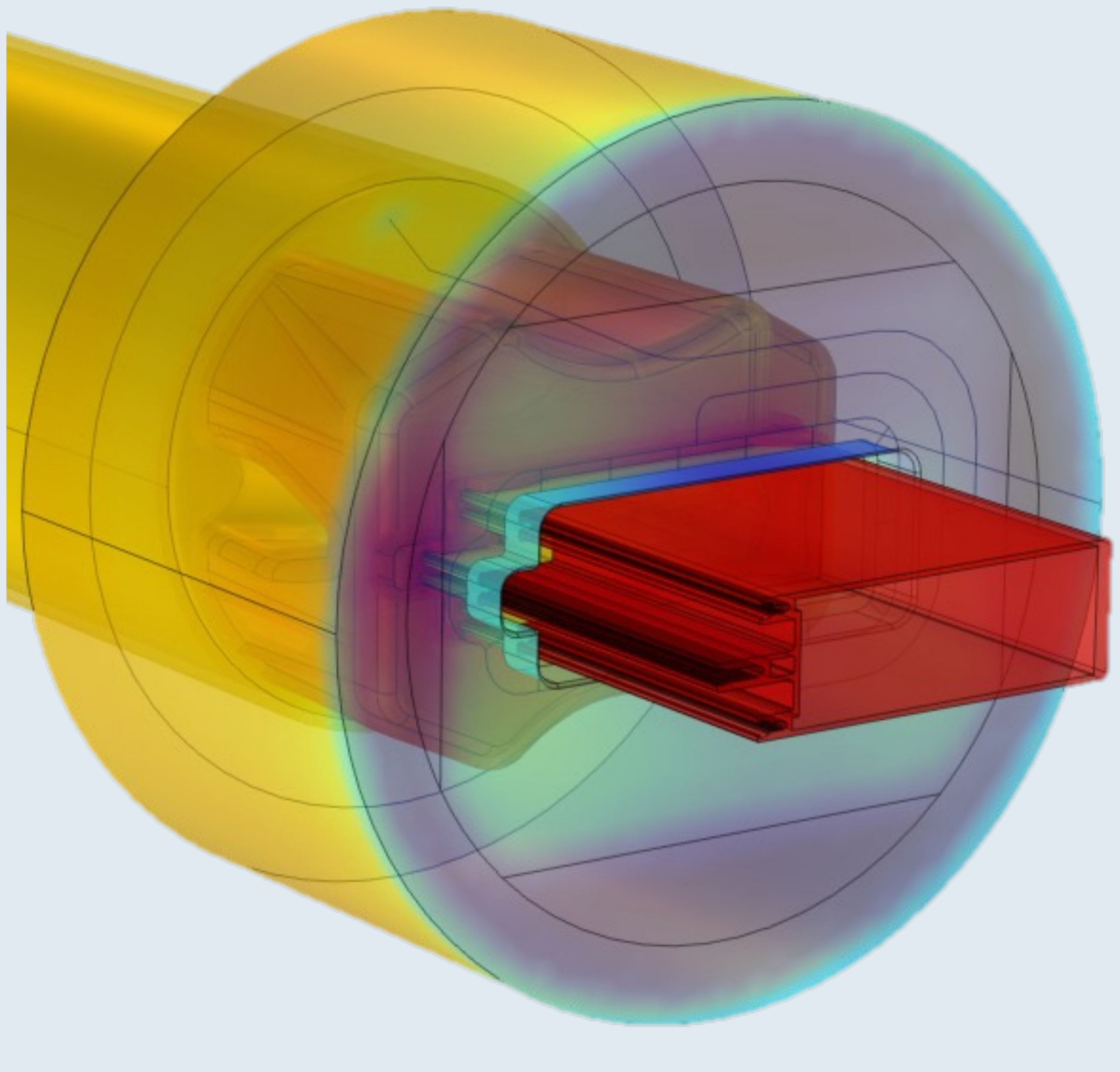

Advanced Multiphysics Models for the Optimization of the Hot Extrusion Process of Light Alloys

This work aims to describe innovative 3D numerical models for the extrusion process by combining different modules. Several industrial case studies were discussed to show and handle some challenges for the advanced optimization of the process through numerical simulation.

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Abstract

Aluminum extrudates have become prominent in several industrial fields such as furniture design, railway transportation and construction due to their high flexibility in shape complexity, high strength-to-density ratio and corrosion resistance. In response to the growing demand for high-quality and complex profiles, numerical simulation offers a competitive solution for process optimization, scrap reduction and productivity enhancement. In this context, this work aims to present innovative numerical models developed within COMSOL Multiphysics® for simulating the extrusion process. Several industrial case studies were presented, discussed and simulated by coupling different interfaces (Laminar Flow, Heat Transfer in Solid and Fluid, Solid Mechanics, Non-Isothermal Pipe Flow, Topological Optimization, Phase Field) depending on specific objectives.

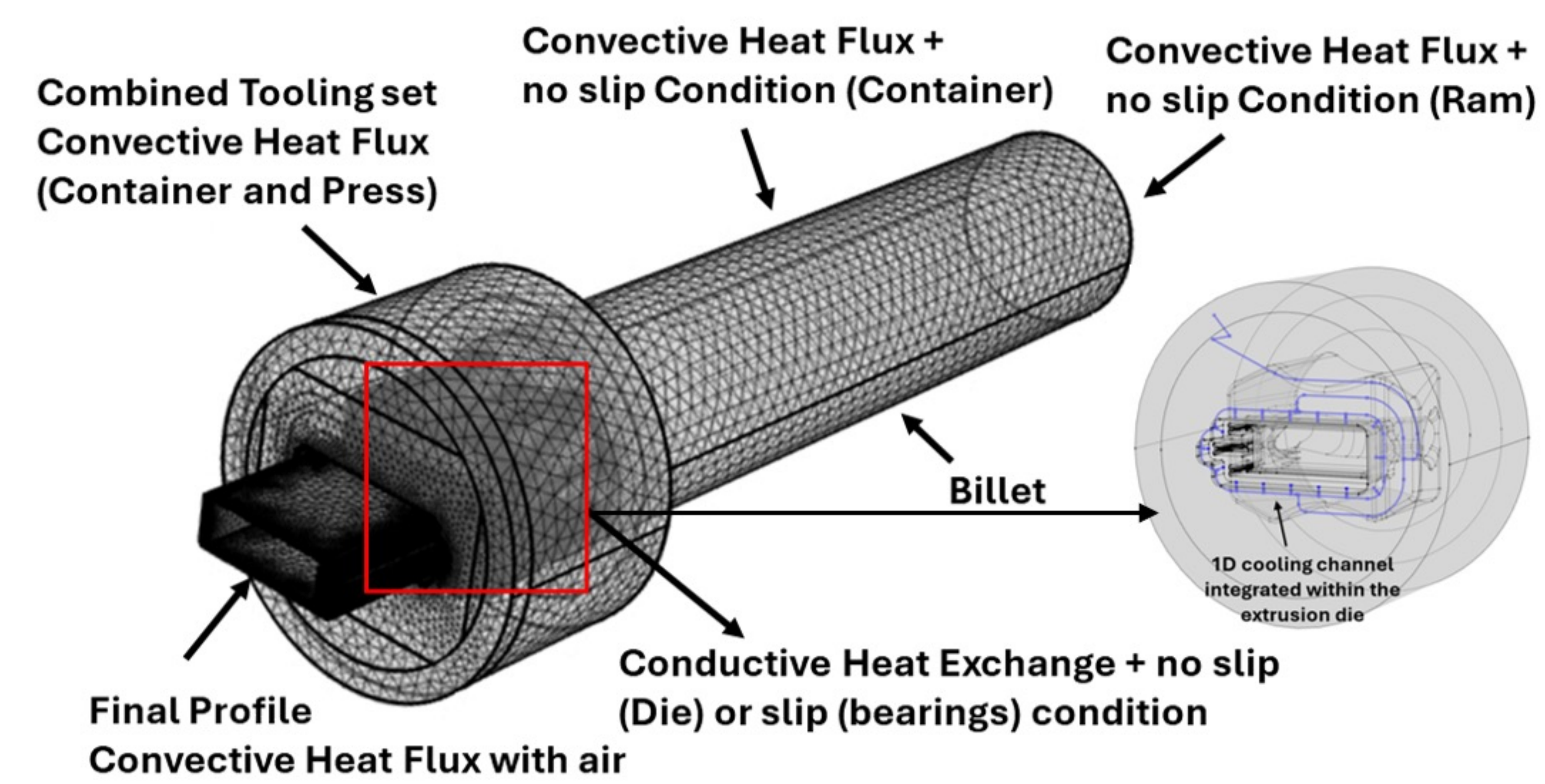

Fig. 1 Example of 3D Eulerian model of the extrusion process implemented within COMSOL®.

The 3D Model of the Extrusion Process

During the hot extrusion process, a cylindrical pre-heated billet is inserted into a container and is forced by a hydraulic press to flow through a shaped die in order to obtain, as final product, a profile with a constant cross-section. The metal flow under deformation is treated as a non-Newtonian fluid with very high viscosity (**Laminar Flow interface**), which simultaneously exchanges heat with the tooling set (**Heat Transfer in Solid and Fluid interface**) and the cooling channels (**Non-Isothermal Pipe Flow interface**). The cooling system, using liquid nitrogen as a coolant (**homogenous fluid** approach to account for the **nitrogen phase-change**), contributes to reduce temperatures in critical zones. If a die-stress analysis is necessary to assess the quality of the die design, the **Solid Mechanics interface** should be added.

The fully coupled model, as presented, allows the prediction of the thermal field, the extrusion load, the die stress and the velocity field of the material flow during the whole extrusion process. If required, the **phase field model** can be integrated to evaluate the evolution of the transition zone between two subsequent extruded billets, which is an unavoidable scrap to be reduced during multi-billets extrusion. The topological **Optimization Module** can be used to design the cooling channel, where the die is treated as a porous volume "virtually milled" by the nitrogen flow (**Darcy flow model**) in order to fulfil specific objective functions such as homogenous cooling, minimization of the nitrogen consumption. In addition, it is demonstrated that **COMSOL®** and **MATLAB®** can be integrated with an external optimizer to **automatically design the tooling set** by using genetic algorithms.

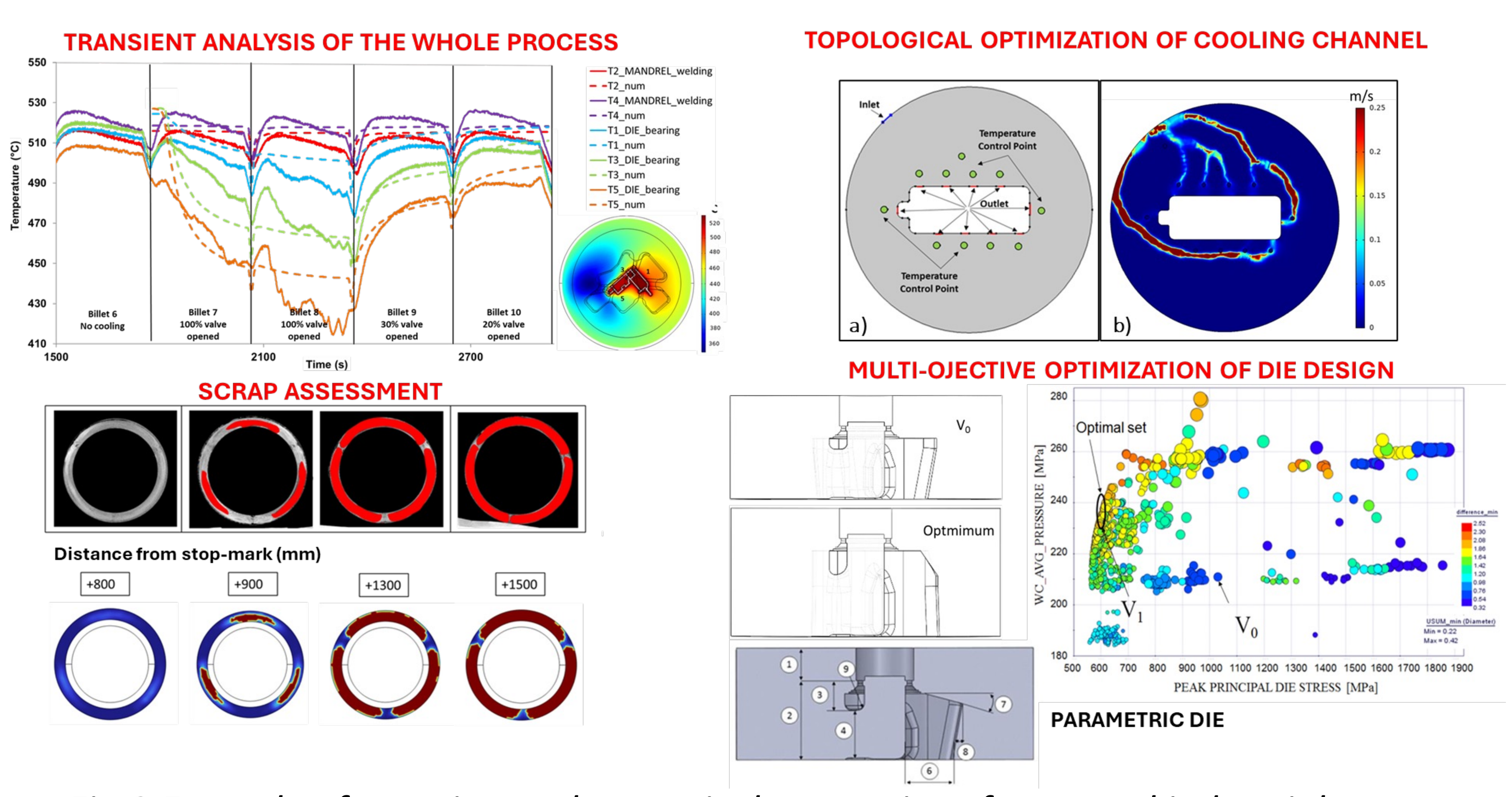

Fig.2 Example of experimental-numerical comparison for several industrial case studies. In all cases, the simulation also evidenced the limits of industrial practices, which are often still based on experience and/or empirical approaches.

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