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Rapid communication

Effects of time and temperature on the creep forming of 7075 aluminum alloy: Springback and mechanical properties

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ABSTRACT

This paper deals with the experimental investigations of springback and mechanical properties of 7075 Al alloy in creep forming process. Results indicate that springback increased with decreasing time and temperature. Incorporating spring back and mechanical properties, it can be found that the appropriate forming cycle was 150 °C/24 h among all forming conditions.

1. Introduction

There are increasing demands in aerospace industry for manufacturing better performance aircraft panels with improved strength and toughness, lower weight and increased resistance to fatigue and corrosion [1–3]. Creep forming as a novel process, that involves simultaneous forming and artificial ageing, is currently applied to production of aerospace metal structures [4,5]. In this process, a solution treated component is loaded onto the tool and then heated to a temperature proper to simultaneous ageing, creep and stress relaxation. Finally the part is released and partially springback to a shape somewhere between its original shape and the tool shape [1–7]. Springback occurs because of limitations on the maximum usable temperature and the forming time dictated by microstructure requirements [1,8]. It is one of the key factors affect the quality of the formed sheet metal parts. High springback often results in the formed component being out of tolerance, and the consequent problems during assembly [9]. In the past two decades, several studies have been carried out on creep forming of aluminum alloys [10–13]. They have mostly studied the creep forming behaviors of Al-Cu based alloys. However, there is limited information on the creep forming of 7*xxx* Al alloys in the literature. It is known that this class of aluminum alloys could gain their optimised properties through artificially ageing treatment. So that, the creep forming could offer a novel manufacturing process to produce high strength 7*xxx* aluminum alloy components such as fuselage, empennage and integral wing panels [3,14].

The aim of this study is to determine the suitable forming time and temperature during creep forming of 7075 aluminum alloy by establishing a balance between mechanical properties and springback.

2. Experimental

2.1. Material

A 3 mm thick AA7075 aluminum alloy sheet with the chemical composition shown in Table 1 was used in this study.

2.2. Definition of tool surface and sheet

Sheet specimens with the dimensions of 400 mm × 100 mm × 3 mm were used for creep forming tests. The tool surface was in a cylindrical form with a curvature radius of 310 mm which leads to a maximal displacement d_{max} = 65 mm in the middle section of the tool. Fig. 1a shows the schematic view of the tool surface.

2.3. Forming test

All specimens in as received conditions were solution treated at 475 °C for 50 min followed by water quenching. Then creep forming was performed as following sequence:

Step I: the specimen was mounted on the tool (lower die).

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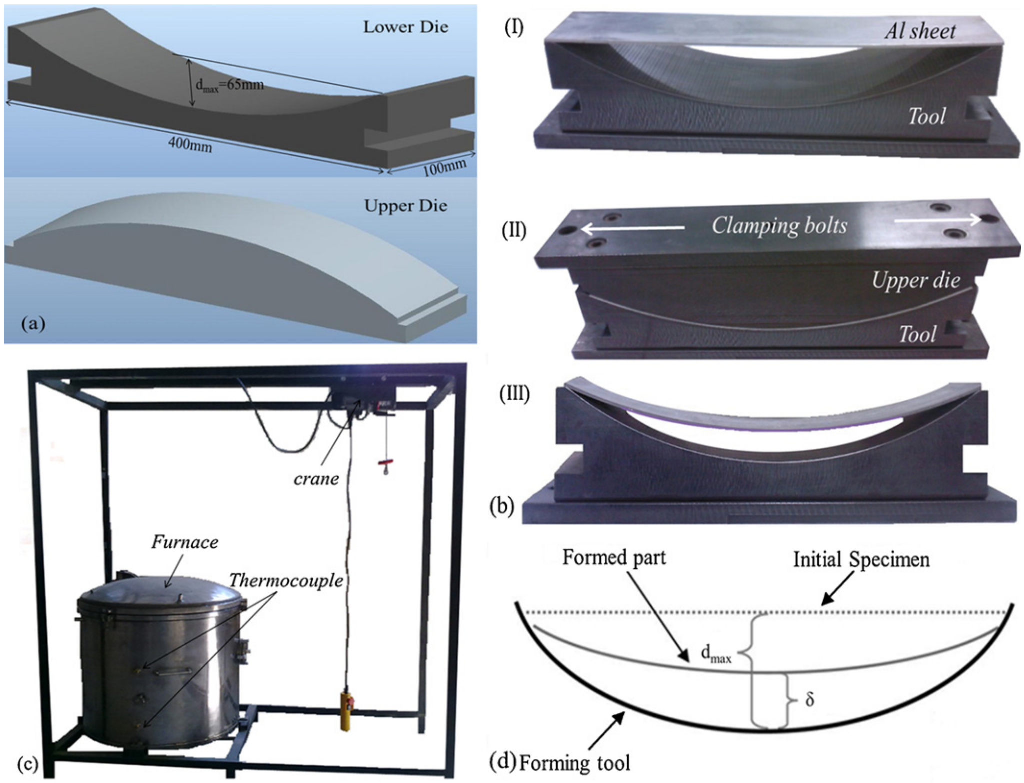

Fig. 1. (a) Schematic illustration of the tool surface, (b) CAF process: I: flat sheet prior to CAF; II: sheet reconfigured to the tool; III: final formed sheet after springback, (c) CAF furnace, and (d) definition of springback.

Step II: the load (upper die), weighing 60 kg, was placed on the specimen to deform it into complete contact with the tool. The specimen was then clamped using bolts at each end of the upper and lower dies (see Fig. 1b).

The whole assembly was placed in the furnace and isothermally heated to the temperature of ageing. The furnace was equipped with two controlling thermocouples (see Fig. 1c), one in the hot zone of the furnace and the other at the end of the tool. The temperature tolerance was ±2 °C.

Step III: After ageing for certain times, the tool, load and specimen were cooled out of the furnace.

The amount of springback was measured at the center of the length as shown in Fig. 1d according to Eq. (1):

$$\text{Springback}\,(\%) = 100\left(\frac{\delta}{d_{\max}}\right) \tag{1}$$

The forming temperature is determined according to the metallurgical properties required for the material. For 7*xxx* alloys ageing temperature is typically between 120 °C and 190 °C. In the case of aluminum alloys, creep temperatures lie between 0.4–0.5 $T_{M,}$ where T_M is the melting point of aluminum [15]. Therefore, to obtain a good combination of mechanical properties and low level of springback, the ageing treatments were conducted at 150 °C and 190 °C for 6–72 h.

Table 1
Chemical composition of 7075 Al-alloy (wt%).

Al	Zn	Mg	Cu	Fe	Si	Cr	Other
Bal.	5.20	1.95	1.22	0.25	0.23	0.17	0.08

2.4. Hardness and tensile testing

Tensile tests in the rolling direction were carried out at room temperature using an INSTRON 5500 machine operating at a constant crosshead speed of 2 mm/min. The stress–strain curves were used to determine UTS and yield (0.2% offset) points. The Brinell hardness measurement was carried out with an $F/D^2 = 5$ ratio.

3. Results and discussion

Fig. 2 illustrates the springback of the creep formed specimens under various forming conditions. As can be seen in this figure,

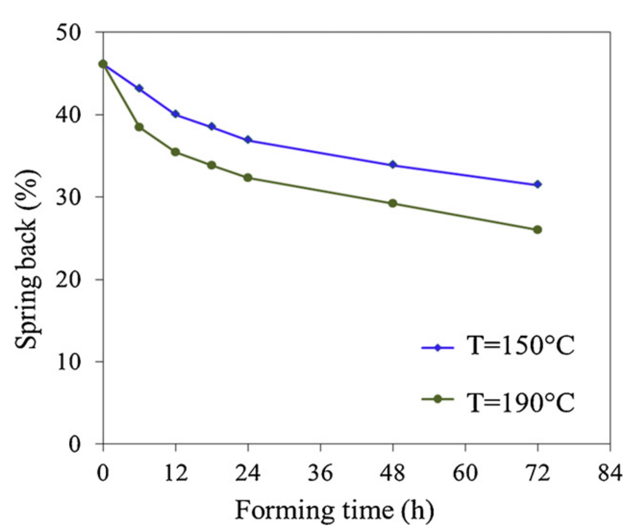

Fig. 2. Variations of springback with forming time and temperature.