Abstract

The present comprehensive research comprises of comparative investigations on the warm forming behaviour of automotive grade AA5754-H22 and AA6082-O aluminium alloy sheets. Tensile tests at five different temperatures and three different strain rates were performed to investigate the elevated temperature deformation behaviour correlating with the Cowper-Symonds strain rate sensitive hardening model. The laboratory scale warm forming test facilities were designed and fabricated to perform limiting dome height and deep drawing tests to characterise forming limit strains and drawability of both the materials at different tool temperatures. Drastic improvement in forming limit diagram (FLD) was observed at 200 ℃. Significant enhancement in the deep drawn cup depth was observed when the temperature of punch and dies were set to 30 ℃ and 200 ℃, respectively. In order to further enhance the forming depth, a novel warm forward redrawing setup was developed, and a process sequence was proposed. The complete redrawing of cups was ensured by maintaining the temperature of redrawing die and binder at 200 ℃ and water circulated cooling punch near to room temperature. Thermomechanical FE models of all the investigated warm forming processes were successfully developed incorporating temperature dependent material properties using Barlat-89 anisotropic yield model coupled with Cowper-Symonds strain rate dependent hardening model, and the experimental FLDs were used for failure prediction during the deformation. The forming behaviour in different isothermal and nonisothermal conditions were validated in terms of part depths, maximum thinning/failure locations and surface strain evolution. It was found that a nonisothermal temperature gradient of approximately 105 ℃ between the cup wall and cup bottom centre was established at the onset of deformation, and this non-uniform temperature distribution helped in improving material flow into the die cavity during the warm redrawing process. A fixture of ring hoop tensile test (RHTT) was developed, and the hoop strength, ductility and energy absorption of redrawn cup wall were successfully evaluated. It was observed that the AA5754 redrawn cups showed better post-forming characteristics in terms of hardness, hoop strength and energy absorption capacity compared to that of AA6082 cups. However, the solution heat treatment and subsequent ageing cycle showed a pronounced effect on the post-forming characteristics of AA6082 cups.

Keywords: Warm forming, Aluminium alloys, Nonisothermal redrawing, FE modelling, RHTT, Post-forming characterisation