EXPLORE iJET International Journal of Engineering & Technology CENTRE OF PROFESSIONAL RESEARCH PUBLICATIONS ISSN 2049-3444

International Journal of Engineering and Technology Volume 2 No. 9, September, 2012

Dynamic Crystallization: An Influence on Degree of Prior Deformation and Mechanical Strength of 6063 Aluminum Alloy

Gbenebor, O.P, Aasa S.A
Department of Mechanical Engineering, Covenant University, PMB 1023 Canaanland,
Sango-Otta, Ogun State Nigeria.

ABSTRACT

This research is aimed at investigating the influence dynamic solidification of melts on degree of mechanical deformation and mechanical strength of 6063 aluminum alloy. Cylindrical samples of 14mm diameter and 140mm long were die cast following two techniques – vibration and static. Prior deformation via forging was imposed on each solidified sample to achieve 7%, 14%, 21% and 28% thickness reductions respectively for each casting technique. Average deformation load, average hammer velocities and the average energy absorbed were recorded. Tensile properties of each sample were studied via the use of Monsanto tensometer. Mechanical agitation of mould and its content increased the machinability of the alloy even at higer pre deformation. This was justified by the failure of the 28% reduction sample cast on static floor during machining to a tensile piece. The energy absorbed during deformation influences the tensile strength of the material. This increases with increase in percentage deformation except for 28% reduction whose magnitude was lower than that subjected to 21% reduction; vibrated samples possessed superior properties. From results obtained, vibrating a sample and subjecting to 21% pre-deformation possessed the best tensile strength.

Key words: *Prior deformation, forging, dies casting, energy absorbed, vibration and static processes.*

1. INTRODUCTION

The 6*xxx* alloys are heat treatable and possess moderately high strength with excellent corrosion resistance. An outstanding feature displayed by these groups of alloys is their great formability, which enhances the possibility of forming complex shaped products in diverse architectural forms. These products are designed in such a way that they would be capacitated to efficiently carry the maximum tensile and compressive stresses. This feature is a particularly important advantage for structural members where stiffness criticality is important [1-2].Metal components are mechanically formed in other to have higher strength, better corrosion and wear resistance. Forging, being a metal working process, entails deforming metals plastically to desired shapes and sizes via a compressive force. The process has been employed to refine coarse and columnar grains, hence, increasing their yield and tensile strengths; impurities (in the form of inclusions) are broken up to obtain structural homogeneity by enhancing uniformity of such inclusions throughout the metal [3].

Solution treatment has been devised to improve the strength of extruded 6063 aluminum alloy. Here, treatment temperature and holding time were observed to have decisive effects on the strengthening capacity of the alloy. Aged alloys pocessed greater strengths than as-cast alloys[4]. Mechanical mould vibration has been used in recent times to refine metal grains . A fine microstructure is associated with high solidification rates which could affect mechanical properties. For instance, best values of UTS and elongation to fracture are obtained for small compact grains .The increase in mechanical performance (improved fracture strain) of cast A350 aluminum alloy for instance, is attributed to the fact that the mould, in which the melt was poured was subjected to vibration of high ampliteue to enhance dynamic solidification of melts and a non-dendritic structure was formed[5-6] . In a study to decipher the efficacy of prior deformation on 5052 alloy, different cold rolling reductions were imparted on it. Severe dislocation introduced by prior deformation was discovered to be a factor that enhanced the crack propagation resistance and reduced crack propagation rate [7]. Asides the single application of mechanical working, solution heat treatment and grain refinment enhancement during solidification of melts, the combined effects of two of these techniques : grain- refining a melt and further subjection to mechanical working as this work is concerned, needs to be studied.

2. EXPERIMENTAL PROCEDURE

Aluminum alloy of Al – Mg – Si type was cast in a pre heated steel mould. This was done on two different surfaces : a static (on a bare floor) and a vibrating surface (with the use of a vibrator). Heating the ingot to 663^{o}C, casts on the static surface was achieved by pouring the stirred molten charge in the cylindrical mould cavity of the die which was placed on a cemented floor. As regards the vibrating surface, the melt was poured into the die cavity placed on a vibrator operating at 0.5Hz. After twenty seconds, the die with its content were made to cool to ambient temperature. The cast samples were ejected from the die after solidification by unlocking the mould and for each casting a 40mm diameter and 140mm long cylindrical sample was achieved. Four castings, one for each reduction via deformation were carried out on both static and vibrating floors respectively.

Hammer forging was carried out to reduce each sample thickness mechanically by 7%, 14%, 21% and 28% using a 6kN hammer. A lever on the machine was lifted to enable the hammer, which was 23cm from the anvil surface , apply compressive loads (kN) on each specimen. Successive loads applied to achieve the desired thickness reductions waere read on the machine and the average values were taken. Each forged sample was machined to a tensile piece whose dimension is shown in Figure 1. Tensile test was carried out on Monsanto tensometer. Each test piece was positioned in between the chucks and a gradual increase in load was applied until the test piece finally fractured.The machine was designed in such a way that an autographic recorder, coupled with a pricker, were attatched to it whicch plotted the variation of tensile loads with corresponding extension.

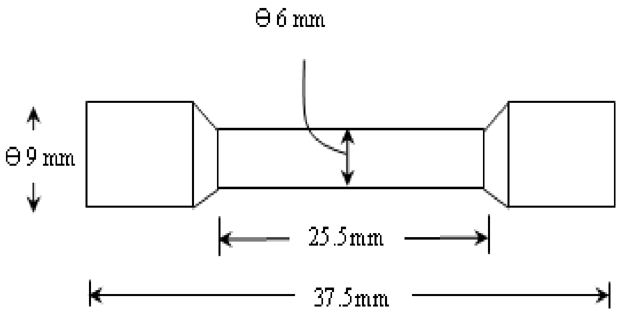

Figure 1. Tensile piced geometry

3. RESULTS AND DISCUSSION

3.1 Average Deformation Load and Velocity

Curves for calculated average deformation load with varying percentage reductions shown in Figure 2 elaborate the discrepancies in deformation loads for each casting technique. Vibrating melts during solidification engendered deformation loads of higher magnitude (up to 21% reduction) as compared to when melts were allowed to solidify under undisturbed conditions. Knowing the average load and the height between the hammer and the sample surface for each reduction, the average velocity V was derived using Newton's laws (equation 1) to obtain relationships as shown in Figure 3.

$$V = P \text{ x} \left(\sqrt{\frac{2h}{g}}\right) \text{ x } \frac{1}{m} \qquad (1)$$

V is the average hammer speed, P, the average deformation load, h, the distance between hammer and the sample surface at each stroke, m, the hammer mass and g , the acceleration due to gravity. Both curves (for average load and velocity) are of the same pattern which implies that greater velocity was required by the hammer in other to impart a heavier load.

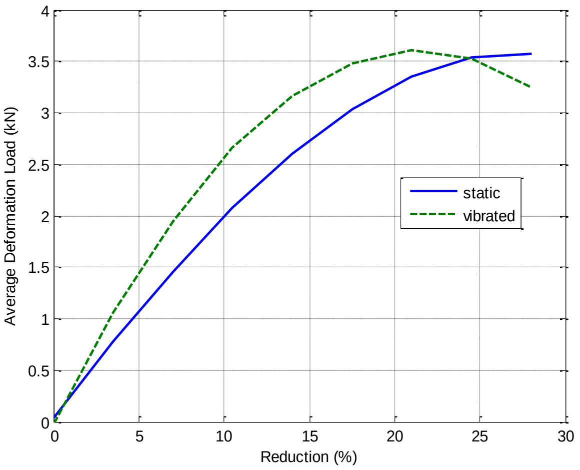

Figure 2: Variation of average load with percentage reduction

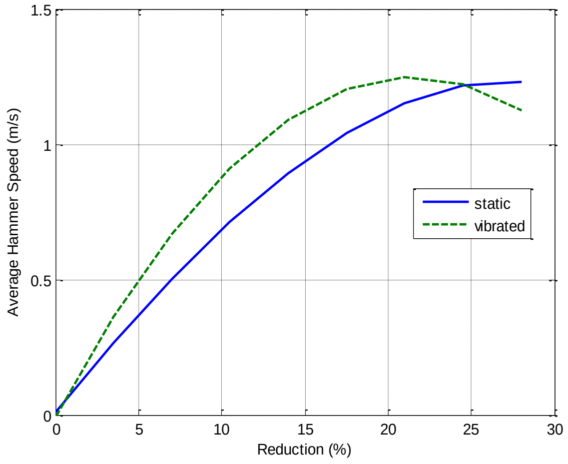

Figure 3. Variation of Average Velocity with Percentage Reduction

4. EFFECTS OF ENERGY ABSORBED DURING DEFORMATION

The average energy absorbed during deformation for each percentage reduction was calculated by using equation expressed [8]

$$E = \frac{1}{2}mV^2 + W_y \qquad (2)$$

Where m is the mass of the hammer, V, the average velocity and Wy is the additional work done by the hammer weight as it acted vertically downwards, deforming the sample. Figure 4 explains that for each sample, more energy was absorbed as deformation became more severe. More energy is required for the deformation on vibrated samples except at 28% reduction, where the reverse was the case.

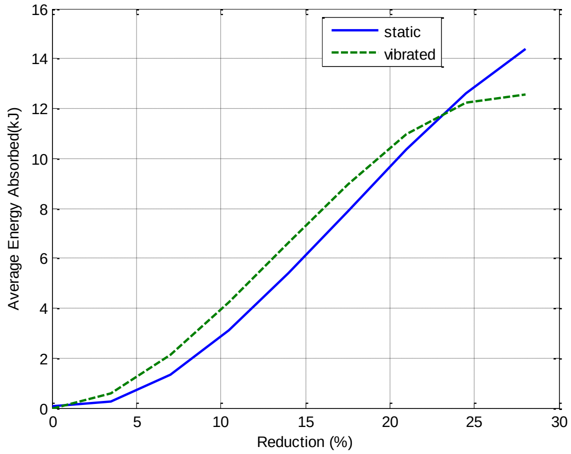

Figure 4.Variation of average absorbed energy with percentage reduction

3.3 Tensie Test Results

Figure 5 shows the engineering stress-strain curves for samples cast on static floor and pre deformed to specified reductions. Results show that each sample deformed plastically to different degrees before fracture. Sample subjected to 21% reduction by forging showed the most superior strength and response to deformation having attained maximum stress and strain values of 185MPa and 1.99 respectively. Tensile result for the 28% reduction sample could not be measured because of its excessive brittleness as it broke during machining to tensile piece.The curves for vibrated floor casting as shown in Figure6 reveals that successive increase in thickness reduction increases tensile strengths of pre- deformed samples with the exception for a 28% reduction material, whose tensile strength is lower than that of 21%. Ductility, which is a function of sample strain, is mostly exhibited by the 28% reduction sample, followed by that pre- deformed by 21% thickness reduction Comparing results obtained from these two casting processes, and considering each thickness reduction, ductility and tensile strength of vibrated samples are of better magnitudes.

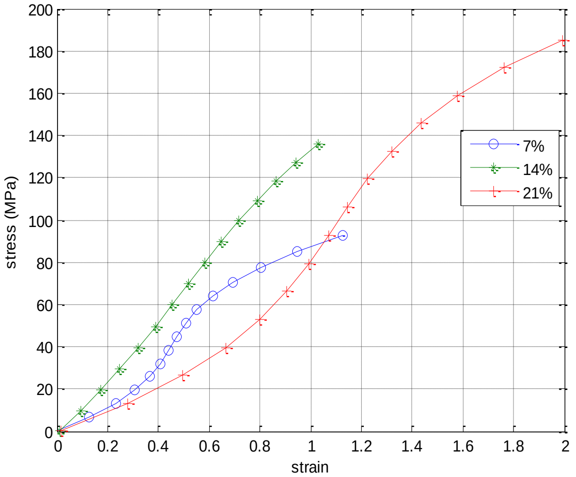

Figure 5: Variation of stress with strain for samples cast on static floor

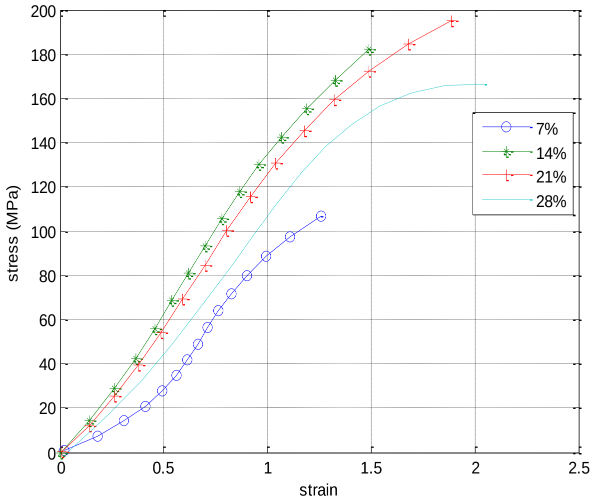

Figure 5.Variation of stress with strain for samples cast on vibrated floor

5. CONCLUSION

This study has shown that dynamic crystallization of melt during casting improves machinability. This is evident for the sample cast on static floor and subjected to 28% deformation which fractured when machining to tensile test piece. This could be attributed to the limited or unfavorable sizes of Mg_2Si chip forming particles. Greater energy is absorbed as deformation becomes more severe for both processes with the vibrated samples having higher magnitudes. An exception is discovered in the 28% reduced sample, where the reverse occurred. Deformation load has an effect on the tensile and fracture strengths of the alloy. Though pre deforming an alloy to a degree of deformation increases mechanical strength, inducing dynamic crystallization via mechanical vibration improves strength, formability and machinability.

From results obtained, vibrating a sample and subjecting to 21% pre deformation possessed the best tensile strength, though lower energy (compared to 28% reduction) is required to achieve this.

REFERENCES

[1] Introduction to aluminum alloys and tempers, http://www.asminternational.org/pdf/spotlights/6180_pg87-118_web.pdf

[2] G. Mrówka-Nowotnik, J. Sieniawski and M. Wierzbiñska. Intermetallic phase particles in 6082 aluminum alloy. *Archives of Materials Science and Engineering*, No.2, Vol.28, pages:69-76, 2007.

[3] P.C. Sharma, A text book of production technology. *S.Chand and Company Limited* pages: 213, 234-236, 2007.

[4] D.E.Esezobor and S. O. Adeosun, Improvement on the strength of 6063 aluminum alloy by means of solution

heat treatment. *Materials Processing Challenges for the Aerospace Industry*, pages: 245-255, 2006.

[5] J. Deshpande, The effects of mold vibration on the performance and characteristics of aluminum alloys. *Research Programs. Department of Manufacturing Engineering, Worcester Polytechnic Institute*, pages:1-113, 2006.

[6] P.Appendino, G. Crivellone, C.Mus and S.Spriano, Dynamic solidification of sand-cast aluminum alloys. *Metallurgical Science and Technology*, ppages:7-32.

[7] K.Tsung Huang, T.Sheng Lui and L.Hui Chen, Effect of prior deformation on tensile and vibration fracture resistance of friction stirred 5052 alloy. Materials Transactions, no10, vol47, pages: 2504-2511, 2006.

[8] Introduction to impact loading, www.PDHcenter.com .