

STUDY OF THE SIZE EFFECT ON FRICTION CONDITIONS IN MICRO-  
EXTRUSION: PART 1-MICRO-EXTRUSION EXPERIMENTS AND ANALYSIS

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Microforming is a relatively new realm of manufacturing technology that addresses the issues involved in the fabrication of metallic microparts, i.e., metallic parts that have at least two characteristic dimensions in the sub-millimeter range. The recent trend towards miniaturization of products and technology has produced a strong demand for such metallic microparts with extremely small geometric features and high tolerances. Conventional forming technologies, such as extrusion, have encountered new challenges at the micro-scale due to the influence of 'size effects' that tend to be predominant at this length scale. One of the factors that of interest is friction. The two companion papers investigate the frictional behavior and size effects observed during micro-extrusion in Part I and in a stored-energy Kolsky bar test in Part II. In this first paper, a novel experimental setup consisting of forming assembly and a loading stage has been developed to obtain the force-displacement response for the extrusion of pins made of brass (Cu/Zn: 70/30). This experimental setup is used to extrude pins with a circular cross-section that have a final extruded diameter ranging from 1.33 mm down to 570 microns. The experimental results are then compared to finite-element simulations and analytical models to quantify the frictional behavior. It was found that the friction condition was non-uniform and showed a dependence on the dimensions (or size) of the micropin under the assumption of a homogeneous material deformation. Such assumption will be eliminated in Part II where friction coefficient is more directly measured. Part I also investigates the validity of using high-strength/ low friction die coatings to improve the tribological characteristics observed in micro-extrusion. Three different extrusion dies coated with diamond-like carbon with silicon (DLC-Si), chromium nitride (CrN) and titanium nitride (TiN) were used in the micro-extrusion experiments. All the coatings worked satisfactorily in reducing the friction and correspondingly, the extrusion force with the DLC-Si coating producing the best results.

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