# Free-surface computation of steady-state flows constrained by unilateral contact using a fixed-point coupling approach

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## ABSTRACT

Compared to conventional incremental formulations, direct calculation of steady-state flows allows speeding-up simulation times by factors ranging between 10 and 50 [1], but removing time from the equations introduces another unknown, the steady final shape of the domain, which needs to be computed simultaneously to the other problem unknowns. Though the coupling between the domain shape and the material flow is very strong, the resulting multi-fields problem is solved using a staggered fixed-point algorithm that alternates (1) the computation of the thermo-mechanical fields on a prescribed domain shape - by solving a Stokes like problem - and (2) the correction of the domain shape for an assumed velocity field - by solving a weak form of the stationary condition v.n = 0 using a Streamline Upwind Petrov Galerkin (SUPG) formulation [1]. Contact equations appear both in the contact and friction terms of the flow computation, as well as in the non-penetration condition of the free-surface correction. Their coupling turns out to be a master key, with difficulties coming from their difference in nature. After developing a fixed-point approach based on the derivation of pseudo-contact forces from the free-surface problem, another coupling approach is investigated. It is based on nodal collocation and penalty formulation. This work is carried out in the frame parallel computing and metal forming applications resulting into unstructured 3D meshes and complex shapes. It is more specifically applied to the finite element simulations of the rolling of long products, as presented in figure 1.

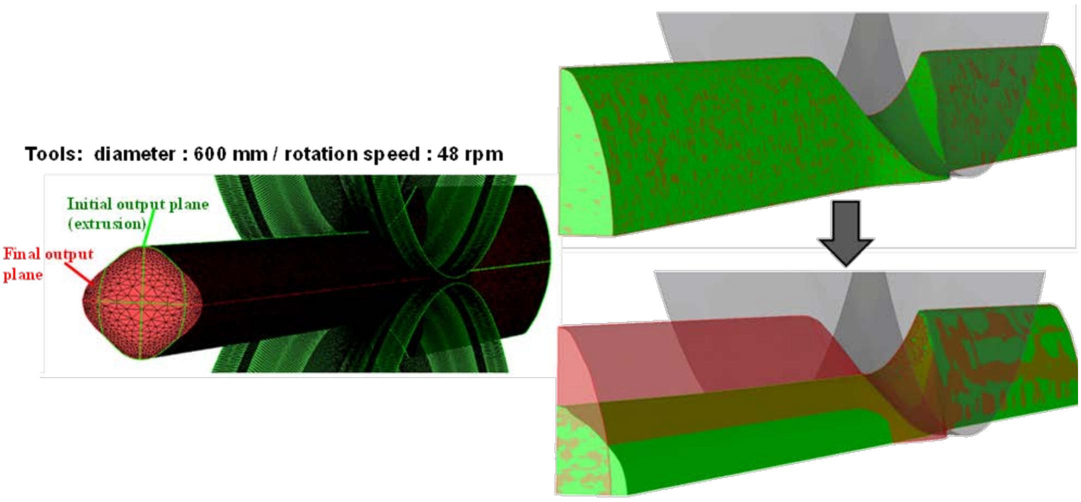


*Figure 1: Oval to square rolling of long product: process geometry (left), initial configuration for the fixed-point algorithm (top-right), final steady-state solution (bottom-right)*

## REFERENCES

[1] U. Ripert, L. Fourment, J.-L. Chenot, “An upwind least square formulation for free surfaces calculation of viscoplastic steady-state metal forming problems”. Adv. Model. and Simul. in Eng. Sciences 2(1): 15:1-15:27 (2015)