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Warm forming behavior of high strength aluminum alloy AA7075

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Abstract: The formability of aluminum alloy AA7075 at elevated temperature was investigated through experiment. Stress—strain relationship at different temperatures and forming speeds were investigated through tensile testing. Deep drawing and stretch formability were also tested through limiting drawing ratio (LDR) and limiting dome height (LDH) tests. Finally, post forming mechanical property testing was conducted to investigate the effects of exposure to warm forming temperatures on the mechanical properties. Results show that deep drawing and stretch formability of AA7075 can be significantly improved when the blank is heated to 140−220 °C. At temperature over 260 °C, formability and post forming mechanical properties begin to decrease due to the effect of the heating and forming processes on the material's temper.

Key words: aluminum alloy 7075; warm forming; limiting drawing ratio (LDR); limiting dome height (LDH)

1 Introduction

Weight reduction has long been identified as a key priority for improving automotive fuel economy [1, 2]. One of the methods in weight reduction of automotive structures is to replace steel with light materials such as aluminum and magnesium alloys [3]. To date, several parts of the vehicle body and powertrain have been converted to aluminum such as the engine block and heads, wheels and some body panels to reduce mass [4]. For most body panel applications, AA5xxx and AA6xxx series aluminum alloys are sufficient in terms of strength [5−7]. However, for some parts of a vehicle such as the B-pillar, a higher level of specific strength is needed to satisfy future roof crush and side impact safety standards. Currently, high strength steel is the preferred solution in steel vehicles for strength-limited applications such as the B-pillar. For weight reduction, high strength aluminum alloys such as AA7075 can potentially be used to replace high strength steel [8].

Due to its high price and poor formability at room temperature, AA7075 has limited applications in the automotive industry in present. The conventional forming process of AA7075 part is forming annealed AA7075 alloy, followed by solution heat treating and then artificial aging. In most cases this requires a secondary calibration process to fix the distortion due to the high temperature solution heat treat and quenching process. For complicated deep draw parts, superplastic forming is often utilized [9, 10]. Superplastic forming is a low speed, high temperature process that also requires a high temperature heat treatment and perhaps calibration step after forming. Both of these technologies are not well suited to the high volume production rates of the automotive industry. One process that may be suitable for automotive manufacturing is warm forming. This process is targeted at a temperature at which the formability of the alloy is expanded sufficiently to stamp complex parts while not too high to destroy the T6 temper. Some research works focused on characterizing warm forming behavior of AA5xxx and AA6xxx series aluminum alloys have been reported [11−13]. However, there are few works focused on warm forming of AA7xxx series (Al−Zn−Mg−Cu) aluminum alloys [14, 15]. In the current research more detailed deep drawing and stretch formability investigation has been performed to characterize the warm forming behavior of AA7075. A key element of this process is the preservation of the high strength temper and hence it is critical that the effect of warm forming temperature on the mechanical properties should be studied.

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2 Experimental

2.1 Materials

The material tested was taken from a rolled sheet of 2 mm-gauge aluminum alloy AA7075 in the T6 temper supplied by Kaiser Aluminum Company. Composition specification of AA7075 is shown in Table 1.

Table 1 Chemical composition of AA7075 (mass fraction, %)

Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Other each	Other total
0.38	0.47	1.8	0.26	2.2	0.20	5.5	0.20	≤0.05	≤0.15

2.2 Laboratory warm forming tools

Tensile tests were performed in a MTS Sintech 30/G universal testing machine. A high temperature extensometer which could reliably measure up to 50% strain and capability of operating at temperatures up to 400 °C was used to measure strain. The testing environment was enclosed in a Thermotron Model FR−4−CH environmental chamber (Fig. 1) which can heat the sample to target temperature in a few seconds.

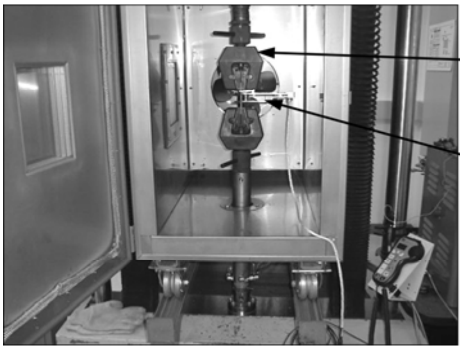

Fig. 1 Warm forming tensile test equipment used in experiment

A formability tool system capable of operating at elevated temperature was established for LDR and LDH tests, as shown in Fig. 2. The forming tool system was placed in a 100 t retro-fit MTS hydraulic double-action press. The tools were heated via sub-plates containing cartridge heaters, which allow for the use of multiple formability tools. High temperature insulation was installed around the forming tool to isolate it from the operators and keep the forming tool at the specified temperature.

2.3 Tensile test

Sub-size dog bone tensile specimens were water-jet cut per ASTM Standard E8. Specimens were placed inside the environmental chamber and allowed to reach a pre-specified temperature before the test was started. Three tensile tests were completed at seven different temperatures of 20, 60, 100, 140, 180, 220 and 260 °C with a constant crosshead speed of 2 mm/s (initial strain rate of 0.058 s^{-1}). Tensile tests were conducted in a second trial at 140, 180 and 220 °C for two additional crosshead speeds at 0.25 and 0.76 mm/s (initial strain rates of 0.008 and 0.025 s^{-1}, respectively).

2.4 Limiting dome height (LDH)

Schematic of the LDH tooling geometry used in the present work is shown in Fig. 2(b). A high temperature lubricant, AL278, provided by Fuchs, was brushed on both sides of specimens before experiments were performed. A pre-heater was used to heat specimens to the target forming temperature before forming. Specimens were then transferred into the warm die for forming. A very high blank-holder force of 100 kN with a draw-bead on both rings was used to prevent material from flowing into the die cavity. A punch load drop of

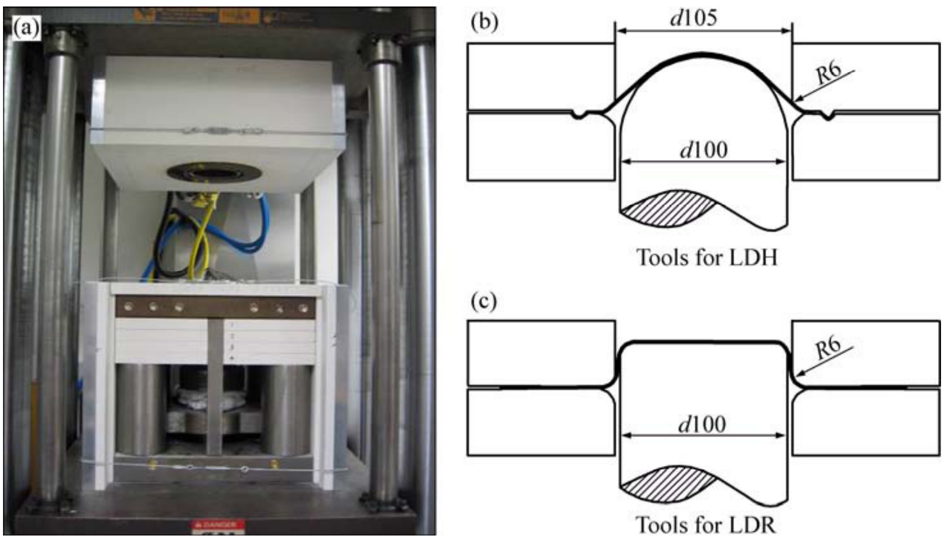

Fig. 2 Equipment for warm forming formability test: (a) Pictures of formability system (with some of front insulation removed); (b) Tool geometries used in LDH tests; (c) Tool geometries used in LDR test