Multiscale Modeling of the Micro-Plasto-Hydrodynamic Lubrication, a Crucial Mechanism for Friction in Metal Forming

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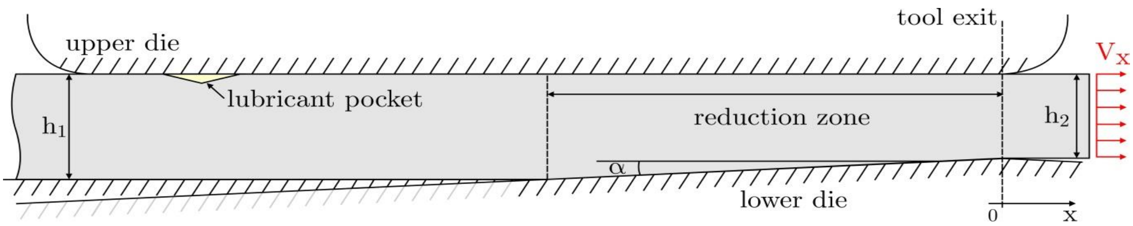
ABSTRACT

This paper presents a Finite Element numerical model able to predict the occurrence of Micro-Plasto-Hydrodynamic (MPH) lubrication. This physical phenomenon, which was first proposed by Mizuno and Okamoto, appears in the mixed lubrication regime. It consists in lubricant flows at the microscopic scale leading to a lubrication of the tool-piece solid contacts and therefore to a macroscopic friction drop. For instance, Laugier et al. have observed a friction decrease while rolling High Strength Steels for different strip thickness reductions. The only physical explanation to this trend is the MPH lubrication.

Despite the huge influence of MPH lubrication on friction in metal forming processes, only a few numerical models can be found in the literature (see Lo and Wilson, Sutcliffe). Moreover, these models rely on several restrictive assumptions which prevent them from delivering predictive results. Consequently this work consists in the development of the first finite element model capable of predicting the appearance of the MPH lubrication. This model is then used to numerically reproduce the experiments of Bech who studied this phenomenon, in plane strip drawing, by observing the behavior of macroscopic pyramidal lubricant cavities through a transparent die.

In the proposed approach, plane strip drawing is modeled with Metafor, an in-house nonlinear FE code able to deal with fluid-structure interactions for a plastically deforming structure. The model geometry is represented below.



This model allows us to compare the lubricant pressure to the solid-solid contact pressure profile between the upper die and the strip material. Once the lubricant pressure exceeds the solid-to-solid contact pressure, the condition allowing a lubricant flow from the pocket to the neighboring plateaus is fulfilled. The presented FE model is able to predict backward and forward escapes of the lubricant from the pocket. As in the experiments of Bech, several parametric studies have been carried out. The numerical results show that the model correctly reproduces the trends observed experimentally.