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Thermomechanical modelling of cold drawing processes of small diameter tubes

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ABSTRACT

Tube cold drawing processes are used to reduce tube diameters and thicknesses, while pulling them through a conical converging die with or without inner plug. An accurate modelling of the material deformation, friction behaviour and thermal effects is required in order to well describe these processes. Finite element (FE) modelling has already been applied to wire drawing as well as tube drawing [1, 2, 3]. All of these works carry out mechanical studies but none of them justify the value of their friction coefficient. The aim of the present study is to model tube drawing with a thermomechanical finite element analysis. It deals with the cold hollow sinking (without inner plug) and the mandrel drawing of stainless steel 316LVM tubes of small diameters (typically from 1 to 10 mm). It details the method to obtain all required parameters. During the forming process, mechanical and thermal measurements are recorded. Load cells are placed between the die and the frame for the drawing force. A thermocouple is placed inside the tube and a pyrometer, fixed on the die exit, records the tube external temperature. When possible, simulation parameters are determined thanks to mechanical or thermal tests. The material properties implied in the process, such as the anisotropy and the rate-dependence are studied. Shear and tensile tests are performed to determine the 316 stainless steel mechanical behaviour and lead to apply an isotropic temperature-independent Johnson-Cook law. The emissivity and the convection of the tube are determined by thermal tests during experimental tests. An infrared camera placed in front of the shearing device is used to observe the temperature variation fields. As the strain rates are high and the experiments times are short, heat loss through conduction, convection, or radiation can be neglected in comparison to thermoplastic heating. With these fields and a 1D heat diffusion model we estimated the heat sources (volumic plastic dissipation), noted P_{heat} , with the same method as proposed by [4]. If we note the plastic work rate $P = \tau \times \dot{\gamma}$ where τ the shear stress and $\dot{\gamma}$ the shear strain rate, the inelastic heat fraction β is equal to the ratio $\beta = P_{heat}/P$. Process parameters such as friction coefficient or contact conductivity are difficult to estimate with mechanical experimental tests. A

different approach is therefore proposed here, an inverse analysis is carried out to fit these two last parameters. This analysis is based on two remarks. First, once the constitutive equation is determined, the drawing force depends only on the friction coefficient because the temperature does not influence the mechanical behaviour. Secondly, the external temperature depends both on heat generation (plasticity and friction) and on the thermal exchanges (in the tube, in the die, at the interface and at the outer surfaces). Supposing the first contribution is already established, the contact thermal conductance affects then directly the external temperature. The methodology to determine the friction coefficient and the conductivity is given in the diagram of Figure 1. Finally, several drawing tests, with mandrel or not, with different diameters and drawings speeds are modelled with these parameters and compared to experimental data in order to validate the method.

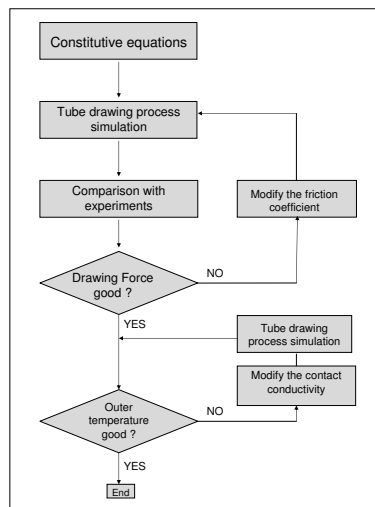


Figure 1: Methodology of the inverse method to estimate the friction and the contact thermal conductance.

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