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Dissertation Abstract

Report no.	(Course-based) No. 1204	Name	Roy Biplov Kumar
Dissertation title	Development of simulation method of the spinning process for cylindrical to hemispherical shape of aluminium alloy at room temperature (アルミニウム合金の円筒から半球形状への室温スピニング加工のシミュレーション方法の開発)		

The research presents in this dissertation a combined numerical/experimental effort to develop a suitable simulation method of mandrel-free multi-pass tube spinning. The purpose is establishing process parameters, identifying the formability limits, and understanding the deformation mechanics of the complex production process.

Rapid trends in the area of tube spinning contributed to a renewed interest in the manufacture of axis-symmetrical, seamless, dimensional precision like a pressurized spherical tank. Tube spinning is one of the most popular incremental metal forming which comprises progressive localized deformation controlling the route of the roller. In the tube spinning process, the target shape is formed through the localized plastic deformation generated by the design roller pass. Process design for tube spinning is inherently challenging due to their complexity in terms of many process control parameters, most of which are interrelated with each other. This situation makes the use of virtual process models highly attractive as a means of eliminating the need for trial and error. This study intends to ensure computational efficiency and qualitative efficiency virtual production method for prediction shape and thickness prior to production.

Different phases of experiments were conducted for verifying the developed FEA model. In the first phase, the experiments were conducted on the thin wall large cylinder, (diameter to thickness ratio (d/t = 144)) to form a partial hemisphere at room temperature,   the second phase,   on the short cylinders (d/t = 50, 34) to form a full hemisphere at room temperature. In addition to the parametric study, such as axial feed rate, thickness, and diameter effect, were evaluated. Shape, thickness, and local plastic strain were measured for comparing experiments and FEA model results. For enhancing computational efficiency, the spinning process was approximated by an axisymmetric model. The implicit commercial FE code Abaqus/Standard was used to simulate this process. FEA models with different types of elements were developed based on the tube spinning experiments. The 3D elastic-plastic models are developed to analyse wrinkle failure. The implicit and explicit commercial FE codes were used to develop the 3D model. FEA models were verified by comparing the results obtained from the experiments using different parametric conditions. Besides, the different element types mode availability and limitation as a virtual prediction method of the final shape and thickness in mandrel-free, multi-pass tube spinning were evaluated. Large strains are expected to develop in this tube-spinning process. A finite element (FE) simulation of the uniaxial tension test was developed. The virtual tensile test was conducted by Abaqus Standard using solid quadratic elements (C3D20R). The large-scale true stress-strain curve was identified inversely by comparing post necking of dog bone tensile specimens.

Based on these findings from observations of different simulation results, it is confirmed that the plastic deformation of the process is highly localized, but the shape and thickness of the deform tube is like an axisymmetric one. Comparing different FEA models to the experiments shows that the computationally efficient axisymmetric model gives reasonable shape and thickness predictions. The shell element model tends to over predict the shape and thickness evolution during spinning while being about 250 times slower. The solid element model provides good agreement with the experiments across the board while being only 2 times slower than the shell element one. Based on the FE simulation, the variations of shape, thickness, and plastic strain are analysed for the virtual manufacturing

process's capability.

Moreover, the verified finite element model has been used to discuss the variations of the distribution's stresses, strains analysis, and numerically on the effects of roller pass number on shape and wall thickness. FEA results of shapes and roller reaction forces of a wrinkle-free model and a wrinkling model were compared. It is assumed that the sudden changes and fluctuations in the tool forces could be used to determine the estimated consequence of wrinkling failure during mandrel free tube spinning.

Due to complex and high computational cost in 3D modelling of tube-spinning, the axisymmetric model can be primarily used to get a basic idea of the resulting shape and thickness and thus to preliminary design the tool path. But for a more accurate analysis of the deformation process, 3D modelling is inevitable. Therefore, it is recommended for industrial practice to use the axisymmetric model for preliminary process design (i.e., selection of toolpath and process parameters) and then refine these selections with the solid element model.