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Dynamic Analysis on Superplastic Forming of Aluminium Alloy Sheet

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Abstract
Superplasticity is the ability of a polycrystalline material to exhibit, in a generally isotropic manner, very large elongations without necking prior to failure. Elongations in excess of 400% are usually referred to as super plasticity, although several alloys have exhibited elongations exceeding 1000%. The highest elongations reported are 4850% in a Pb-Sn eutectic alloy, and greater than 5500% for aluminum bronze. By using superplasticity, complex shapes can be easily formed in high strength alloys. The present work of this paper is to achieve minimum thinning at the optimum process parameters in the superplastic forming of 7075 aluminum alloys.

Keywords: *Superplastic forming, proximity sensor, thickness distribution*

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INTRODUCTION

The technique used to form a near-net shape in superplastic materials is formed by using superplasticity. Single die surface is used for blow forming of superplastic sheets, other than the matched dies. The superplastic sheet material is usually formed into a fixed die cavity. To have this capability, a computer controlled pneumatic operated bulge forming setup was designed and fabricated. The setup consists of the forming die assembly and the software module for control. The problems related to the non-uniform thickness distribution and cavitations often occur during the superplastic forming of Al alloy sheets, leading to a degradation of the mechanical properties of the super plastically formed parts[1]. So far, various papers have discussed ways to improve the thickness distribution and reduce the cavity effect by using the preforming component, which required a special die or controlled machining. The objective of this work is to study the effect of variable pressure cycle and different temperatures on the superplastic forming process of an Al 7075 alloy sheet[2]. Using the optimum process parameters of the forming pressure and temperature not only reduced the forming time, but also maintained the integrity of the formed parts. This study focused mainly on the thickness distribution during deformation.

EXPERIMENTAL SETUP

Super plastic Forming Die Assembly and Accessories

The experimental setup consists of an air compressor, a split type electric furnace, sensors and control units. The forming die consists of the top and bottom parts, and a space is provided in the bottom part to hold the forming sheet. The top part of the die is a complex shape (combination of the rectangular and the dome shape). The die set is placed inside the furnace[3]. Figure 1 shows the Experimental setup. The data acquisition card receives signal from the LVDT. It gives input to the computer which controls the forming process[4]. Figure 2 shows the top die and Figure 3 shows the bottom die (cross-sectional detail).

Software Module

The Laboratory Virtual Instrument Engineering Workbench (LabVIEW) developed by national instruments, is a powerful analysis programming language. LabVIEW is a highly productive graphical development environment with the performance and flexibility of a programming language, as well as high-level functionality and configuration utilities, designed specifically for measurement and automation application. LabVIEW integrates data acquisition, analysis and presentation in one system, making programming simple and manageable.

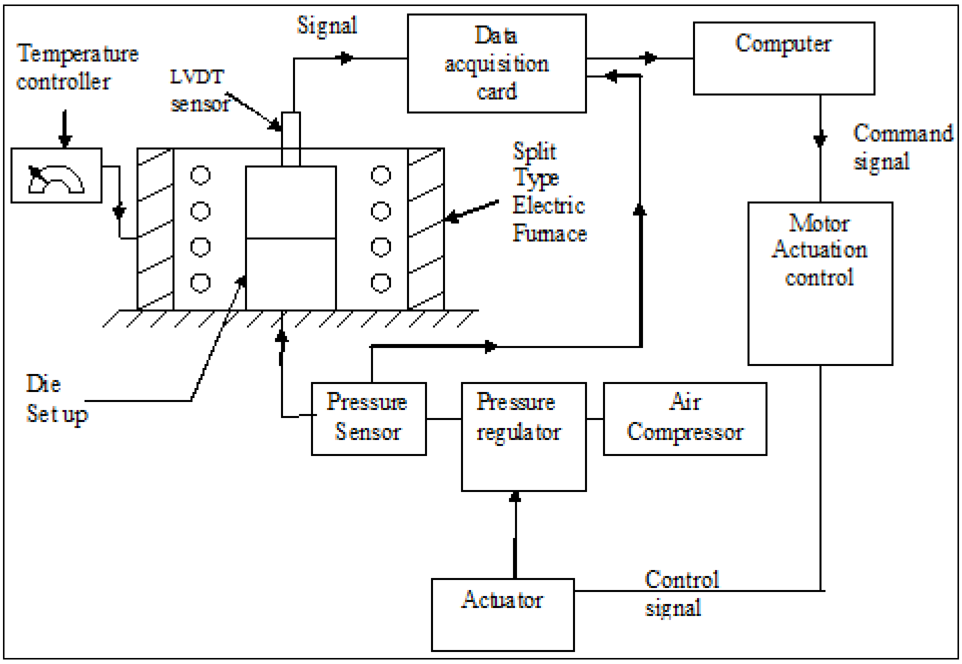
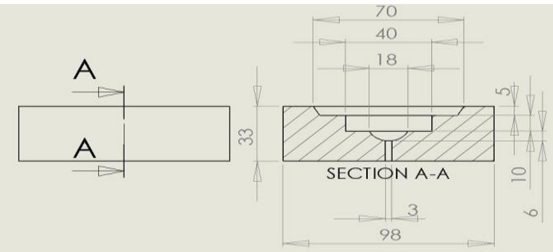


Fig. 1: *Schematic Diagram of the Experimental Setup.*



(All Dimensions in mm).

Fig. 2: *The Cross-Sectional Detail of the Top Pressure-Forming Die.*

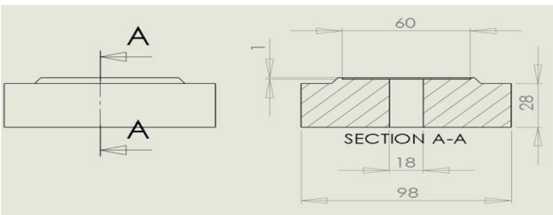


Fig. 3: *The Cross-Sectional Detail of the Bottom Pressure-Forming Die.*

The front panel is the user interface of the virtual instruments. The front panel contains controls and indicators, which are the interactive input and output terminals of the VI, respectively. The block diagram contains this graphical source code, also known as the G code or block diagram code. Figure 4 shows the block diagram of the control program of the process with the algorithm.

Figure 5 shows the front panel of the software program having text boxes for getting various level limits, and their corresponding pressure values. It also has indicators for the measured pressure and dome height values[5].

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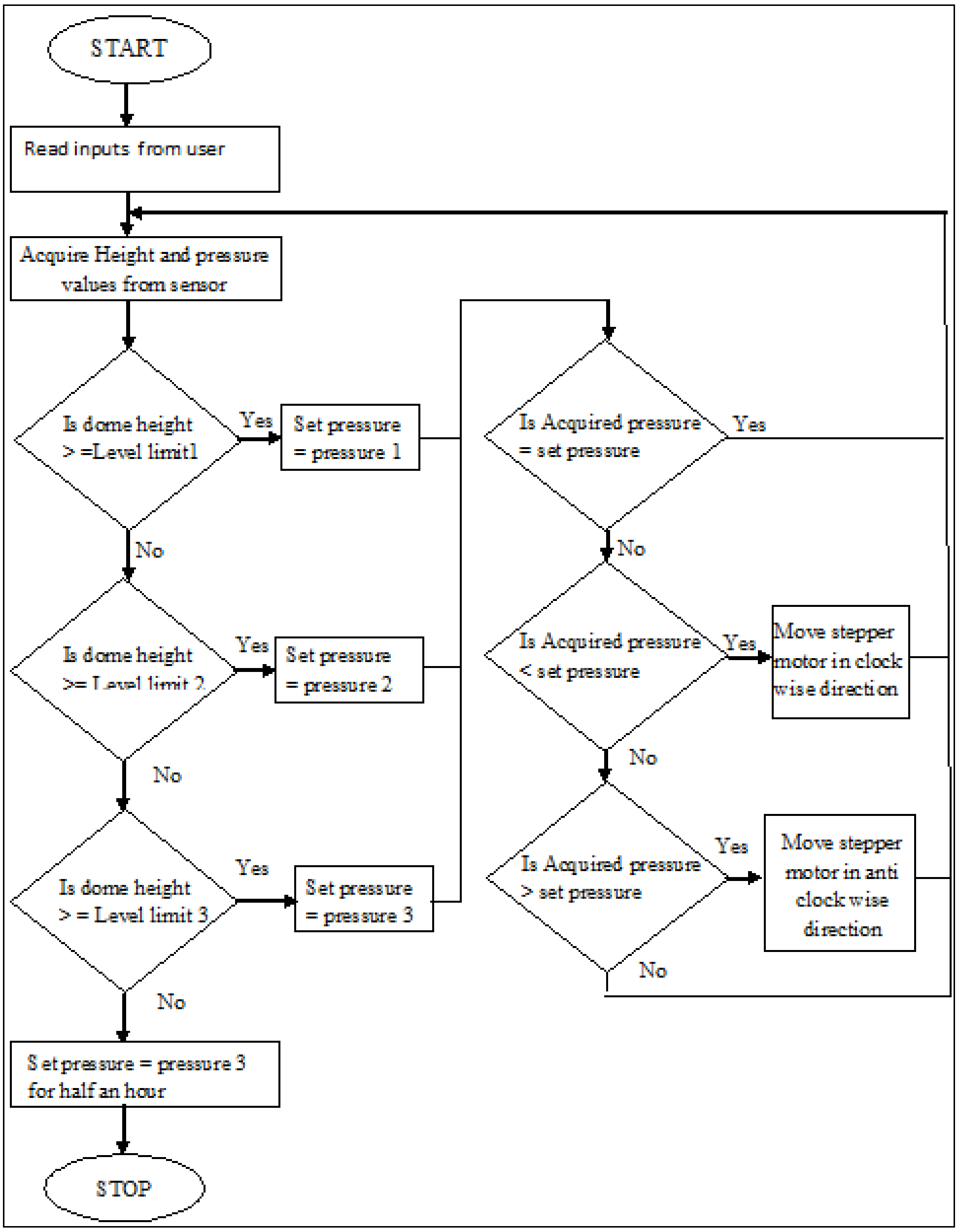

Fig. 4: *Algorithm for the Control Program of the SPF.*

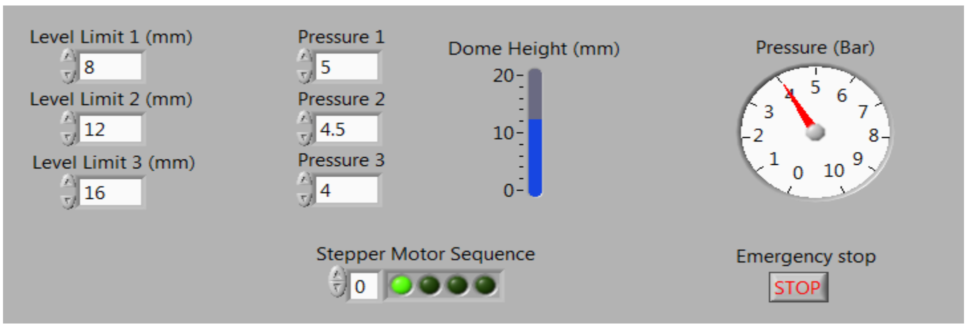

Fig. 5: *Front Panel of LabVIEW Program.*

Experimental Procedure

The experimental work consists of two parts. In the first part only one sample was considered whereas in second part, two samples were considered. In the first part, sample I was formed under the condition of the forming temperature 530°C and the constant forming pressure of 0.5 MPa. The deformed sample was taken out from the die setup, and the thickness distribution was measured, using a digital micrometer, and the cavitation effect was measured in the formed part. In the second part, sample II was formed under two different forming pressures of 0.5 MPa (up to the first 8 mm formation) and 0.45 MPa (up to the next 8 mm formation), and sample III was formed under three different forming pressures of 0.5 MPa (up to the first 8 mm formation), 0.45 MPa (up to the next 4 mm formation), 0.4 MPa (up to the last 4 mm formation) [6]. The forming processes of samples II and III were performed at 530°C. The deformed samples were taken out from the die setup, and the distribution of thickness was measured, using a digital micrometer, and the cavitation effect in the formed part was also measured.

RESULTS AND DISCUSSION

Strain is accumulated during superplastic deformation. The thinning factor was also calculated for each sample. Superplastic materials fail during deformation due to an unstable plastic flow. Sample I, formed under a constant forming pressure, took a less forming time, and had a comparatively lower thinning factor, due to the high forming pressure. Sample II was formed under two variable pressures: the thinning factor was high. Sample III was formed under three different forming pressures; it took high forming time, but gave a high thinning factor, the forming pressure enhanced the thinning factor, because the grains slid in a controlled manner, and in the last stage of formation, the pressure was very less, so, the grains very readily occupy the cavities, reducing the micro voids. Figure 6 shows the formed component and Figure 7 shows the different locations of the thickness measurements. Table 1 shows the thinning factor of samples I, II and III. Figure 8 shows thickness distribution along the transverse cross-section of samples I, II and III.

Fig. 6: *Super Plastically Formed Component of Complex Shape.*

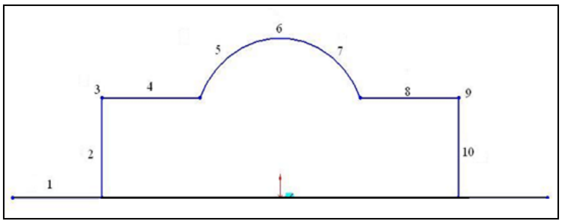

Fig. 7: *Locations of Thickness Measurement in the Component.*

Table 1: *Thinning Factor of Samples I, II and III.*

Sample	Average Thickness, t_{avg} (mm)	Thickness at Pole, t_{pole} (mm)	Thinning Factor, $[t_{pole}/t_{avg}]$
I	1.350	1.10	0.8148
II	1.461	1.23	0.8419
III	1.456	1.28	0.8791

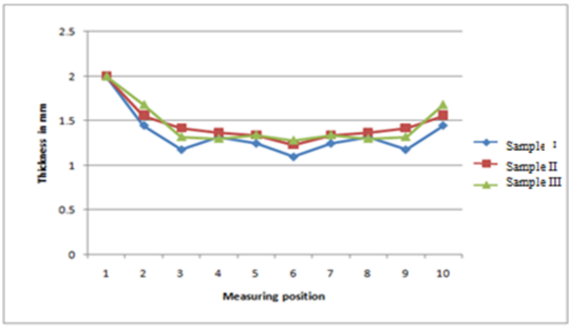

Fig. 8: *Thickness Distribution along the Transverse Cross-Section of Samples I, II and III.*

CONCLUSION

In the constant pressure method the forming time was 20 min, and the grain growth was less due to the high strain rate; dynamic recrystalisation took place, the thinning factor was 0.8148. In the two variables pressure method, the forming time was 40 min, and the small grain growth took place in a high forming time, the thinning factor was 0.8419. In the three different forming pressures method, the forming time was 68 min, and the small grain growth took place in a high forming time, the thinning factor was 0.8791, due to the very slow and controlled formation. Continuous control over the forming pressure enhanced the thinning factor and reduced the cavity volume fraction, due to the controlled and steady deformation.

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