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Experimental study and Uniaxial Hot Tensile Test Properties of Aluminium Alloy 5052

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ABSTRACT - *Superplastic forming/Diffusion bonding process is widely used in the aerospace industries to produce light weight components, complex products with required shape and strength without any welding or riverting operations. Due to interatomic bonding of atoms from one surface to other surface, the bonding strength is relatively weaker than welded joints. The material parameters at high temperature such as strain rate, flow stress, strain rate sensitivity index and material constant are important parameters to be considered during superplastic forming. AA 5052 alloy has been selected for the SPF/DB process with very fine microstructure in the range of 5 to 7 µm. The uniaxial hot tensile experiments has been performed for various temperature (560°C, 570°C and 580°C) at a constant strain rate of 0.09 s^{-1}.*

Keywords: *Superplasticity, Diffusion Bonding, AA5052 and Tensile Test.*

I. INTRODUCTION

1.1 Superplastic Forming

Superplastic forming is a metal working process for forming sheet metal. It works upon the theory of super plasticity, which means that a material can elongate beyond 100% of its original size. It's a neck free elongation process where near net shape can be obtained under low flow stress and low strain rate. To begin with, the material must have an ultra-fine grain size. It is then heated up to promote super plasticity. For titanium this is around 900 °C (1,650 °F) and for aluminium it is between 450–520 °C, Typical aluminium alloy sheets can elongate 10-30% during forming. A class of materials, referred to as superplastic materials, can achieve elongation of more than ten times the level of conventional aluminium alloys. In the case of aluminium alloys, superplastic forming is generally performed at a temperature close to the alloy solution heat treatment temperature. Figure 1 represents a schematic illustration of superplastic forming setup.

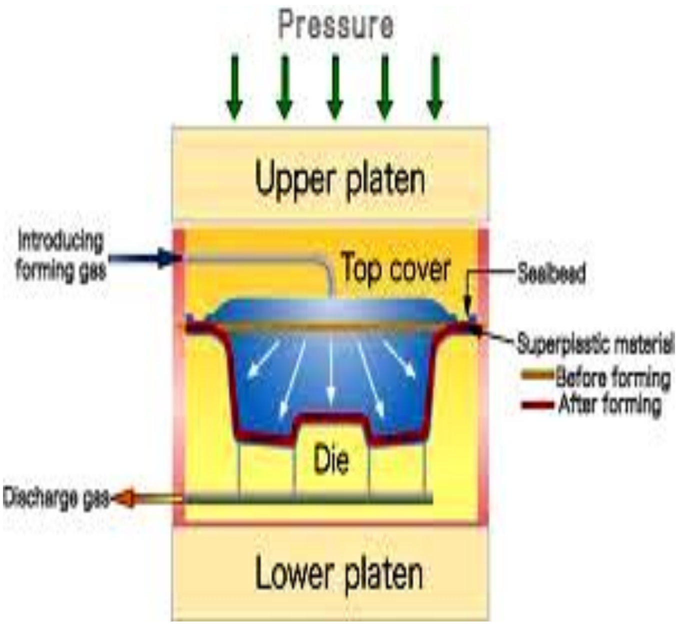

Figure1. Superplastic Forming Experimental Setup

1.2 Diffusion Bonding

Diffusion bonding is only one of many solid-state joining processes wherein joining is accomplished without the need for a liquid interface (brazing) or the creation of a cast product via melting and resolidification (welding). In its most narrow definition, which is used to differentiate it from other joining processes such as deformation bonding or transient liquid phase joining, diffusion bonding (DB) is a process that produces solid-state coalescence between two materials under the

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following conditions. Joining occurs at a temperature below the melting point, Tm, of the materials to be joined (usually >1/2 T m). Coalescence of contacting surfaces is produced with loads below those that would cause macroscopic deformation to the part. A bonding aid can be used, such as an interface foil or coating, to either facilitate bonding or prevent the creation of brittle phases between dissimilar materials, but the material should not produce a low-temperature liquid eutectic upon reaction with the materials to be joined. Thus, diffusion bonding facilitates the joining of materials to produce components with no abrupt discontinuity in the microstructure and with a minimum of deformation.

1.3 Diffusion Bonding/Superplastic Forming

Diffusion bonding is used with Superplastic forming to create more complicated shapes. The following steps explain the processing operations to be done.

Step 1: The sheets have boron nitride placed on the sheets, where no bonding to occur, Sheets are put down in layers (with boron nitride areas between) and heat and pressure are used to bond sheets together. Figure 1.4 illustrates that there is presence of boron nitride stop off in between the sheets to prevent bonding in that selective area.

Figure 2. Boron Nitride Stops Off In Between the Sheet Metals

Step 2: The laminated sheets are put into a mold and superplastic forming is used to shape the outside, pressure is applied by blowing air between the sheets as shown in figure 1.5, the boron nitride that stopped bonding before, now acts as a lubricant.

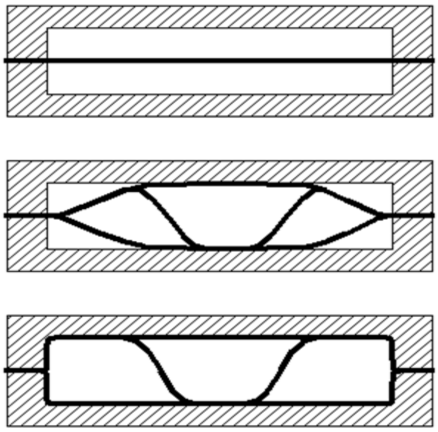

Figure 3. Representation of Superplastic Forming In the Unbounded Region by Blowing Air.

II. MATERIAL SELECTION

2.1 Aluminium Alloy AA5052

Aluminium AA5052 is used in experimentation. Aluminium has unbeatable strength to weight ratiogives it many uses in the transport industry. Aluminium alloycontainsthe elements like copper, magnesium, manganese etc to pin dislocations in its structure to increase its strength.Aluminium alloys are usually classified either with respect to the fabrication processes, heat treated, and non-heat treated, or their chemical composition. AA5052 is a non-heat treatable alloy that is weldable. It is hardened by cold work. It has good forming characteristics and good corrosion resistance, including resistance to salt water.This alloy has relatively fair machineability. It is easier to machine in the hard temper than as annealed and the quality of finish is better if machined in the hard condition. Oil lubricants should be used for machining, except that very light cuts may be done dry.AA 5052 is readily formed at room temperature. Successive cold working decreases the formability.AL 5052 cannot be hardened by means of heat treatment. It does harden due to cold working.

2.2 Chemical Composition and Mechanical properties of AA5052 alloy

Table 1 gives the chemical composition of AA5052 alloy and Table 2 gives the mechanical properties of AA5052aluminium alloy.

Table 1. Chemical Composition of AA5052 Alloy

S.No	Material	Composition %
1	Aluminum	Balance
2	Chromium	0.15 - 0.35
3	Copper	0.1 max
4	Magnesium	2.2 - 2.8
5	Manganese	0.1 max
6	Remainder Each	0.05 max
7	Remainder Total	0.15 mx
8	Silicon + Iron	0.45 max

Table 2. Mechanical Properties of AA5052 Alloy

S.No	Properties	Values
1	Ultimate Tensile Strength	230 MPa
2	Tensile Yield Strength	195 MPa
3	Modulus of Elasticity	70-80 GPa
4	Poisson's Ratio	0.33
5	Melting Point	649^oC
6	Hardness, Vickers	60
7	Density	2.68 x 1000 kg/m^3
8	Thermal Conductivity	137 W/m-k

III. RESULTS AND DISCUSSION

Results from Uniaxial Hot Tensile Test

AA 5052 plate of cross section area (6mmx1mm) is subjected to uniaxial hot tensile test under 580◦C, 570◦C, 560◦C.

Figure 4. AA5052 (Uniaxial hot tensile test at 580◦C)

Figure 4 shows the elongation of the specimen at 580◦C, AA 5052 of 1mm thickness which has gauge length 6mm, cross sectional area 1mm and initial length being subjected to uniaxial hot tensile test is 12mm. The figure also shows the breaking region. Since, it has elongated beyond the necking region and crossed the ultimate tensile strength. The load varies gradually for the linear displacement of every 0.5mm and finally it was estimated that the elongation reached 16mm. And hence the percentage elongation is 133%, which indicates the principle of superplastcity.

The Load Vs Displacement, Stress Vs Strain rate and log stress Vs log strain rate graphs are shown in the figure 5, 6 and 7 respectively.

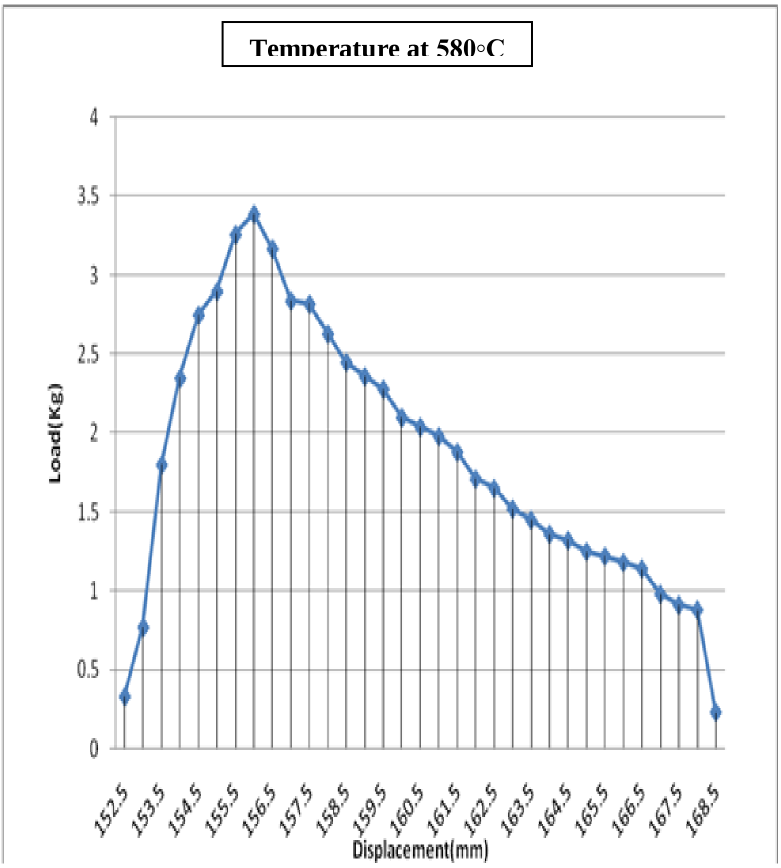

Figure 5. Load Vs Displacement at 580◦C

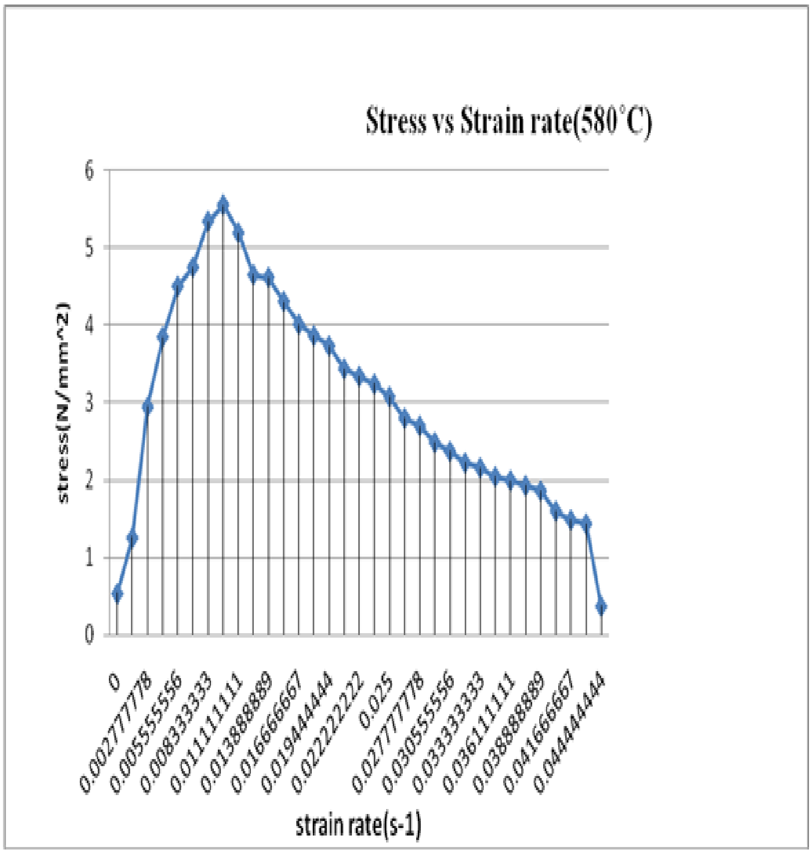

Figure 6. Stress Vs Strain rate at 580◦C

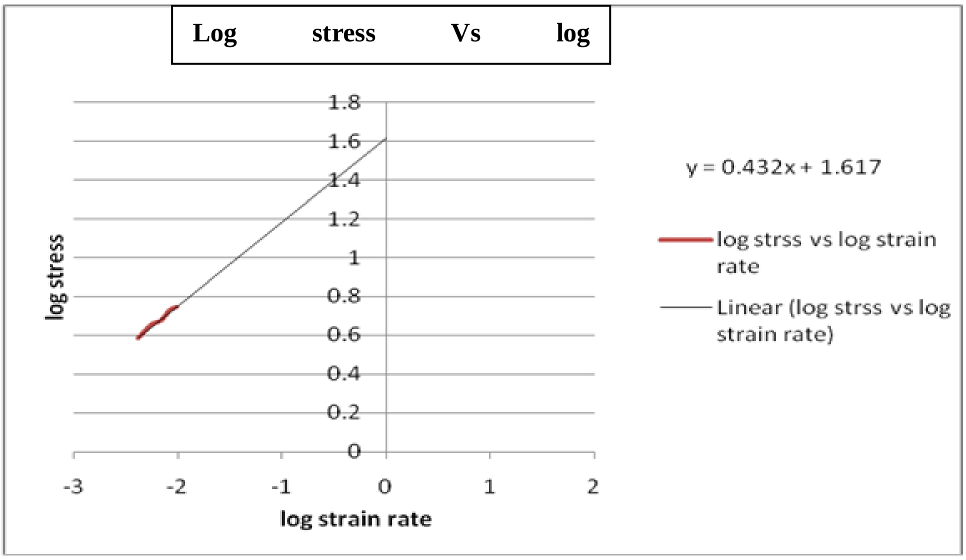

Figure 7. Log stress Vs Log strain rate (580◦C)

Figure 8 shows the elongation of the specimen at 570◦C and here the change in displacement was observed to be 18mm and here the percentage elongation is 150%. The Load Vs Displacement, Stress Vs Strain rate and log stress Vs log strain rate graphs are shown in the figure 9, 10 and 11 respectively.

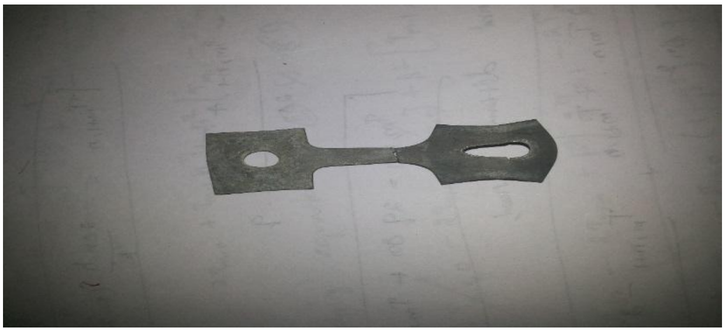

Figure 8. AA5052 (Uniaxial hot tensile test at 570◦C)

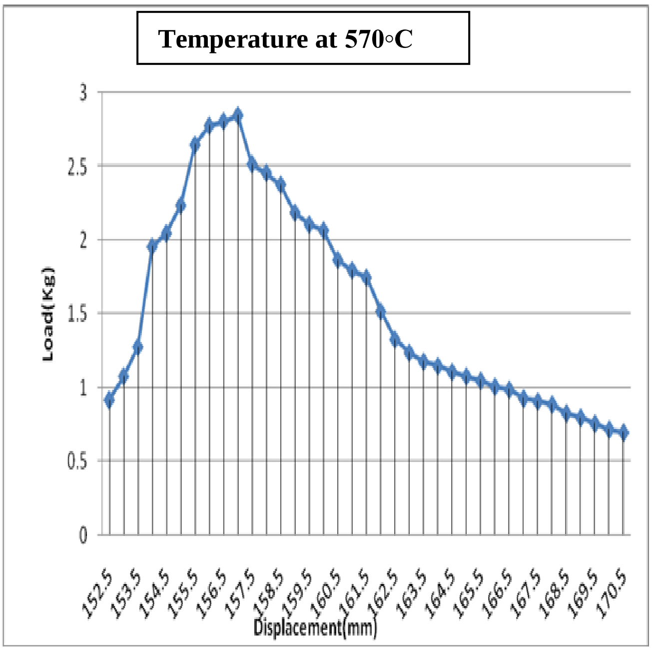

Figure 9. Load Vs Displacement at 570◦C

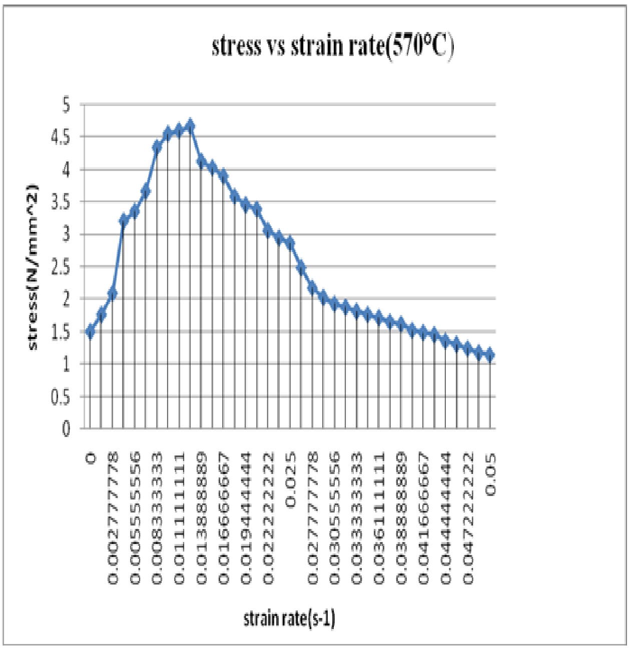

Figure 10. Stress Vs Strain rate at 570◦C

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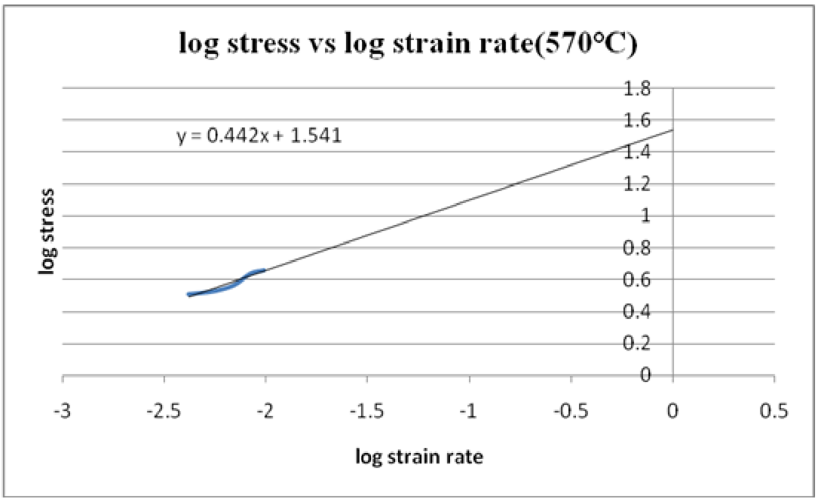

Figure 11. Log stress Vs Log strain rate (570◦C)

Figure 12 shows the elongation of the specimen at 560◦C and here the change in displacement was observed to be 24mm and here the percentage elongation is 200%. The Load Vs Displacement, Stress Vs Strain rate and log stress Vs log strain rate graphs are shown in the figure 13, 14 and 15 respectively.

Figure 12. AA5052 (Uniaxial hot tensile test at 560◦C)

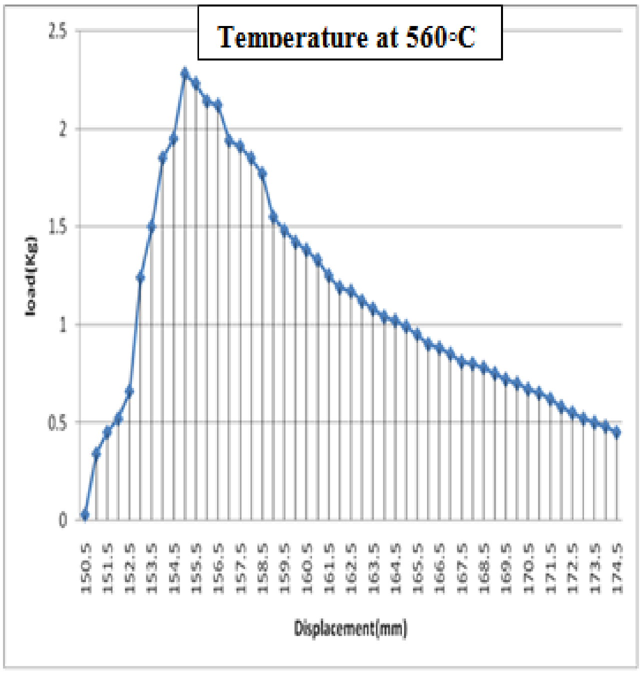

Figure 13. Load Vs Displacement at 560◦C

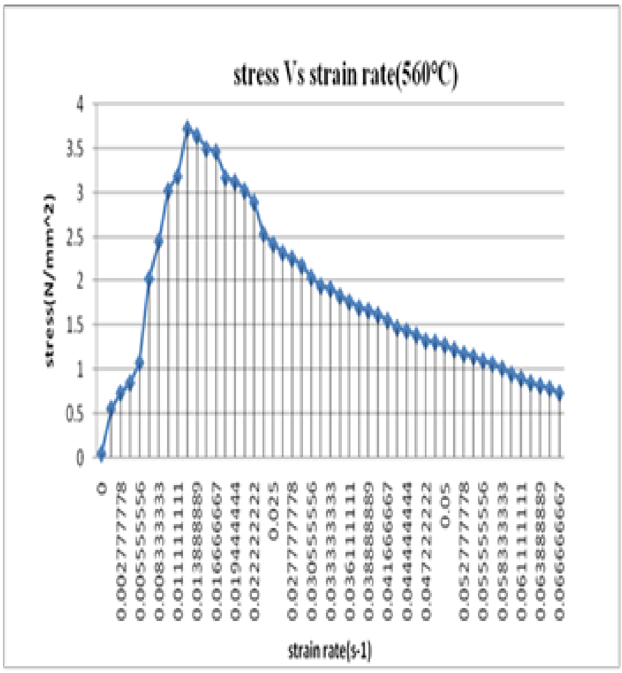

Figure 14. Stress Vs Strain rate at 560◦C

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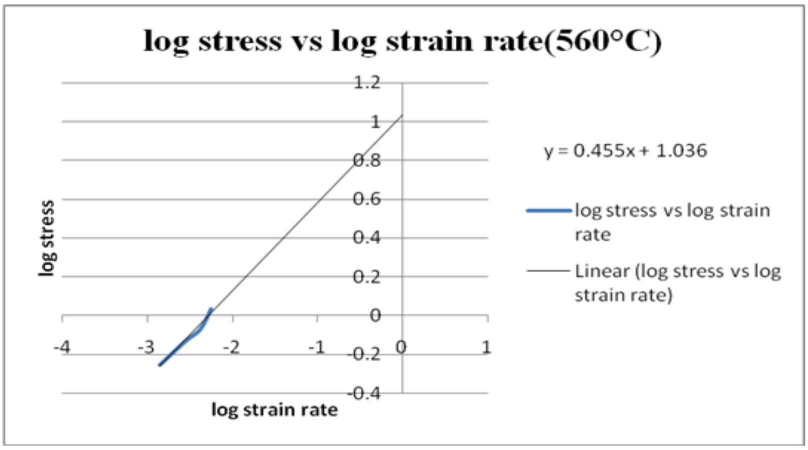

Figure 15. Log stress Vs Log strain rate (560◦C)

IV. CONCLUSION

The Diffusion bonding/Superplastic forming die setup has been designed and fabricated for the experimentation. AA 5052 alloy has been identified for the experimental work and it was procured. The chemical composition and microstructure of AA 5052 alloy was studied. DB/SPF experiments were conducted for varying conditions of temperature, pressure and time and finally super plastically formed diffusion bonded sheets with required honeycomb structures are obtained in which our objective of this project work has been attained successfully. Uniaxial hot tensile experiments are conducted to analyse the superplastic material parameters and its results were almost nearer to the biaxially formed specimens. I agreed with the experimental results and the intention of this project work was satisfied which increases the scope in the future that this type of DB/SPF honeycomb structures may use in the aerospace industries at low cost and economically useful.

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