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Research paper

Effect of Sheet Thickness during Superplastic Forming of AZ31B Alloy into a Hemispherical Die

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Abstract:

This paper deals with the effect of various combinations of temperature and pressure in the Superplastic forming process of AZ31B Magnesium alloy of different thickness into a hemispherical die. Using the time taken and the corresponding depth formed, the values of strain, strain rate and strain rate sensitivity were calculated. From these values, graphs were plotted. From the graphs, the effective pressure and temperature combination for specific thickness was determined.

Keywords: *Superplastic forming, Magnesium alloy, Hemispherical die.*

1. Introduction

SUPERPLASTIC FORMING

When a solid crystalline is deformed beyond its breaking point, then the material attains its superplasticity state [1]. This process is carried out at the elevated temperature of the material. Using superplastic forming, parts can be produced which are impossible to form using conventional techniques [2]. It has many advantages than other metal forming process. The only drawback of the process[3] is that it requires more time because of its slow forming rate. Due to this reason, lower volume of products can only be produced. Moreover, the lightweight and low cost material like AZ31B alloy [4] is chosen for aerospace components as the microstructure can be modified. Response Surface Methodology also can be applied to predict the maximum thickness [5] during the process. The thickness distribution of the superplastic formed sheet plays a major role in Ti biomedical implants. Fig 1 shows the superplastic forming of a complex shaped structure [6].

MAGNESIUM ALLOYS

Magnesium alloys are mixtures of magnesium with other metals such as aluminium, zinc, copper, silicon and rare earths [7]. This alloy (AZ31B) is chosen for this work because it is the lightest structural metal. Its strength is equal to aluminium alloys but it is lighter than aluminium alloys [8]. The magnesium alloy (AZ31B) sheets are shown in fig. 2.

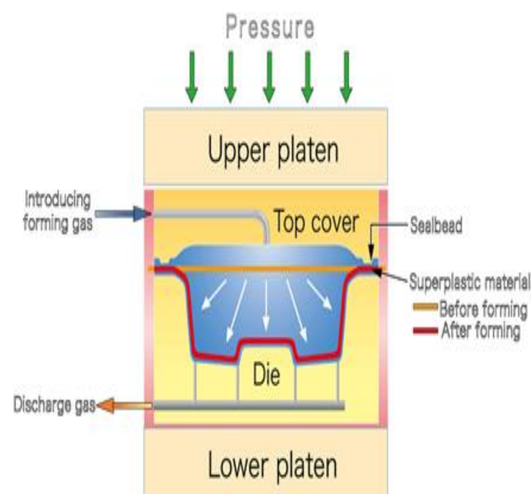

Figure 1: Schematic of superplastic forming of a complex shape.

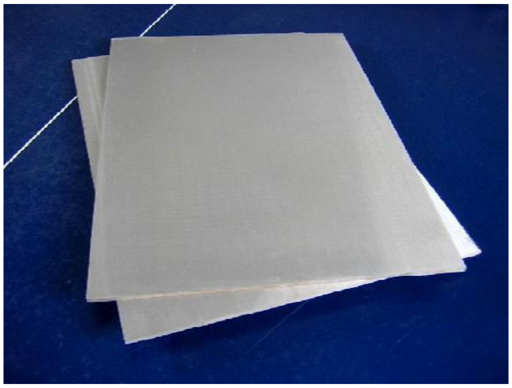

Figure 2: Magnesium alloy (AZ31B) sheets

2. Experimental Setup

Superplastic forming is a new trend in metal forming techniques. This overcomes many problems and the disadvantages faced by the conventional techniques [9]. This process is selected for the manufacturing of a complex shape structure which can be formed as a single part without the need of extra machining process. This process is done at the elevated temperature of the material (AZ31B) with the application of an argon gas pressure [10].

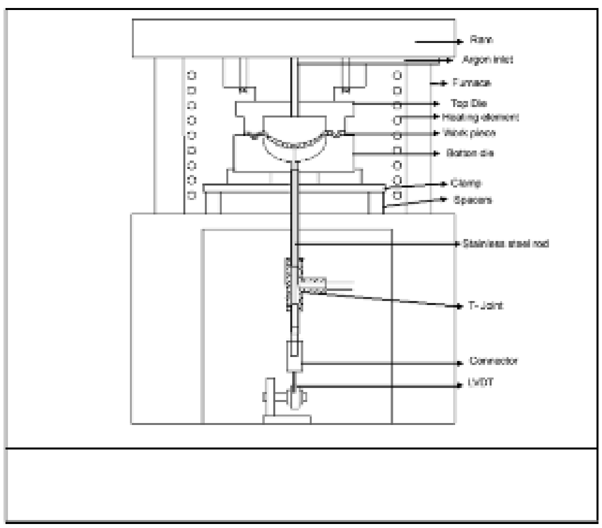

Figure 3: Schematic experimental setup of SPF into a hemispherical die

The basic components required for the superplastic forming are a heater setup with a controller, [11] top die through which inert gas pressure is applied, a bottom die of hemispherical shape and a clamping setup to hold the top die over the bottom die. Using a measuring scale, the forming depth can be calculated. The schematic experimental setup of superplastic forming into a hemispherical die is shown in Fig 3 [12].

3. Experimental Procedure

The experiments are carried out for AZ31B alloy of thickness 1.5, 2 and 2.5 mm into a hemispherical die. Pressures are maintained at 0.3, 0.5 and 0.7 MPa and the temperatures are at 350 ^{O}C, 400 ^{O}C and 450 ^{O}C. Initially the top die and bottom die are heated upto the required temperature [13]. Then the work piece is placed in between the die. The gas pressure is applied after securing the setup. Thus the forming is started. This experiment is carried out till the material [14] is formed completely into the die or till the material gets failed. Fig. 4 and 5 show the formed samples of magnesium alloy [15].

Figure 4: Specimen formed by superplasticity at 0.5MPa, 450 ^{O}C of thickness 2 mm.

Figure 5" Specimen formed by superplasticity at 0.5 MPa, 350 ^{O}C of thickness 2.5 mm.

4. Calculations

Let p = Applied Pressure

R= Radius of the hemispherical die

h = Instantaneous depth formed

s_o = Sheet thickness

Therefore, true stress can be given by the expression,

$$\bar{\sigma} = \frac{p(R^2 + h^2)^2}{4\,h\,R^2 s_o}$$

Instantaneous thickness is calculated by the following expression:

$$s = \frac{R^2 s_o}{R^2 + h^2}$$

True strain is calculated by:

$$\varepsilon = \ln\left(\frac{s}{s_0}\right)$$

The ratio of true strain to instantaneous time is known as strain rate and is given by the following expression:

$$\dot{\varepsilon} = \frac{\varepsilon}{t}$$

Effective strain rate is given by:

$$\bar{\dot{\varepsilon}} = \frac{\dot{s}}{s}$$

Therefore, train rate sensitivity is given by the following expression:

$$m = \frac{d\log\bar{\sigma}}{d\log\bar{\dot{\varepsilon}}}$$

The graph shown in fig. 6 is drawn between the time taken for forming and the corresponding depth reached [16]. The graph is drawn for the sheet thickness of 2mm, of different pressure and temperature combinations. It is observed from this graph that the foming rate of sheet at 400^{O}C temperature and 0.3 MPa is higher than that at 450^{O}C temperature and 0.5 MPa.

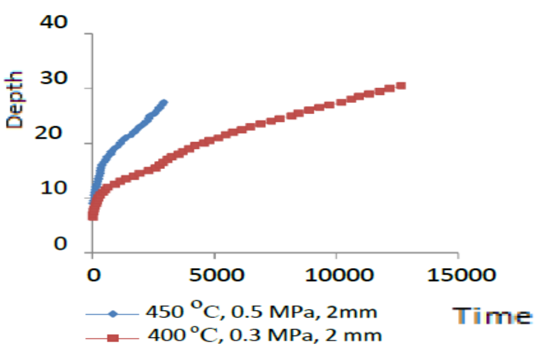

Figure 6: Forming time vs depth

5. Results and Discussion

Using Design of experiments the number of experiments is reduced. The selection of the experiments is done by DOE methods using MINITAB software, from which three combinations of temperature and pressure are selected for each thickness of sheets.

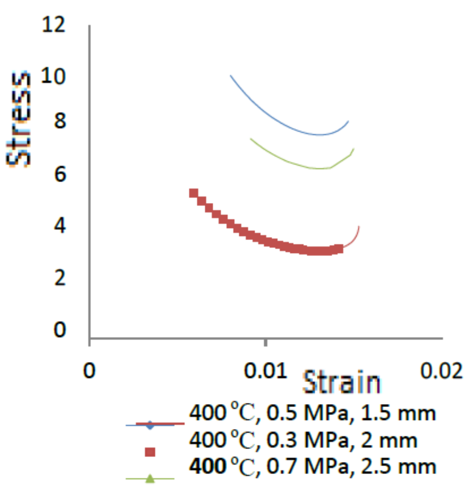

Figure 7 :Stress vs strain

The graph shown in fig. 7 represents the stress vs strain relation of sheets 1.5, 2 and 2.5 mm at constant temperature [17],[18] and varying pressures. As the strain increases the stress is reduced and after certain limit the stress value increases again [19].

From the value of strain rate and true stress, strain rate sensitivity has been determined[20],[21] and the graph is drawn as shown in Fig. 8.

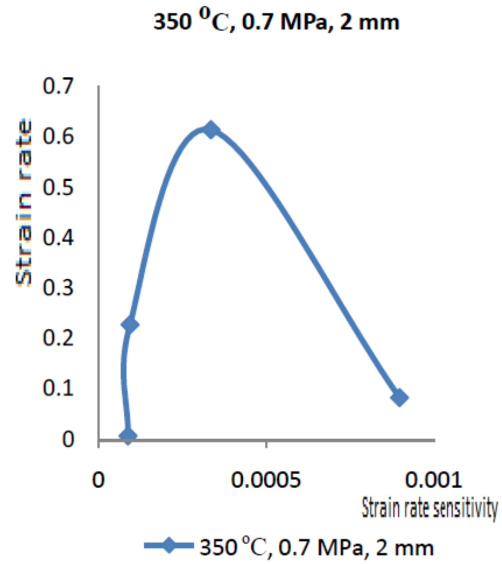

Figure 8:" Strain rate vs strain rate sensitivity

The graph shown in fig.8 gives the relation between the strain rate and strain rate sensitivity of sheet thickness of 2 mm at temperature 350^{O}C and at a pressure of 0.7MPa [22].

6. Conclusions

Superplasticity is a novel forming technique used to manufacture difficult geometric designs such as spheres and cylinders. Though as a technique it has widely been accepted, fresh research and experiments are conducted for new alloys and to estimate and model their behaviour. The calculation of stress, strain, strain rate and strain rate sensitivity of the formability of Magnesium alloy was done. The above experiments were conducted for the thickness of 1.5, 2 and 2.5 mm into hemispherical die. Further the experiments were conducted at temperatures 350 ^{O}C, 400 ^{O}C, 450 ^{O}C and at pressures 0.3, 0.5 and 0.7 MPa to estimate the sensitivity to physical parameters. From these calculations and the graphs obtained between stress and strain, stress and strain rate, strain rate and strain rate sensitivity, it is clearly concluded that the optimized formability of the AZ31B Magnesium alloy can be obtained at temperature and pressure of 350 ^{O}C and 0.3 MPa for 1.5 mm thickness, 400 ^{O}C and 0.3 MPa for 2 mm thickness and 350 ^{O}C and 0.5 MPa for 2.5 mm thickness.

These experimental works will be very useful for practitioners and researchers in utilising the above parameters for achieving higher productivity and lower costs for industrial applications. The above experiments have been done considering the existing constraints of laboratory facilities and accuracy. Further experiments are possible for different alloys and at different strain rates.

References

[1] Luo Y, Luckey S.G, Friedman P.A, Peng Y, 2008, "Development of an advanced superplastic forming process utilizing a mechanical pre-forming operation" International Journal of Machine Tools & Manufacture 48, 1509–1518.

[2] Carrino L, Giuliano G, Napolitano G, 2003 "A posteriori optimisation of the forming pressure in superplastic forming processes by the finite element method" Finite Elements in Analysis and Design 39, 1083–1093.

[3] Hwang YM, Lay HS, Huang JC, 2002 "Study on superplastic blow-forming in a rectangular closed-die" International Journal of Machine Tools & Manufacture 42, 1363–1372.

[4] Khraisheh MK, Abu-Farha FK, Nazzal MA, Weinmann KJ, 2006 "Investigation of Post- Superplastic Forming Properties of AZ31 Magnesium Alloy" Annals of CIRP.

[5] Balaguru, S, Deenadayalan, K, Vela Murali & Chellapandi, P 2014,'Influence of welding speed over dilution for Circular Grid Plate Hardfaced with Colmonoy-5', Applied Mechanics and Materials, vol. 565, pp. 53-58.

[6] Ragab R 1982 "Thermoforming of Superplastic sheets in shaped dies" Metals Technology.

[7] Jung-Ho Cheng 1996 "The determination of material parameters from superplastic inflation tests" Journal of Materials Processing Technology 58, 233-246.

[8] Balaguru, S, Vela Murali & Chellapandi P 2016, 'Effects of different Operating Temperatures on the Tensile Properties of the Grid Plate Hardfaced with Colmonoy in a Pool Type Sodium-Cooled Fast Reactor', Science and Technology of Nuclear Installations, vol. 2017, pp. 1-9.

[9] Javier Bonet, 2006 "Simulating superplastic forming" Comput. Methods Appl. Mech. Engg.195, 6580–6603.

[10] Pin-Hou Sun, Horng-Yu Wu, Hsin-Han Tsai, Chih-Chao Huang, Ming-Da Tzou , 2010 "Effect of pressurization profile on the deformation characteristics of fine-grained AZ31B Mg alloy sheet during gas blow forming" Journal of Materials Processing Technology 210, 1673–1679.

[11] Balaguru, S, Vela Murali & Chellapandi P 2016, 'Measurement of the Residual Stresses and Investigation of Their Effects on a Hardfaced Grid Plate due to Thermal Cycling in a Pool Type Sodium-Cooled Fast Reactor', Science and Technology of Nuclear Installations, vol. 2016, pp. 1-8.

[12] Hamilton CH, Ghosh AH, 1988 "Superplastic sheet forming" Materials Handbbok, 9th Edition, Vol.14, ASM, Metals Park, 852-873.

[13] Cheng JH, 1994, "A procedure for designing initial thickness variation for superplastic free inflation" International Journal of Mechanical Sciences, vol. 36, 981-1000.

[14] Balaguru, S, Vela Murali & Chellapandi P 2015, 'Effects of Welding speeds on Macro and Microstructures in Hardfacing of Colmonoy on Un-grooved and Grooved 316 L(N) SS Base metal', International Journal of Applied Engineering Research, vol. 10, pp. 25627-25631.

[15] Shailesh P, Vijaya Kumar K, Babu J, 2017 "Evaluation of Strain and Strain rates at different stages of Superplastic Cone Forming" Materials Today Proceedings, vol. 4, 835-841.

[16] Yang HP, Fu MW, To S, Wang GC, 2016, "Investigation on the maximum strain rate sensitivity (m) superplastic deformation of Mg-Li based alloy" Materials & Design, vol. 112, 151-159.

[17] Du ZX, Liu JS, Jiang SD "Strain rate dependence of microstructural evolution in β titanium alloy during subtransus superplastic deformation" Journal of Alloys and Compounds, vol. 647, 1-5.

[18] S.Ramesh Babuab, V.S.Senthil Kumar, L.Karunamoorthy, G.Madhusudhan Reddy 2014," Investigation on the effect of friction stir processing on the superplastic forming of AZ31B alloy", Materials & Design, Vol. 53, 338-348.

[19] K.Sathish, S.T.Selvamani, P.Ramesh, D.Sivakumar, M.Vigneshwar & S.Divagar 2017, "Finite Element Analysis on Optimized Condition of Super Plastic Forming of AZ31B Magnesium Alloy Sheets", Materials Today Proceedings, vol. 4, 6678-6687.

[20] D.Sorgente, G.Palumbo, A.Piccininni, P.Guglielmi & S.A.Aksenovc 2018," Investigation on the thickness distribution of highly customized titanium biomedical implants manufactured by superplastic forming", CIRP Journal of Manufacturing Science and Technology, vol.20, 29-35.

[21] MuhammedShafi. P,Selvakumar.S*, Mohamed Shakeel.P, "An Efficient Optimal Fuzzy C Means (OFCM) Algorithm with Particle Swarm Optimization (PSO) To Analyze and Predict Crime Data", Journal of Advanced Research in Dynamic and Control Systems, Issue: 06,2018, Pages: 699-707

[22] Selvakumar, S & Inbarani, Hannah & Mohamed Shakeel, P. (2016). A hybrid personalized tag recommendations for social E-Learning system. 9. 1187-1199