ABSTRACT

In the present work, formability of three different ultra-thin sheet materials, namely AA1050, C101 and SS304, were evaluated, and the feasibility of stamping and hydroforming processes for fabrication of micro-channels in these sheets was explored. Uniaxial tensile tests were conducted in order to determine the mechanical properties of the ultra-thin sheets. A sub-sized stretch forming test setup of 30 mm punch diameter was designed and developed to determine the formability of these sheets in terms of forming limit diagram (FLD). The effect of different parameters such as the circular grid diameter, orientation of sheet with respect to rolling direction, punch diameter and deformation speed on the limiting strains of SS304 ultra-thin sheets was evaluated. Further, the formability of these sheets was analysed in terms of limiting dome height (LDH) and strain distribution profile. The conventional stamping technology was used to fabricate the micro-channels in the above three ultra-thin sheets. In this regard, finite element (FE) simulation of the stamping process was carried out implementing the anisotropic properties of the sheets and FLDs of the materials as the damage criterion to determine the critical dimensions of the die, punch and blank holder of the stamping setup. The formability of the stamped micro-channels was investigated through the channel depth, channel uniformity and thickness distribution. Moreover, the mode of deformation during the stamping process was determined. The surface quality of the micro-channels was accessed through surface roughness parameter, and further a correlation was made between the roughness and accumulated plastic strain during the deformation. The coefficient of friction (COF) between the punch and ultra-thin sheets was determined through the developed sub-sized stretch forming setup under both dry and lubricated conditions considering the maximum contact pressure at the inflection point during the biaxial tensile deformation of the sheets. The evaluated COF was further validated with the results obtained from conventional tribometer. The FE models of the stretch forming process and stamping of serpentine shaped micro-channels were developed incorporating the experimentally evaluated COF. The effect of lubrication was studied on the formability of the sheets during both stretch forming and stamping of micro-channels. It was observed that during the stretch forming, the strain path changed from biaxial to equi-biaxial deformation mode due to application of lubrication resulting in the increase in dome height. Moreover, the strain distribution was found to be more uniform and fracture location shifted towards the pole. In case of the stamping process, it was observed that the forming load decreased, and a reduction in maximum thinning of the channels was observed with the application of lubrication. Further, the feasibility of the sheet hydroforming (SHF) process to fabricate the micro-channels in the ultra-thin sheets was investigated. In-house fabrication methods, namely punch-less SHF and die-less SHF processes were developed on a 200 kN press to manufacture the channels. The manufacturability of the hydroformed channels was examined through channel depth, aspect ratio and thickness distribution. The average channel depth and aspect ratio were found to be higher in the case of the die-less SHF compared to punch-less SHF, and the failure was found to occur in AA1050 material under plane strain deformation mode near the die corner region and punch corner region for punch-less and die-less SHF processes, respectively. The laser welding of two ultra-thin sheets of AA1050 material with micro-channels was carried out using wobbling technique in order to produce a hermetic joint. Post the welding process, the quality of the weld was evaluated in terms of lap shear load and microhardness measurements. Further, the microstructural characterization of the welded joint was carried out through EBSD, and fractography analysis was done to understand the mode of failure.

Keywords: Ultra-thin sheets; Forming limit diagram; Micro-channels; Stamping; Coefficient of friction; Lubrication; Hydroforming; Laser welding