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Size effect affected springback in micro/meso scale bending process: experiments and numerical modeling

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Abstract

The springback behavior has been revealed to affect the dimensional accuracy of sheet metal products significantly in the forming process. As the forming scale decreases to micro/meso level, the deformation behavior of sheet metals has been reported to be different from that at the macro level due to the so-called size effect. This study thus aims to investigate and characterize the springback behavior of sheet metals affected by the size effect at micro/meso scale. The copper specimens with different thicknesses and grain sizes were employed in the uniaxial tensile, nano-indentation and micro hardness tests to analyze the size effect on the material elastic/plastic deformation behavior at first. The flow stress, yield strength and hardness are revealed to decrease with the increase of grain size. Following that the bending experiments with three different punch angles were performed. The effects of both feature and grain sizes on the springback angle were investigated. The springback angle is found to decrease with the punch angle, the grain size, the ratio of thickness to grain size (t/d) and the reduction of thickness. To dig the fundamental mechanism behind the size-effect affected springback behavior, a composite model based on the surface layer theory was employed to describe the constitutive plastic deformation of material with different grain size and thicknesses. The model was further applied in the finite element (FE) simulations of bending process. Based on the experimental and FE results of sheet metals at micro/meso scale bending process, the interactive effect of feature and grain sizes is revealed to be critical in microforming processes. As a preliminary work, the flow stress reduction described by the