ABSTRACT

To reduce the weight of the automotive parts and improve the crashworthiness, hot tube forming processes of ultra-high strength steel hollow products have been developed in both compression and bulging deformations. Accordingly, the control and generation of the required internal pressure have been simplified by innovative techniques.

Although high strength steel sheets are increasingly hot-stamped to improve the formability and obtain a high strength of about 1.5 GPa, the shape transferability and rapid cooling for die quenching of high strength tubes become poor due to the inside hollow shape. Hence, it is desirable to generate an internal reaction force as an internal pressure to produce ultra-high strength hollow products for greater lightweighting applications. To solve the aforementioned problems during hot stamping of hollow products, an ice mandrel was inserted in the tube to hold the tube with sufficient contact pressure. The effect of the ice mandrel on heating and deformation behavior was investigated. The ice-filled steel tubes were able to heat over austenitizing temperature by adding thermal insulation sheets during rapid resistance heating. Moreover, utilization of the ice mandrel simplifies the controlling process by generating a reaction force to prevent buckling, improve the dimensional accuracy, and increase the strength of hollow parts by die quenching. Furthermore, to increase the strength of the ice mandrel under compression and prevention of ice melting without the requirement of insulation sheets, fiber-reinforced ice mandrels were introduced. The estimated internal pressure of the tube using the fiber-reinforced ice mandrel was increased about twice compared with the pure ice mandrel and thus the shape accuracy and die quenching of hot-stamped tubes were enhanced.

On the other hand, a sealed-air gas forming process was proposed not only to simplify the high controlled-gas internal pressure equipment but also to change the volume and cross-section of the ultra-high strength hollow components. Therefore, the pressure of the sealed air automatically increased with increasing temperature of the air inside the resistance-heated tube, and the start of bulging deformation was controlled by axial feeding while preventing tube thinning. The effects of the initial internal pressure and heating temperature on the bulging deformation and quenchability of the tubes were investigated. Additionally, as the process variations are rapid and dynamic during hot gas forming, the measurement of parameters has become a challenge. Therefore, an in-situ measurement of the bulging height and temperature during forming was proposed. Consequently, ultra-high strength steel bulged parts were produced even in the comparatively low initial internal pressure of sealed air.