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CENTRE DE MISE EN FORME DES MATERIAUX

Postdoctoral position 18 months

2-scale modeling of mixed / boundary lubrication in aluminum alloys hot strip rolling

Build a numerical model predicting the tool-strip friction in the hot strip rolling process, aiming at guiding formulation of light alloy hot rolling lubricants.

Based on the analysis of micro-physical mechanisms, this model shall determine essential tribological variables (lubricant film thickness, contact temperature and pressure…), to be compared with efficiency windows of well-known additive families: desorption of friction limiters, decomposition of extreme-pressure additives…

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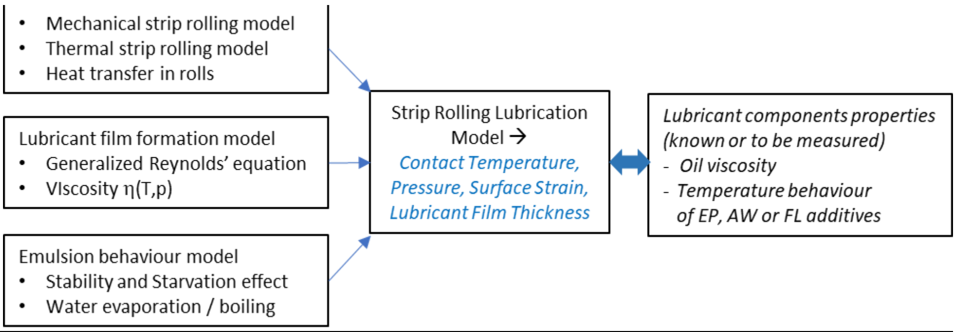

CONTEXT AND GOALS

Lubrication plays a major role in metal forming processes such as light alloys hot rolling. The evolution of environmental regulations puts pressure on formulators towards more benign components (oil, additives). With a restricted choice, it is all the more important to choose them on "objective" grounds, e.g. contact temperatures and pressures. To this aim, it is necessary to (1) develop a model predicting friction together with pressure and temperature reached in the contact, and (2) compare them with the pressure and temperature intervals in which each potential additive family is known to be efficient.

Predicting friction in hot rolling requires coupling 3 types of models :

1-the mechanics of hot metal plastic deformation, which rules the local pressure and slip. Metal behavior strongly depends on its temperature, this points to a thermo-mechanical, macroscopic model ; this item is well understood |1].

2- the capacity of the lubricant to separate surfaces under the abovementioned conditions : one cannot avoid a micro-mechanical analysis of tribological phenomena. It includes wetting of the hot strip by the emulsion, its impact on lubricant film thickness (generalized Reynolds' equation [2]), conformation of strip and roll roughness asperities ; such models have been developed in the 1990 [3-5].

These first two points are coupled since pressure at the macroscopic scale is a function of microscale-dependent friction stress ; this type of coupling is now well mastered, but mainly for cold processes. Extension to hot rolling could e.g. use ideas set up in [6].

3- when the lubricant no more plays its role fully, as in the boundary lubrication regime, adhesion occurs and transfers metal from the strip to the roll surface, transforming the latter's roughness [7]. In turn, roughness strongly impacts friction.
One must therefore:
- build a multifactorial adhesion criterion [8] with (i) lubricant film thickness, (ii) a critical temperature above which lubricant additives lose efficiency (thermal desorption), (iii) surface damage.
- adhesion thus triggers a transition between two contact mechanisms: from the impression of longitudinal roll grinding lines on the strip surface under low SRR (Slide-Roll Ratio), a rather benign mechanism, to deep scratching by 3D asperities which leads to much higher friction and to adhesion amplification (snowball effect). A local ploughing friction model (e.g. [9]) must then be included in the tribological model.

This complex multi-physical system requires simplifying assumptions, to be founded on a deepened knowledge of this context: physical and mechanical modelling is thus a core component of the proposed work. The figure below offers a first glimpse at the software organization.

Model validation will be based on well-known laboratory tribometers for certain aspects : emulsion stability and high-temperature "plate-out" behavior, critical temperatures for friction limiting additives desorption / extreme-pressure additive reaction, adhesion conditions.

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[3] Sutcliffe M.P.F., Johnson K.L., Lubrication in cold strip rolling in the mixed regime, Proc. Instn.Mech. Engrs. 204 (1990) 249–261

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[5] N. Marsault, P.Montmitonnet, P. Deneuville, P. Gratacos: Un modèle de laminage lubrifié en régime mixte. Revue de Métallurgie - Science et Génie des Matériaux 98, 5 (Mai 2001) 423-433

[6] W.R.D. Wilson, C.J. Wong: Analysis of the lubricant film formation process in plane strain forging. ASME J. Lub. Tech. 95, 4 (1974) 605-610

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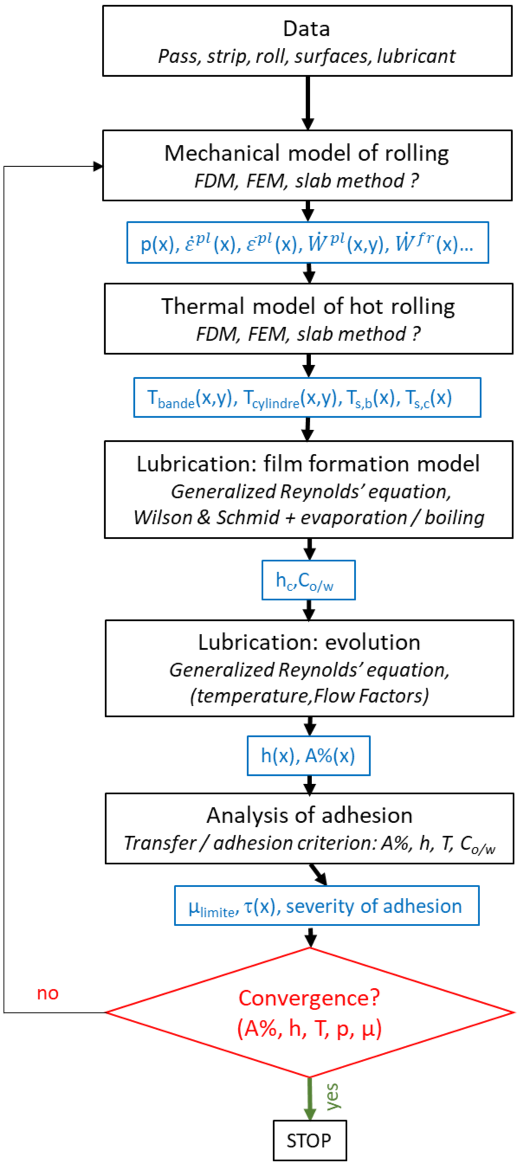
[8] O. Filali : Approche multiphysique du contact frottant en grande déformation plastique : prédiction numérique du grippage d'alliages d'aluminium en mise en forme à froid. Thèse, UPHF (2020)

[9] W.R.D. Wilson: Friction models for metal forming in the boundary lubrication regime. J. Engg. Mat. Technol. (Trans. ASME) 113, 1 (1991) 60-68



General flowchart of the software and of the work

CANDIDATE PROFILE

- ✓ The candidate has a PhD in Applied Mechanics and Modelling.
- ✓ Core skills : Numerical modelling, Python language, Mechanics.
- ✓ A first experience in tribology and/or Heat transfer would be appreciated.
- ✓ Motivation for modelling and simulation.
- ✓ Aptitude to teamworking / Rigour and engagement
- ✓ a good knowledge of English (B2 level at least).

TOOLS

Programming : Fortran, Python
Validation on tribometers (protocols to be defined during work)

KEYWORDS

Hot rolling ,tribology, numerical modelling,
Heat transfer, adhesion, lubricants and additives

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