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A Process-Centered Approach of lubrication and wear in cold and hot metal forming

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Cold and hot metal forming processes are families of manufacturing processes where tools apply compressive forces to shape a workpiece to a given geometry. These compressive forces generate high contact pressures and high plastic strains near the workpiece surface. They lead to shear stresses due to friction, and an increase of local temperature due to plastic strain and friction sliding. Consequently, specific lubricants are required to control friction at the workpiece/tool interface, to cool down tool surfaces to avoid overheating and a drop of tool hardness, and to protect workpiece and tool surfaces. Numerous lubricants have been developed to fulfill these requirements: liquid lubricant based mineral or vegetal oils, most of them containing chlorine, phosphorus, or sulphur additives, solid lubricant such as complex conversion coatings or polymers, etc. Tendencies are to limit the use forming lubricants containing hazardous compounds or based on non-renewable resources, such as mineral oil, and to turn to new environmentally friendly lubricants. Nonetheless, selecting a new lubricant remains a challenge for the manufacturer. Choosing a lubricant not adapted to the forming process may have dramatic consequences, untimely wear of tools, surface defects on the workpiece, resulting in an increase of the production cost.

The keynote focuses on liquid lubrication and how lubricant may affect the quality of the final workpiece. Two studies based on a Process-centered approach (PCA) are presented (Fig. 1) [1]. Study 1 refers to the connection between the plasto-hydrodynamic lubrication and the final roughness of the workpiece. The PCA was applied to identify the conditions of contact in terms of contact pressure, plastic strain/strip reduction, sliding velocity, and forward slip (for the rolling process). These results were used as input conditions in lubrication model. The model is based on an iterative scheme involving Reynolds's equation to compute the lubricant pressure at the asperity scale and the leakage of lubricant from one asperity to another, and FEA to calculate the asperity plastic strain [2]. It was then possible to predict the final roughness of the workpiece according to the process and lubricant properties. The lubrication model was first applied to the rolling process of a stainless strip. It came that increasing the rolling speed increased the final roughness, while increasing of friction reduced the final roughness (Fig. 2) [3]. The lubrication model was also applied the strip drawing of aluminium to quantify the effect of roughness angle and lubricant viscosity on the lubrication regime. The lubrication model was able to distinguish micro-plasto-hydrodynamic lubrication (MPHDL) and micro-plasto hydrostatic lubrication (MPHSL), and provided results in good agreement with experiments. It clearly identified the initial lubricant film thickness as a key parameter in a lubrication analyses [4].

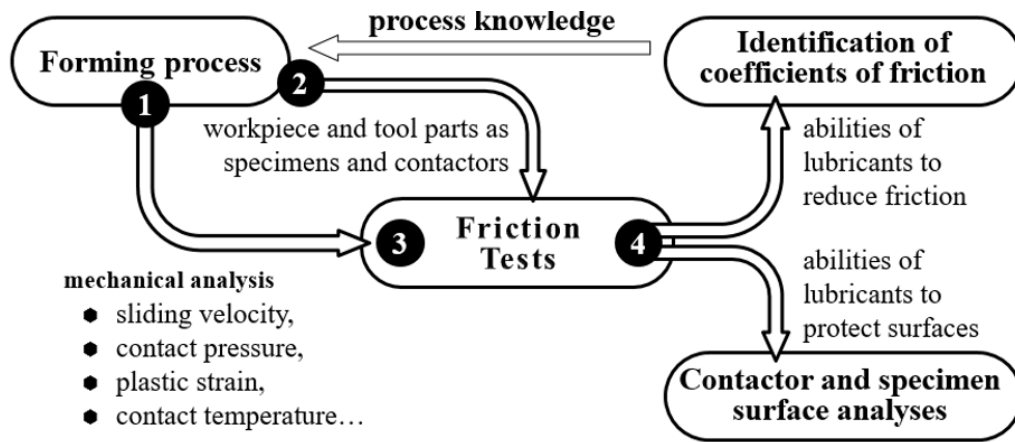


Fig. 1: scheme of the process centered approach to the tribology of material processes

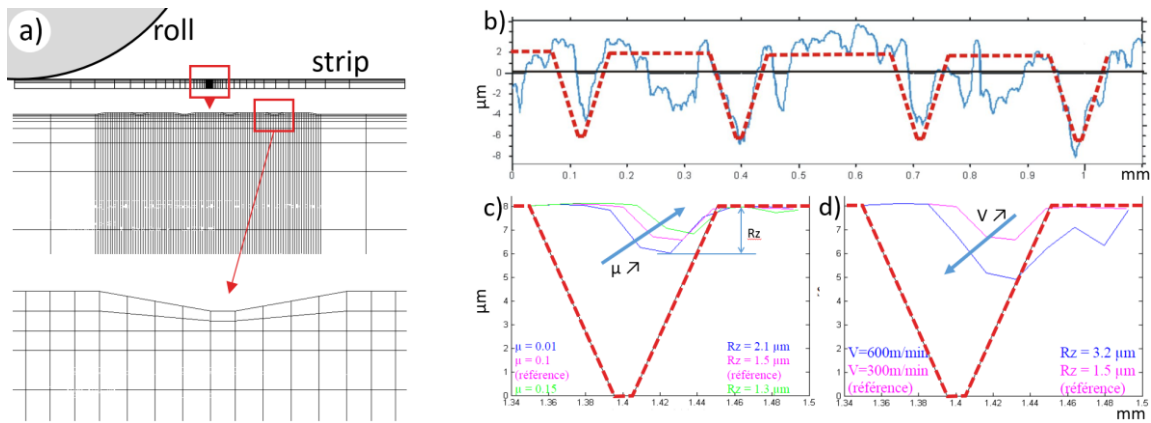


Fig. 2: Lubrication of cold rolling process. a) FEA, b) simplified profile roughness, c) effect of friction on final roughness height, d) effect of rolling speed on final roughness height

Study 2 is related to the manufacturing of spring for automotive applications. The PCA was developed to quantify the effect of lubricant and oxide on friction and wear of the wire guides (Fig 3.). The Upsetting-Sliding Test (UST) was used as friction test. Specimens were machined from spring wire and contactors were machined from new tools, and from tools in mid-life and in end of life. All the contactor were analyzed in terms of surface topography and metallurgy (SEM-EDS). Then UST were performed to quantify the effect of tool wear, lubrication and sliding speed on friction. It came that lubricant has to be avoided since it leads to wear drift and uncontrolled increase in friction coefficient. The study also showed that oxide deposits formed during cold winding acted as a thermal barrier, and played a significant role in protecting the tool/spring interface. It helped reduce the friction coefficient below $\mu = 0.125$, regardless of the speed regime. The oxide layer could increase the lifespan of the tool if it is preserved in the wear groove [5].

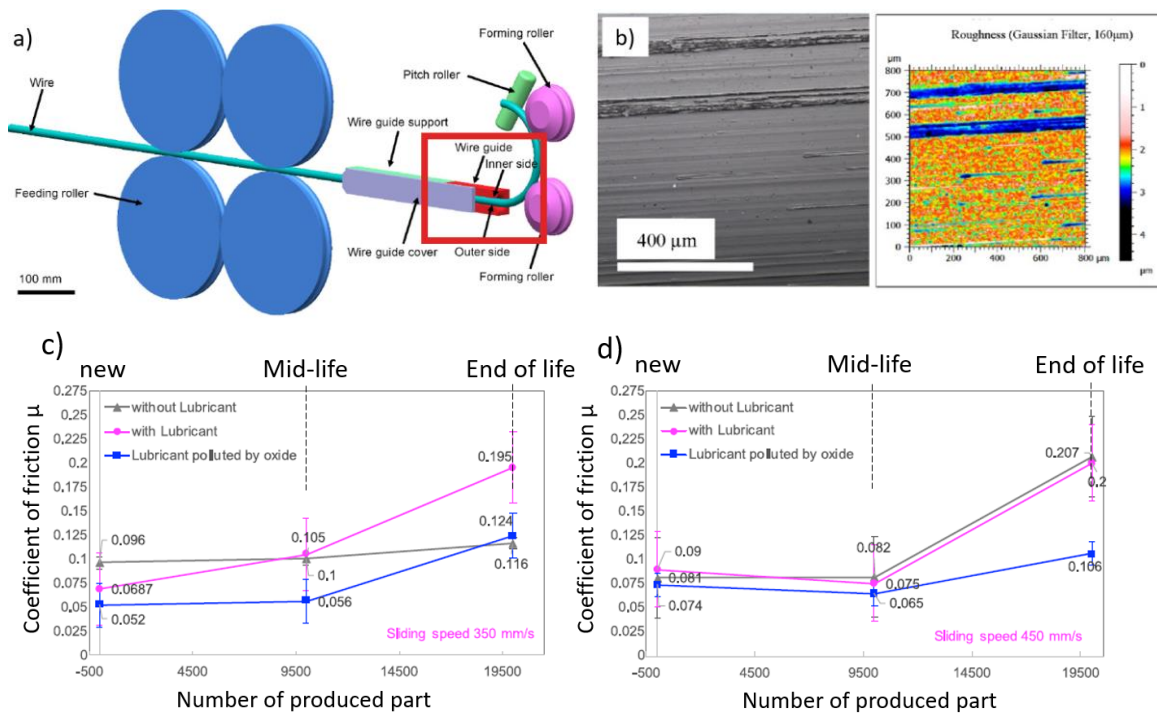


Fig. 3: Scheme of the process (a). Example of surface analyses on the smooth surface of worn tool at their end of life (b), coefficient of friction vs produced parts at 350 mm/s (c) and 450 mm/s (d)

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