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SUPERPLASTIC FORMING CHARACTERISTICS OF AL6061/B4C NANO COMPOSITES

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Abstract

Super plastic forming is a long neck free elongation at low flow stresses. In super plastic forming more than 500% of elongation can be obtained. Due to higher percentage of elongation, intricate shapes are formed. More than 500 components were produced by super plastic forming process. Composite materials have high strength to weight ratio. Composites formed with nano particles have high strength as well as ductility. It is necessary to find the super plastic forming characteristic in composites. In this work, super plastic forming characteristics like percentage of elongation and strain rate sensitivity index.

Keywords : Aluminium6061, Elongation, nano particles, composite materials and strain rate.

1.0 INTRODUCTION

1.1 Superplasticity:

Manufacturing of complex light weight automotive structures that meet cost and product goals is a competitive challenge facing industry. Superplastic forming (SPF) is a valuable tool for the fabrication of complex parts used in the aircraft and automobile industries. Superplastic forming (SPF) of sheet metal has been used to produce very complex shapes and integrated structures that are often lighter and stronger than the assemblies they replace. Superplasticity in metals is defined by very high tensile elongations, ranging from two hundred to several thousand percent. Superplasticity is the ability of certain materials to undergo extreme elongation at the proper temperature and strain rate. The process typically conducted at high temperature and under controlled strain rate, can give a ten-fold increase in elongation compared to conventional room temperature processes. Components are formed by applying gas pressure between one or more sheets and a die surface, causing the sheets to stretch and fill the die cavity.

1.2 Superplastic Forming

Superplastic forming (SPF) of sheet metal has been used to produce very complex shapes and integrated structures that are often lighter and stronger than the assemblies they replace. The finished product has excellent precision and a fine surface finish. It also does not suffer from spring back or residual stresses. Products can also be made larger to eliminate assemblies or reduce weight, which is critical in aerospace applications Examples of super plastic materials are some fine-grained metals and ceramics.

1.3 Characteristic of Superplastic Metals:

The characterization of superplastic behavior includes the characterization of flows, internal cavitation's, and fracture behavior. The parameter that is commonly selected as measure of superplastic formability is the tensile elongation at the optimum superplastic temperature and strain rate. Because this is a highly strain rate sensitive property and real component can experience significant variation in strain rate during forming, tensile elongation is measured as a function of strain rate.

The forming temperature is just an important a variable in superplastic forming as the strain rate. Temperature variation in a forming die is a primary source of localized thinning. Characterization of material behavior should therefore include not only determination of the optimum superplastic temperature but also the sensitivity of flow stress and elongation to temperature. A large temperature sensitivity of flow stress is not desirable, because local hot spots will lead to severe strain localization. The modes of failure in superplastic forming are strain localization and necking. Therefore fracture occurs in most superplastic materials of engineering application.

1.4 Grain Size Distribution Effects on Stress-Strain Rate

Grain size has a profound influence on the super plasticity of metals. When the grain size is fine, the flow stress is low, the value of „m" (strain rate sensitivity index) is generally high, and the tensile elongation is greater. Characterization of grain size is therefore important in the overall characterization of super plasticity. A few coarse grains in an otherwise fine grain structure can control the strain rate range over which „m" is high, and may in some cases cause the appearing of a threshold stress. The important effect of low grain size distribution in real materials is to produce a relatively high m (m>0.5).

1.5 Variables in Superplastic Forming

Superplastic flow may be described by an equation

$$\sigma = k \quad m$$

´σ´ is effective flow stress (N/m2) ´ ´ is strain rate, (s-1)

´k´ is material constant depends upon temperature and grain Size ´m´ is strain rate sensitivity index

The value of ´m´ has a controlling influence on the stability of superplastic flow. The value of ´m´ lies between 0.3 and 0.9 for most of the superplastic materials. The high value of ´m´ imports to the material resistance to localized deformation such as necking and thinning so that the specimen can undergo large deformation without failure. A high value of ´m´ causes the flow stress to be highly sensitive to the strain rate. An ideal value of m=1 would correspond to Newtonian viscous flow which leads to complete neck-free tensile deformation.

1.6 Super Plastic Forming Methods:

1.6.1 Vacuum Forming:

Vacuum forming is a simplified version of thermoforming, whereby a sheet of plastic is heated to a forming temperature, stretched onto a single-surface mold, and forced against the mold by a vacuum (suction of air).

1.6.2 Thermo Forming:

Thermoforming is a manufacturing process where a plastic sheet is heated to a pliable forming temperature, formed to a specific shape in a mold, and trimmed to create a usable product. The sheet, or "film" when referring to thinner gauges and certain material types, is heated in an oven to a high-enough temperature that permits it to be stretched into or onto a mold and cooled to a finished shape.

2.LITERATURE REVIEW

Gowri Shankar and Jayashree, (2013) described the aluminum Metal Matrix composites with reinforcements are finding increased application in aerospace , automobile, space, underwater, and transportation applications. This is mainly due to improved mechanical properties like strong, stiff, abrasion and impact resistant. Using different types of aluminum alloy like, Al6061 alloy with silicon carbide (SiC) and boron carbide (B4C) reinforcement of composites to improve physical and mechanical properties by varying weight percentage.

Pradeep and Ramesh, (2011) explained the application of aluminum Metal Matrix composites (MMCs) as engineering materials has exceedingly increased in almost all industries sectors. Aluminum MMCs are preferred to other conventional materials in the fields of aerospace, automotive and marine applications owing to their improved properties like high strength to weight ratio, good wear resistance etc. Cast Al6061-SiC composites were prepared successfully using metallurgy technique. Hardness of the composites found increased with increased SiC content. Finer the grain size better is the hardness and strength of composites leading of wear rate.

Dinesh pargunde and Kulkarni, (2013) described the present method a modest attempt would be made to develop Aluminum based silicon carbide particulate MMCs with an objective to develop a conventional low cost method of producing MMCs and to obtain homogenous dispersion of ceramic material. To achieve these objectives two step-mixing method of stir casting technique has been proposed and subsequent property analysis has been made. The trend of hardness and impact strength with increase in weight percentage of SiC would be observed and recommendation made for the potential applications accordingly. Impotent of the casting quality by minimizing the entrapped air during the shot sleeve process.

Chan and Tong (2004) analyzed the deformation and cavitation behaviors of the aluminum silicon carbide composite under biaxial stress rates with a variable strain rate path were investigated and compared with a composite tested under a constant path. The following conclusions were reached from the study: The strain distribution of the composite deformed under a variable path is similar to that obtained under a constant path. The cavity growth rate parameter under the variable path was found to be slightly greater than the constant one. The experimental limit strains under the two-stage path were found to be smaller than those of the constant path.

Syn and Lesuer, (2001) Al 5083 disks of a super plastic forming grade were gas pressure formed to hemispheres and cones at constant forming pressures with and without back pressure. The forming operation was performed using in-house designed and built biaxial forming apparatus. The temporal change of dome heights of the hemispheres and cones were measured for the different forming and back pressures applied. The flow stress and strain rates developed at the top of the dome during the forming step were shown to closely follow the flow stress-strain rate relationship obtained from the strain rate change tests performed at the same temperature using uniaxial tensile samples. The level of dome height achieved is higher for the specimens formed in conical die and highest in the specimens formed with back pressure.

Tong and Chan (1997) analyzed high-strain-rate superplastic gas pressure forming behavior of an Al6061/SiCw composite sheet has been examined for the first time under the constant applied flow stress condition. A hemisphere diaphragm is successfully formed in about 17.6 seconds at the applied flow stress of 4.0 MPa and at the temperature of 873K. From the experimental findings, three distinct deformation regimes were observed from the polar heigh vs time curve, which is similar to the creep behavior of most metallic alloys and structural ceramics at a condition of constant stress. The predicted thinning factors based on the m value determined by tensile test are shown to be not in reasonably agreement with experimental results. It is believed that the m value under biaxial tension may be different from that under uniaxial tension

3. MATERIAL SELECTION

3.1 Workpiece (Al 6061/B4C):

3.1.1 Aluminum 6061:

6061 is a precipitation hardening aluminum alloy, containing magnesium and silicon as its major alloying elements. Originally called "Alloy 61S," it was developed in 1935. Aluminum alloy 6061 is one of the most extensively used of the 6000 series aluminum alloys. It is a versatile heat treatable extruded alloy with medium to high strength capabilities. It has good mechanical properties and exhibits good weld ability. It is one of the most common alloys of aluminum for general purpose use.

3.1.2 Key Properties:

Typical properties of aluminum alloy 6061 include:

- Medium to high strength
- Good toughness
- Good surface finish
- Excellent corrosion resistance to atmospheric conditions
- Good corrosion resistance to sea water
- Can be anodized
- Good weld ability
- Good workability
- Widely available

3.1.3 Properties:

Density	2.7 g/cm3
Melting Point	Approx. 580°C
Modulus of Elasticity	70-80 GPa
Poisson's Ratio	0.33
Co-Efficient of Thermal Expansion (20-100°C)	23.5x10-6 m/m.°C
Thermal Conductivity	173 W/m.K
Electrical Resistivity	3.7 – 4.0 x10-6 Ω.cm

3.1.4 Boron Carbide (B4C):

Boron carbide (chemical formula approximately B4C) is an extremely hard boron–carbon ceramic material used in tank armor, bulletproof vests, engine sabotage powders, as well as numerous industrial applications. Boron carbide was discovered in 19th century as a by-product of reactions involving metal borides; however, its chemical formula was unknown.

3.1.5 Properties:

- Third hardest material after diamond & cubic boron nitride.
- High cross section for absorption of neutrons (i.e. good shielding properties against neutrons)
- Stability to ionizing radiation and most chemicals.
- Vickers hardness (38 GPa)
- Elastic Modulus (460 GPa)

4. EXPERIMENTAL METHOD

4.1 Casting:

4.1.1 Ultrasonic vibration casting method:

However, two main severe issues associate with the fabrication of in situ particulate reinforced aluminum composites by using conventional mechanical stirring cast technique. One is the clustering of formed particles. The effect of the mechanical stirring is not ideal for dispersing small particles with less than a few microns in diameter. Aggregation of the reinforced phase has been shown to lead to a severe degradation of the mechanical properties, such as tensile strength and fatigue resistance. The other one is the high porosity which leads to a degradation of the mechanical properties, especially the corrosion resistance of the composites. In general, porosity arises from the following causes, (a) gas entrapment during mixing, (b) hydrogen evolution, and (c) shrinkage during solidification. In the fabrication of

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Al matrix composites via stir casting technique, the gas entrapment during mixing is the primary factor of forming pores in the melt.

Ultrasonic vibration has been extensively used in the purifying, degassing, and refinement of metallic melt, for the injection of ultrasonic fields in a liquid gives rise to nonlinear effects such as cavitation and acoustic streaming. Furthermore, ultrasonic vibration can improve the wet ability between reinforced particles and metal matrix, and distribute particles uniformly in the metal matrix. Some work has been reported that ultrasonic vibration had been used to prepare the particulate reinforced composites, and the reinforcements were added into the melts directly. However, very little work has been reported on the fabrication of in situ particulate reinforced aluminum composites by using ultrasound assisted in situ technique.

A)Ultrasonic Cavitation arrangement

B) Stirring the molten melt in crucible

4.2 THERMO-MECHANICAL TREATMENT:

4.2.1 Heat Treatment and Rolling:

Before roll the component, it requires heat treatment (i.e) place the material in the furnace at the temperature of 400 degree Celsius for one hour. Through hot rolling, the material gets elongate without any damaging of grain structure. While rolling, the material will achieve greater strength to superplastic forming.

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Rolling machine   Component, after rolling

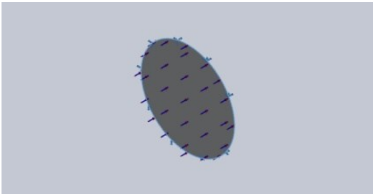
4.3 Superplastic Forming:

Fix the, rolled component (Circular shape) between the die and bolt it tightly, and placed inside the superplastic forming equipment contains induction coil. The optimum temperature is 580 degree Celsius to form the component, so we have to wait until the temperature attain in the control monitor. Then, give the pressure (6 bar) from the compressor through the lower die. Slowly the component will starts deform varies with the rate of time.

Formed Components

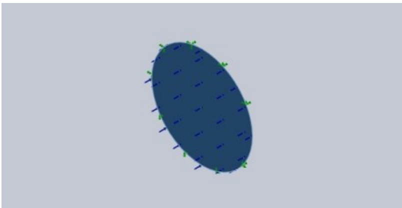
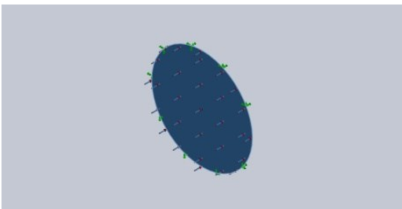
5. SIMULATION

Loads and Fixtures

Fixture name	Fixture Image	Fixture Details
Fixed-1		**Entities:** 1 edge(s) **Type:** Fixed Geometry

Resultant Forces

Components	X	Y	Z	
Reaction force(N)	-0.00512695	0.00671005	19242.3	
Reaction Moment(N-m)	0.00015947	-0.00227213	0	

Load name	Load Image	Load Details
Pressure-1		**Entities:** 1 face(s) **Type:** Normal to selected face **Value:** 5 **Units:** N/mm^2 (MPa)
Temperature-1		**Entities:** 1 face(s), 1 component(s) **Temperature:** 348 Celsius

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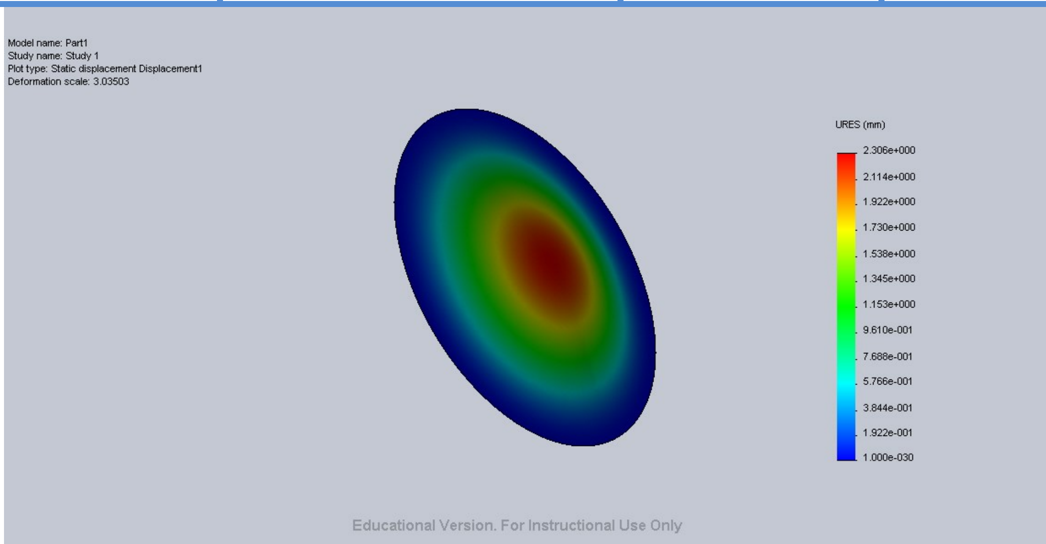
Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0 mm Node: 1	2.3064 mm Node: 131



Part1-Study 1-Displacement-Displacement1

Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	0.000652451 Element: 693	0.0133175 Element: 1880

6. CONCLUSION

The superplastic experiments were conducted in Al6061/B4C composites. Maximum dome heights of 11mm were obtained. The same were simulated in solidworks.

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