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Research Article

Ultimate Tensile Strength of AL-6063 Thixoformed at Different Temperatures

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Abstract

The Thixoforming process is a new method for manufacturing complicated and net shape component through which high strength materials can be formed more easily. The high mechanical, geometric and surface quality of components produced through Thixoforming can justify the removal of additional production processes such as machining steps and the need for reinforcing inserts. In this study Al alloy 7075 and 6063 which has low extrude ability has been thixoformed by the extrusion process. In this research the effect of Thixoforming with one step, three step induction heating regimes for the temperature range (540 to 580°C) at same die material and same ram speed were investigated. It was found that Ultimate Strength of thixoforming specimen is stable for Al-6 Series alloys in comparison with initial Hot Extrusion ones under T6 tempering condition. The yield strength of Thixoextrusion specimen is comparable with initial hot extrusion ones for Al- (6 and 7) Series alloy under T6 tempering condition. During Thixoforming Process, the materials shows thixotropic behaviour as it is in semi-solid state (Containing 30-40 % liquid and 60-70 % solid). Due to this behaviour the extrusion of the material becomes easier.

Keywords: *Thixoforming process, Ultimate Tensile Strength, AL-6063 etc.*

Introduction

In general extrusion may be defined as a process by which a block of metal is reduced in cross-section by forcing it to flow through a die under high pressure.

Main advantage of extrusion is that high compressive stresses are set up in the billet due to its reaction with a container and die. These stresses are effective in reducing the cracking of materials during primary breakdown from the billet. Due to this the difficult metal can be extruded for e.g. stainless steel , Nickel based alloy and other high temperature materials. Extrusion can be used both for hot and cold working. Also bars, hollow tube and shape of irregular cross-section can be extruded. Extrusion could will be considered has adaption of closed die forging, the difference being that in a forging, the main body of the metal is the product and flash is cut away and discarded, in extrusion the flash is the product and the slug remaining in the die is not used. In simple it is defined as the process of shaping material, such as aluminum, by forcing it to flow through a shaped opening in a die. Extruded material emerges as an elongated piece with the same profile as the die opening. The most important factor to remember in the extrusion process is temperature. Temperature is most critical because it gives aluminum desired characteristics such as hardness and finish.

Thixoforming Process

Thixoforming process consists of an injection into the component die of material at semisolid state. In order to get the thixotropic behavior of the material (viscosity which decreases with increase of shear stress and time), its structure before injection has to be composed of solid globular dendrites dispersed in liquid eutectic fraction (rheocast structure). Therefore the material has to be undergone at a preliminary procedure for obtaining billets having the right structure suitable for thixoforming process. More methods are available for reaching this structure: electromagnetic stirring, mechanical stirring, passive stirring, grain refinement. Electromagnetic steering is the most used for aluminium alloys. During solidification, the steering breaks the tree dendrites which solidify with spheroidal shape.

Literature Review

(Xue Y. *et al.*) In this paper the fatigue model for aluminum alloy developed by McDowell *et al.* is modified to consider the structure–property relations for cyclic damage and fatigue life of a high strength

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aluminum alloy 7075-T651 for aircraft structural applications. The multistage model was developed as a physically-based framework to evaluate sensitivity of fatigue response to various micro structural features to support materials process design. In this work, the model is first generalized to evaluate both the high cycle fatigue (HCF) and low cycle fatigue (LCF) for multi-axial loading conditions.

(Chayong S. *et al.*) In this paper Heat treated condition (505MPa and 11% elongation) commercially extruded 7075 alloy has been used as a feedstock for thixoforming in order to investigate thixoformability of a high performance aluminium alloy. The microstructure in the semi-solid state consists of fine spheroidal solid grains surrounded by liquid. The results of thixoforming with one step, two-step and three-step induction heating regimes are presented. Typical defects in poorly thixoformed material (e.g. liquid segregation, impedance of flow by unrecrystallised grains and porosity) are shown alongside successfully thixoformed material (thixoforming temperature of between 615 and 618 ◦C with a three-step induction heating regime). The highest yield strength and elongation obtained for material thixoformed into a simple graphite die and heat treated to the T6 condition is 478MPa and 6.9% elongation. For thixoforming at 615 ◦C into a tool steel die heated to 250 ◦C, the highest yield strength and elongation obtained are 474MPa and 4.7% (ram velocity 2000 mm/s). These values (particularly for strength) are approaching those of 7075 in the wrought.

(Vaneetveld G. *et al.*) Thixoforging is a type of semi-solid metal processing at high solid fraction ($0.5<f_s<1$). 7075 aluminium alloy has been used as a feedstock for Thixoforging in order to investigate thixoformability of a high performance aluminium alloy at high solid fraction. Higher solid fraction of 7075 alloy is less sensitive to a drop in temperature, avoids metal splash at high speed, and allows laminar flow at high speed. Hot tool is used to slow down the solidification rate of the high solid fraction metal by decreasing thermal exchanges. To determine the best parameters to achieve maximum mechanical properties in Thixoforging of 7075 aluminum alloy, we need to consider the impact of some parameters such as tool temperature, shear rate. For this, we use extrusion tests with constant speed where these parameters are known. The result of this study is that each parameter has its level of impact on the Thixoforging: the temperature of the tool and the deformation rate shouldn't be high to avoid cracks. Thermal exchanges between the material flow and the tool have to be reduced to avoid high solidification rate.

6063 Aluminum Alloy: 6063 is an aluminum alloy, with magnesium and silicon as the alloying elements. The standard controlling its composition is maintained by The Aluminum Association. 6063 is mostly used in extruded shapes for architecture, particularly window frames, door frames, roofs, and sign frames.

6063 Aluminium alloy (mole %)

Si	0.4
Fe	0.1
Cu	0.0071
Mn	0.016
Mg	0.04
Cr	0.009
Ni	0.004
Zn	0.01
Al	98.8

Methodology and Procedure

1. Melting the raw material in melting furnace.
2. Cast the billet into hot top billet casting.
3. For RAP process billets must be heated to approximately700 ºC.
4. After a billet reaches the desired temperature, it is transferred to the loader where a thin film of smut or lubricant is added to the billet and to the ram. The smut acts as a parting agent (lubricant) which keeps the two parts from sticking together.
5. The billet is transferred to the cradle.
6. The ram applies pressure to the dummy block which, in turn, pushes the billet until it is inside the container.
7. Under pressure the billet is crushed against the die, becoming shorter and wider until it has full contact with the container walls. While the aluminium is pushed through the die, liquid nitrogen flows around some sections of the die to cool it. This increases the life of the die and creates an inert atmosphere which keeps oxides from forming on the shape being extruded. In some cases nitrogen gas is used in place of liquid nitrogen. Nitrogen gas does not cool the die but does create an inert atmosphere.
8. As a result of the pressure added to the billet, the soft but solid metal begins to squeeze through the die opening and it is also called extrusion
9. As an extrusion exits the press, the temperature is taken with a True Temperature Technology (3T) instrument mounted on the press platen. The 3T records exit temperature of the aluminium extrusion. The main purpose of knowing the

temperature is to maintain maximum press speeds.

10. The target exit temperature for an extrusion is dependent upon the alloy. For example, the target exit temperature for the alloys 6063, 6463, 6063A, and 6101 is 930° F (minimum). The target exit temperature for the alloys 6005, and 6061 is 950° F (minimum).
11. Extrusions are pushed out of the die to the lead out table and the puller, which guides metal down the run-out table during extrusion. While being pulled, the extrusion is cooled by a series of fans along the entire length of the run-out and cooling table and sometime also cooled by water. (Note: Alloy 6061 is water quenched as well as air quenched.)
12. Not all of the billet can be used. The remainder (butt) contains oxides from the billet skin. The butt is sheared off and discarded while another billet is loaded and welded to a previously loaded billet and the extrusion process continues.
13. When the extrusion reaches a desired length, the extrusion is cut with a profile saw or a shear.
14. Metal is transferred (via belt or walking beams systems) from the run-out table to the cooling table.
15. After the aluminium has cooled and moved along the cooling table, it is then moved to the stretcher. Stretching straightens the extrusions and performs 'work hardening' (molecular realignment which gives aluminium increased hardness and improved strength).
16. The next step is sawing. After extrusions have been stretched they are transferred to a saw table and cut to specific lengths. The cutting tolerance on saws is 1/8 inch or greater, depending on saw length.
17. After the parts have been cut, they are loaded on a transportation device and moved into age ovens for aging process. Heat-treating or artificial aging hardened the metal by speeding the aging process in a controlled temperature environment for a set amount of time.
18. After the aging operation the next important thing is studies its different mechanical properties which includes strength , hardness etc. of material
19. **Output Parameters:** The output parameters define the properties and behavior of the material formed.

Result and Analysis of UTS

In order to find the mechanical properties of the extruded material, Ultimate Tensile Stress (UTS) was done in order to find tensile strength, proof strength, upper yield and lower yield strength, elongation and percentage reduction of area.

Analysis of UTS

Tensile Test

The tensile test is used for finding UTS which is done by subjecting a test piece to a continually increase tensile strain. The tensile testing machine should be verified in accordance with IS 1828-1, and should be Class 1 or better. It should possess sufficient force capacity to break the test piece.

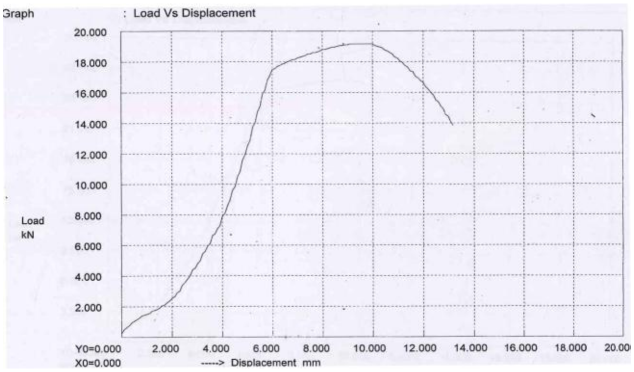
Preparation of test piece

The test piece should be prepared in such a way that there is no change in its tensile properties due to heat or cold working.

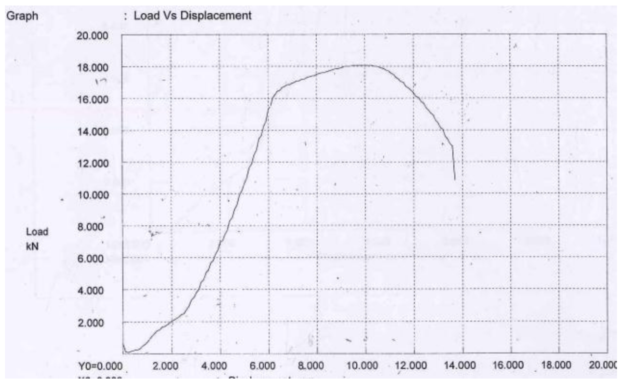
Test temperature

The test should be carried out at a temperature between 10 °C and 35 °

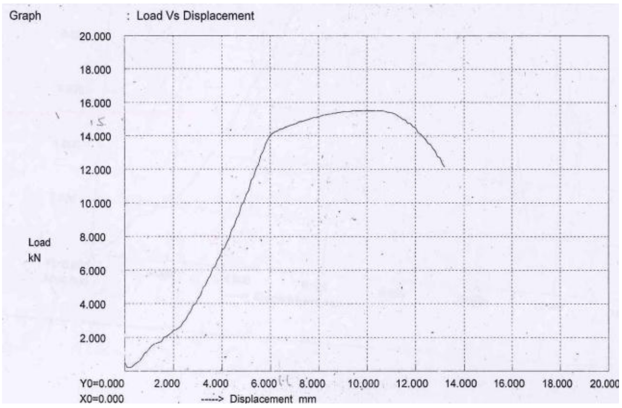
Trial No.	Alloy	Temperature (ºC)	Ultimate Stress (N/mm2)	Proof Stress (N/mm²)	Elongation %	Reduction Area %
1	6063	545°C	197	180.8	13.6	57.75
2	6063	545°C	230	214	14.6	57.75
3	6063	545°C	241	194	18.6	66.36
4	6063	545°C	244	226	14.8	58.23



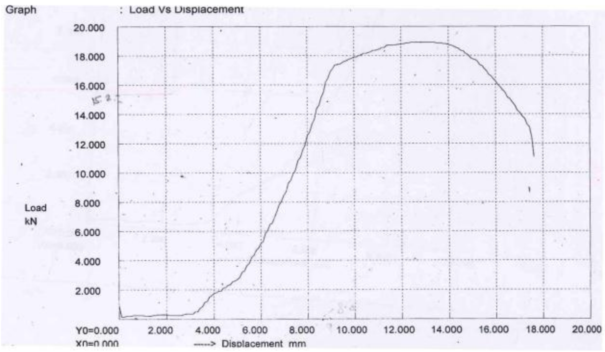
UTS of 6063 Al alloy at 545ºC [Trail 1]



UTS of 6063 Al alloy at 545ºC [Trail 2]



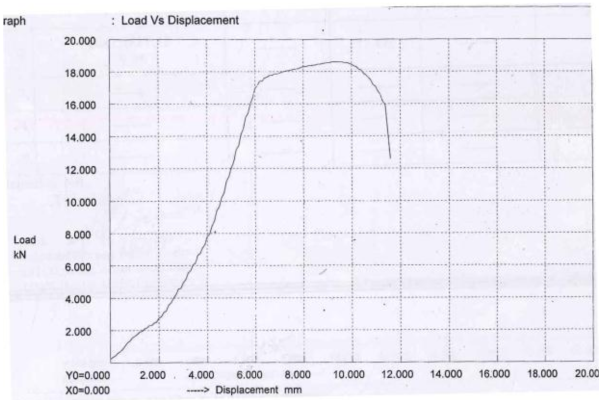
UTS of 6063 Al alloy at 545ºC [Trail 3]



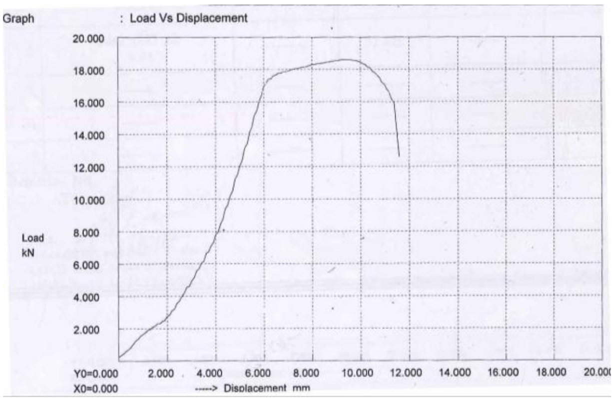
UTS of 6063 Al alloy at 545ºC [Trail 4]

Tensile test of 6063 at temperature 560°C

Trial No.	Alloy	Temperature (ºC)	Ultimate Stress (N/mm²)	Proof Stress (N/mm²)	Elongation %	Reduction Area %
1	6063	560°C	235	203	16	56
2	6063	560°C	251	230	14	39.16
3	6063	560°C	249	226	18	51
4	6063	560°C	260	206	12.2	49



UTS of 6063 Al alloy at 560ºC [Trail 1]



UTS of 6063 Al alloy at 560ºC [Trail 3]

Conclusions

Following conclusions has been generated in the present study:

Ultimate Strength of thixoforming specimen is stable for Al-6 Series alloys in comparison with Simple Extrusion.

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