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A parametric study on residual stresses and loads in drawing process with idle rolls

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ABSTRACT

A comprehensive study of drawing process with flat idle rolls of round wires is presented through 3D mechanical finite element simulations. An elastic–plastic model is used for the wire material and contact behavior is simulated by a sliding–sticking friction model. The results of numerical simulations are compared with measurements on wires produced with a laboratory equipment. The comparison of drawing load and some geometrical characteristics of experimental samples with numerical model predictions allowed to establish a good correspondence of model with experimental findings, thus validating the numerical model. Residual stress of flat roll drawn wires, pressure distribution on the forming rolls and drawing load are studied. The effects of main process parameters such as initial workpiece diameter, forming rolls diameter and percentage of deformation are investigated. The results present a helpful insight into the process parameters effect in wire drawing with flat idle rolls thus furnishing the basic guidelines for process design and optimization.

1. Introduction

Drawing is a metalworking process of bars, rods and wires mainly employed in electric and automotive industries. The process consists of reducing the workpiece cross-section by forcing the wire through series of dies. During the drawing operation, a plastic deformation is achieved, and depending on the material characteristics, and particularly its drawability, different percentage of reductions can be obtained. Because drawing is mostly employed for wires manufacturing, axis-symmetrical converging dies are usually involved for the purpose. The main problem concerning the employment of such tool geometry is represented by the high frictional forces arising at the wire-tool interface which cause a significant increase of drawing load. In addition, the shear stress produced by frictional forces may reduce the tool life due to wear. An alternative method to overcome such drawbacks in usage of traditional converging dies would be the employment of idle rolls, namely roll drawing process (RD). Indeed, the utilization of idle rolls allows to reduce the frictional forces acting at the wire-tool interface by changing the friction mechanism from shearing to rolling which also allows the reduction of tool wear. In the last decade, idle or motorized rolls are being even more utilized as working tool in several metalworking processes. Because of high flexibility and production rate, motorized grooved rolls are used in roll forming of thin sheets [1,2]; flat or grooved rolls are used in joining processes of thin metal sheets such as in roll hemming [3–6]. Other than sheets processes, flat or grooved rolls are also employed in bulk metalworking processes as cold rolling [7–9] and roll drawing. However, although the close similarity of flat rolling of wire and wire drawing with idle rolls, the adoption of the only front tension on the wire as forming load and the employment of idle rolls determine significant differences of products properties achieved with these two processes.

The simplest RD process uses a couple of flat idle rolls at 180° for production of flat wires. Such a product is used for manufacturing of springs, piston segments, flat wire electrodes (in arc welding), among other products. Similarly to flat rolling process, RD involves a highly inhomogeneous deformation depending on process parameters and material properties; therefore, information about the mechanical deformation is required in order to properly define processing parameters. As in other metalworking processes, deformation inhomogeneity has a crucial effect on the contact stress distribution, drawing load and residual stress of final product. Although several studies have been conducted on the analysis of residual stress, contact pressure on tools and required loads for similar processes, i.e., flat rolling and traditional drawing processes, a few investigations have been carried out on roll drawing process. Several theoretical solutions have been presented in the literature concerning the drawing process with traditional converging dies in which the effect of process parameters effect on drawing stress is accounted [10]. The effect of die angle, friction coefficient and the dead metal zone on plastic deformation is investigated by Eivani and Karimi Taheri [11] using upper bound method. An experimental and numerical analysis of forces, energies, stresses and strains during wire drawing process is conducted by Luis et al. [12]. The effects of various process variables on drawing parameters

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