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Study of Process Parameters in gas Pressure Super Plastic Forming

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Abstract: In the field of aerospace, transportation, and other industries, the demand for light weight, high strength, high corrosion resistance materials are growing. Superplastic forming is a process that has been used since 1960s for manufacturing complex, strong, light weight components. The aim of the present work is to design and fabricate a die for Superplastic forming, producing a hemispherical cup and study the process parameters of the experiment carried out. The super plastic material provides unique design capabilities for advanced structures. A review of these emerging advanced technologies is presented in this paper.

Keywords: Super plastic forming, process parameters, Strain rate, superplastic deformation

I. Introduction:

Super plasticity, i.e., the ability to stretch metals to extremely large (several hundred per cent) elongations before failure, can be effectively utilized for forming extremely complex shapes to functionally replace heavy multicomponent structures of an old design.

Superplastic forming is widely accepted as an advanced manufacturing technique for forming complex components in aerospace industry in one forming operation. Superplastic materials show a very high ductility. This is due to both peculiar process conditions and material intrinsic characteristics. Superplastic forming (SPF) is receiving increasing interest as a process capable of radically extending the limitations associated with the more conventional processes. The large tensile elongations and typically low flow stresses associated with a superplastic metal permit the forming of complex parts using methods and forming pressures not previously possible. The potential of forming processes designed to take advantage of this unique capability has been widely recognized, and extensive studies have been conducted over the past 20 years to provide a better understanding of mechanisms and requirements for superplasticity, and to develop new and modified alloys and processing methods which will further extend the number of superplastic materials available.

Superplasticity, as referred to in this paper, is described as the capability of a material to undergo extensive tensile deformation. In a tensile test, elongations of more than 200-300 per cent are generally referred to as superplastic deformation. A characteristic common to all superplastic materials is a high degree of sensitivity of the flow stress to strain rate with flow stresses decreasing with decreasing strain rate. High Superplastic forming of SPF materials strain rate sensitivity is typically associated with a fine grain microstructure.

The prerequisites for Super plasticity is shown by materials with a fine grain size, usually less than 10μm, when they are deformed within the strain rate range 10-5 to 10-1/s at temperatures greater than 0.5Tm, where Tm is the melting point in Kelvin. These are the basic requirements of superplastic flow. No single property or feature is sufficient to define superplasticity. For example, metals which have high elongations due to high rate of strain hardening would not qualify as superplastic materials. Similarly, high strain rate sensitivity alone is not sufficient to define superplasticity, since inherent ductility is needed to achieve high elongations. Todate all superplastic alloys contain at least one metallic phase, implying that deformability, which is an inherent feature of metals, is required for superplastic flow.

SPF can produce parts that are impossible to form using conventional techniques. During the SPF process, the material is heated to the SPF temperature within a sealed die. Inert gas pressure is then applied, at a controlled rate forcing the material to take the shape of the die pattern. The flow stress of the material during deformation increases rapidly with increasing strain rate. Superplastic alloys can be stretched at higher temperatures by several times of their initial length without breaking.

Superplastic forming technology offers the potential to reduce the weight and cost of automotive structural components for advanced vehicle applications.

II. Material and methodology

For a superplastic metal that is tensile tested under proper conditions of temperature, the observed ductility seems to vary substantially with strain rate, for a Tin-lead alloy. There is a maximum in ductility at a particular strain rate, with significant losses in ductility as the strain rate is increased or decreased relative to this maximum.

It is well know that the primary factor related to this behaviour is the rate of change of flow stress with strain rate, usually

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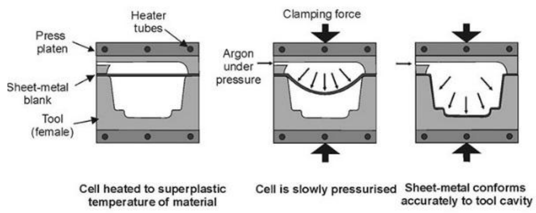
measured and reported as 'm', the strain rate sensitivity exponent.

The sheet metal used in Sn-Pb alloy (60-40). The Superplastic forming operation occurs, where the flow stress of the sheet material is low. The sheet is placed in an appropriate SPF die, which can have a simple to complex geometry, representative of the final part to be produced. The sheet is formed into the hemispherical cup using gas pressure.



Various pressures were applied and parameter like deformation with respect to time, thickness variations of cup and micro structure were studied.

The aim of the present work is to design and fabricate a die for Superplastic forming, producing a hemispherical cup and study the process parameters of the experiment carried out. The sheet metal used in Sn-Pb alloy (60-40). The Superplastic forming operation occurs, where the flow stress of the sheet material is low. The sheet is placed in an appropriate SPF die, which can have a simple to complex geometry, representative of the final part to be produced. The sheet is formed into the hemispherical cup using gas pressure. Various pressures were applied and parameter like deformation with respect to time, thickness variations of cup and micro structure were studied.

Typically a die is loaded in a hydraulic press. The press opens and a flat sheet is loaded into the die. The die then closes and creates a seal.

The SPF process uses gas pressure (typically less than 14 bar) to form sheet metal into vary complex shapes.

Inert gas pressure is introduced at a controlled rate using an inert gas until the sheet is fully formed against the die surface. Each parts geometry is unique and requires a unique pressure/time profile to maintain the appropriate strain rate.

As the sheet thickness decreases, it requires less forming pressure. However as the parts radius decreases, more pressure is required. Since the sheet is in tension throughout the process.

Pressure Time Relation:

A. Dutta & A.K.Mukherjee, Superplastic for an Analytical approach Materials, Science Engineering A157.

$$P = 4\frac{S_o}{a}\sigma\, e^{-\epsilon t}\sqrt{e^{-\epsilon t}\,(1 - e^{-\epsilon t})}$$

$$p = \frac{a}{2\sqrt{e^{-\epsilon t}\{(1 - e^{=\epsilon t})\}}}$$

$$d = p - \sqrt{p^2 - a^2}$$

$$A = 2\Pi\, p\, \left[p - \sqrt{p^2 - a^2}\right]$$

S_0 = initial sheet thickness
ϵ - Effective stain rate t – time,
P = required forming pressure A surface a
D = Depth.

III. Results and tables:

The parameters and variables which are involved in the experimental process and are varied during the process are termed as process parameters.

The parameters which can be varied is Gas pressure.

The process is carried out for a sheet metal of thickness 1MM. Argon gas is passed at a pressure of 5 bar. The pressure is kept constant for a specific period of time. Then the deformation of the sheet metal is measured at regular intervals.

The above process is repeated at a pressure of 3.5 & 2 for sheet metal 1MM thickness.

Pressure(bar)	Time(min)	Depth(mm)
5	3	5.10
	5	10.04
	7	14.00
	10	19.02
	13	23.14
	16	27.50
	18	30.00

Table 3.1 depth variation with time at5 barpressure

Pressure(bar)	Time(min)	Depth(mm)
3.5	5	7.50
	7	13
	10	15.56
	13	15.57
	17	19.02
	20	21.22
	23	23.32
	28	26.72
	31	30.00

Table 3.2 depth variation with time at 3.5 bar pressure

Pressure(bar)	Time(min)	Depth(mm)
2	10	12.51
	20	16.51
	35	18.32
	40	19.04
	50	21.00
	65	23.00
	80	27.50
	95	30.00

Table 3.3 depth variation with time at 2 bar pressure

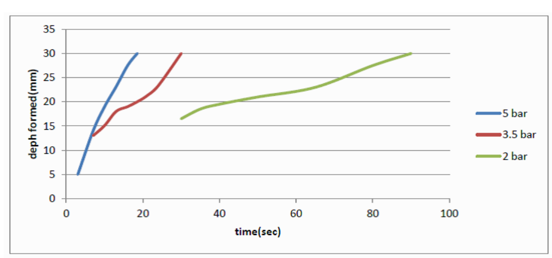


Fig 3.1 DeformationVs time graph

The above graph is drawn by considering Time on the X-axis & Deformation on the Y-axis for three different pressure values. From the graph it is observed that as the pressure is set at a constant value deformation of the blank increaseswith increase in time. And with higher pressures for same blank thickness the deformation is obtained at a faster rate.

The experimental set up

The experimental set up that was used in the SPF Process:

1. Hydraulic Press
2. Argon gas cylinder
3.SPF die assembly

A Sn-Pb (60-40) alloy was casted into slab of dimensions 110 x 100 x 10 (length x breadth x thickness. Then it was rolled to a thickness of 1MM sheet. Thus the grains are elongated and the grain size is reduced. The no. of rolling passes carried for 1,mm thickness was 4. Then a blank of 100 x 100 is cut from the sheet metal prepared and placed in the lower die. The upper and lower die are assembled.

The arrangement is placed on the hydraulic press to constraint the gas pressure. Pressurized argon gas from the argon gas cylinder is passed through the passageway in the upper die. The hydraulic press force acting on the die assembly must be atleast 5 times greater than the force acting on the die due to the gas pressure. Thus preventing the die from lifting up. Hence the assembly is clamped.

Thickness variation of cup:

The thickness of cups formed under 5, 3.5, 2 bar pressures were measured at three different locations at 00, 450, 900 from the centre of diametric axis of the hemispherical cup and the values were as follows.

Thickness variation from pole to equator:

Pressure(bar)	location	Thickness(mm)
5	1	.43
	2	.54
	3	.90

Pressure(bar)	location	Thickness(mm)
3.5	1	.35
	2	.54
	3	.86

Pressure(bar)	location	Thickness(mm)
2	1	.37
	2	.54
	3	.87

Table 3.4 thickness variations from poles to equator for different pressures

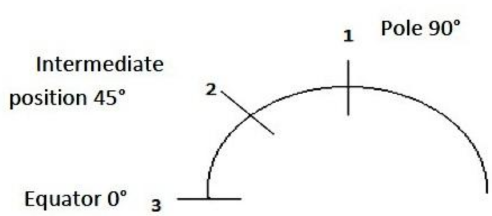


Fig 3.2 Deformation at various locations

It is observed that thickness is least at poles and maximum at equator.

Fig 3.3 super plastically Formed material

Fig 3.4various stages of Forming

Discussion

1. A die to make a hemispherical cup using superplastic forming method has been designed and fabricated

2. Keeping pressure as constant parameter, the superplastic material was deformed to a depth of 30mm with the following 3 pressures:-

(i) With 5 bar pressure, the required depth was obtained in 18.5 minutes

(ii) With 3.5 bar pressure, the required depth was obtained in 31 minutes.

(iii) With 2 bar pressure, the required depth was obtained in 27.5 minutes

3. Pressure variation from 2 bar to 5 bar gave a thickness variation at pole varying from 0.37mm to 0.43mm. At position 2, as shown in fig., at all pressures, same thickness 0.54mm was observed and at equator, a minute thickness variation was observed from 0.87mm to 0.9mm with varying pressure from 2bar to 5bar.

IV. Conclusions:

With increase in pressure, initially the forming rate was observed to be rapid which eventually decreases slowly for all temperature and pressure

• With increase in pressure the time required to form cup of full depth decreases.

• The microstructure of specimen formed under three pressures, namely 2, 3.5, 5 bars. Though there was no noticeable difference, elongation was observed for specimens which were deformed under 2 bar and 3.5 bar pressures and for 5 bar grain chain disintegration was observed from which we can conclude that further raise in pressure may subsequently cause breakage of specimen and from all the three pressures, 3.5 bar is optimum for deformation taking a time of 31mins with fine grain structure, comparatively.

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