

CHARACTERIZATION OF CAST ALUMINIUM 3003 UNIAXIAL FORGED ALLOYS

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Abstract - Aluminium 3003 alloys are light weight material (density of about 2.7g/cc), having good malleability and formability, high corrosion resistance and high electrical and thermal conductivity. However, in the engineering application pure aluminium and its alloys still have some problems such as relatively low strength, unstable mechanical properties. The microstructure of the alloy can be modified and mechanical properties can be improved by alloying and cold working in this regards. In the present paper, the aluminium 3003 alloy with increased weight fraction of Si (from 0.6 to 1.5%) and Zn (from 0.1 to 0.25%) was produced by stir cast technique and the effect of reinforced ratios on the forgeability was examined. The test results show that the increment in weight fraction of reinforcement particles in the alloy produced better mechanical property like greater ultimate tensile strength and increased hardness. It will also result in the change of microstructure of the aluminium alloy. The forgeability of the cast alloy was also varied with the change in thickness of the casting. This practical research analysis and test results on the forgeability will provide useful guidelines to the present day manufacturing engineers.

Key Words: Aluminium 3003, Hardness Test, Optical Microscope, Uniaxial Forging

1. INTRODUCTION

Aluminium offers a wide range of properties that can be engineered precisely to the demands of specific applications through the choice of alloy, temper, and fabrication process[1]. Due to the need for aluminium heat transfer alloys, aluminium and aluminium alloy are gaining huge industrial significance because of their outstanding combination of mechanical, physical and tribological properties over the base alloys. These properties include high specific strength, high wear and seizure resistance, high stiffness, better high temperature strength, controlled thermal expansion coefficient and improved damping capacity[2]. The commercial aluminium 3003 alloy (Al-Mn series) is the material that is preferred for applications in heat-exchangers in the automotive industry, as material for tubes and fins after subsequent brazing. This alloy type is generally not heat treatable, and the primary strengthening mechanism is solid solution strengthening. The alloying elements may be classified as major and minor elements, microstructure modifiers or impurities; however the impurity elements in some alloys could be major elements in others[3]. In this paper the influences of alloying Such as Major elements (Si, Mg), Minor elements (Cu, Fe, Zn) on

microstructures and mechanical properties of aluminium alloys are reviewed. Effect of copper (1, 3, 4.5 and 6%) and silicon (0, 5, 7, 12 and 18%) content on mechanical properties of Al-Cu-Si-Mg alloys was investigated which indicates an increase in tensile strength and hardness due to suppressed precipitation hardening and elongation with increasing copper content[4]. Si particles in the microstructure, acting as stress initiating sites, could be modified by employing proper amounts of Sr, altering their shape from needle-like into fibrous morphology; the outcome is a more ductile material. The strength of components is furthermore governed by proper additions of Cu and Mg, which will be done at the expense of ductility[5]. One approach to improve the specific properties of an alloy is to add specific amount of different alloying elements, allowing for solid solution strengthening. In this work, the effects of increasing the weight percentage of Si and Zn in 3003 Al alloy are studied. The test results show that the increment in weight fraction of reinforcement particles in the alloy produced better mechanical property like greater ultimate tensile strength and increased hardness. It will also result in the change of microstructure of the aluminium alloys[6].

This study aims to impart knowledge and recommendations on selecting Al3003 alloys for attaining high strength components and casting qualities.

2. EXPERIMENTAL PROCEDURE

2.1 Material Selection

The alloys used in this study were mainly, stir cast Al 3003 with varying amounts of Si and Zn contents. The compositions in weight percent are shown in Table 1. The primary alloying elements are magnesium and silicon. The alloy used as cast slabs of 16 mm in thickness and 120mmx120mm in length and breadth.

Table -1: Typical Composition of Aluminium Alloy 3003

S. No.	Components	Standard (weight %)	Changed (weight %)
1.	Aluminium	97.15	96.1
2.	Copper	0.15	0.15
3.	Manganese	1.3	1.3

4.	Iron	0.7	0.7
5.	Silicon	0.6	1.5
6.	Zinc	0.1	0.25

The slab of the aluminium alloy is cut into 5 pieces with the dimensions of 30mmx60mm and forged the above by using the uniaxial cold forging at room temperature (25°C) process with different percentages.



Fig -1: Sample of Aluminium Alloy Prepared by Casting and Cutting

2.2 Forging

Forging is a manufacturing process involving the shaping of metal using localized compressive forces. The blows are delivered with a hammer (often a power hammer) or a die.



Fig -2: Friction Screw Forging Press Machine



Fig -3: Forging of Sample on the Forging Machine

Forging is done under different reduction ratios and their percentage increases by five percent till crack appears.

Table -2: Forging Parameter

Sample	C	D	A	B	E
Reduction ratio/thickness	0%	10%	15%	20%	25%
Initial (mm)	17.6	17.6	17.6	17.6	17.6
Final(mm)	17.6	15.84	14.96	14.08	13.2



Fig -4: Forged Sample with Different Reduction Ratios

2.3 Hardness Test

Micro hardness was calculated by using Micro hardness Vickers's testing machine. A precision diamond indenter is impressed on material at a load of 30 kgf for 15 seconds loading time, and 70 m/s loading speed [7]. Five indentations were done at multiple locations to ensure repeatability of results. In order to avoid the segregation effect of the particles, five readings were taken for each sample and the repeatability value.

2.4 Characterization of Stir Cast and Forged Ingots

For microstructure characterization of the cast ingots, grain size measurements were performed on metallographically prepared samples, (15mmx20 mm) taken in the regions from the surface to the centre of these as-cast ingots, using a polarized light microscopy and image analysis program. The average grain sizes were determined by counting the number of grain boundary intersections per unit length of a circle of known circumference.

3. RESULTS AND DISCUSSION

3.1 Hardness

The Vickers hardness test is performed on the chosen samples for different reduction ratio at different points. Then the mean is taken for the Vickers hardness number and the graph is plotted. The graph shows the variation in hardness to the samples of different reduction ratio. Thus cold forging of aluminium 3003 alloy results in increase in hardness of the material. The results that were obtained after performing the hardness tests on the given samples are shown by the following chart.

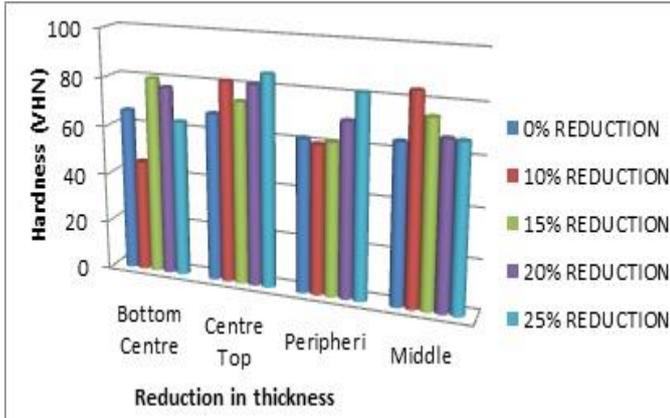


Chart -1: Change in Vickers Hardness at Different Reduction Ratio

Chart 1 shows the change in Vickers hardness at different reduction ratios. The alloy tends to increase in hardness after the subsequent reductions under forging operations.

Increase in hardness can be seen in Table 3.

Table -3: Hardness Reading

S. No.	Sample	10%	15%	20%	25%
1.	66.3	45.4	80.2	77.0	63.5
2.	68.1	81.6	74	81.2	85.7
3.	61.9	60.2	61.6	70.4	81.6
4.	64.5	84.1	74.8	67.4	67.4
Mean	65.12	67.82	72.65	74	74.55

The table shows that when the hardness test is performed on the original sample the hardness comes out to be 65.12VHN. When the reduction of 10% is made the hardness shows a considerable rise and reaches to 67.82VHN. As the reduction ratio is increased further the hardness of the sample continue to increase. The hardness obtained at 25% reduction is the highest which is 74.55VHN. Wear of the test specimens was determined by weight loss. Tests were conducted at room temperature.

3.2 Microstructure of Stir Cast and Forged Ingots

Sample of a cast alloy for metallographic examination were prepared by grinding through different size of grit papers followed by polishing. Then the samples were etched with the etchant i.e. Keller’s reagent (2.5 ml Nitric acid, 1.5 ml HCl, 1.0 ml HF, 95.0ml Water). The etched samples were dried by using electric drier and then the microstructure observed by using scanning electron microscope.

The microstructures of stir cast alloy before and after optimization are shown below:

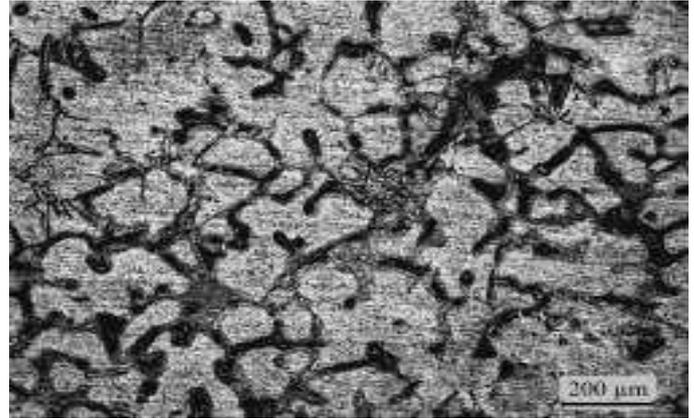


Fig -5: Standard Forged Sample at 10x Magnification

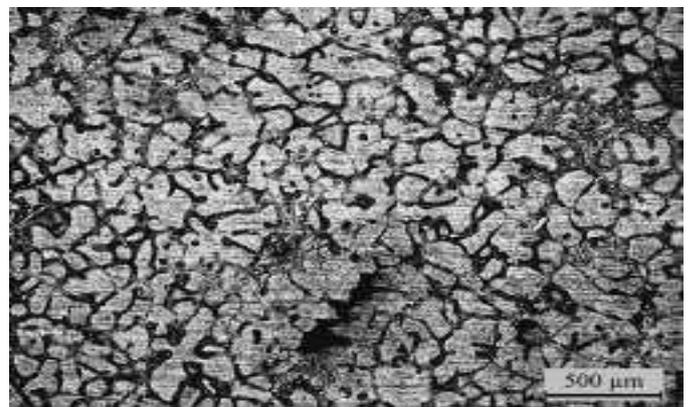


Fig -6: Standard Forged Sample at 5x Magnification

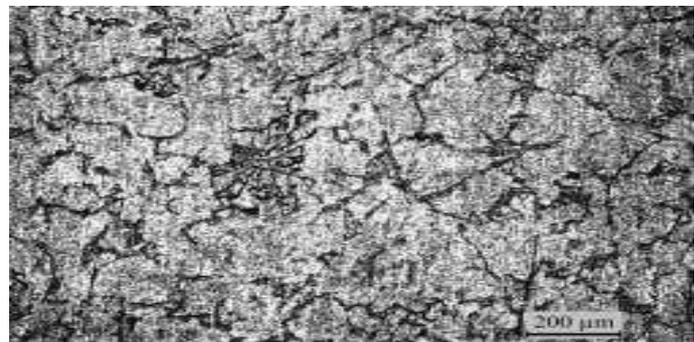


Fig -7: 10% Reduced Forged Sample at 10x Magnification

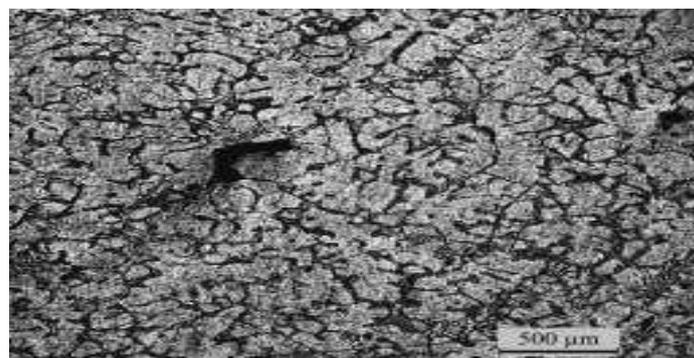


Fig -8: 10% Reduced Forged Sample at 5x Magnification

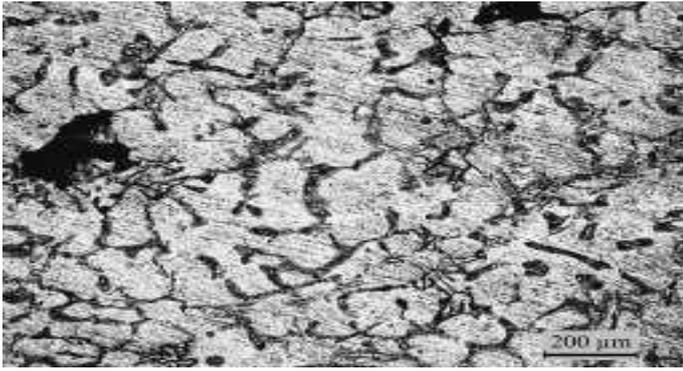


Fig -9: 15% Reduced Forged Sample at 10x Magnification

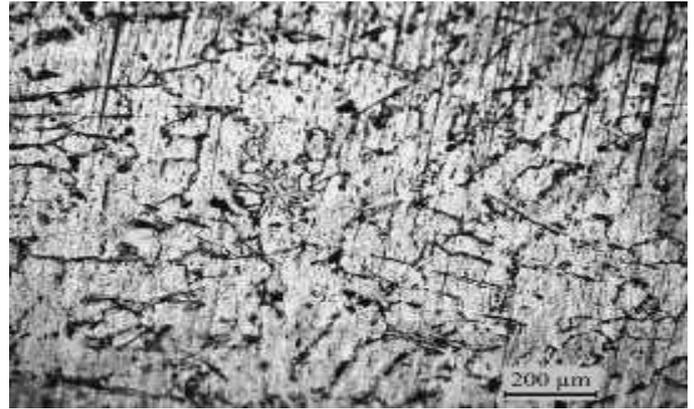


Fig -13: 25% Reduced Forged Sample at 10x Magnification

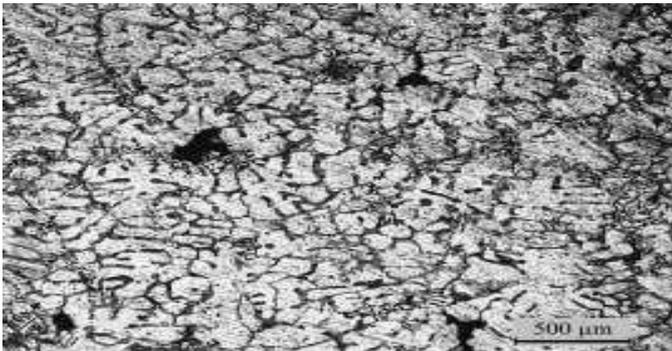


Fig -10: 15% Reduced Forged Sample at 5x Magnification

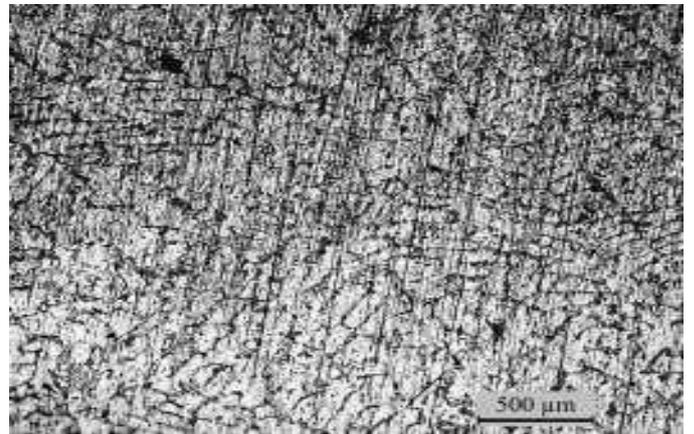


Fig -14: 25% Reduced Forged Sample at 5x Magnification

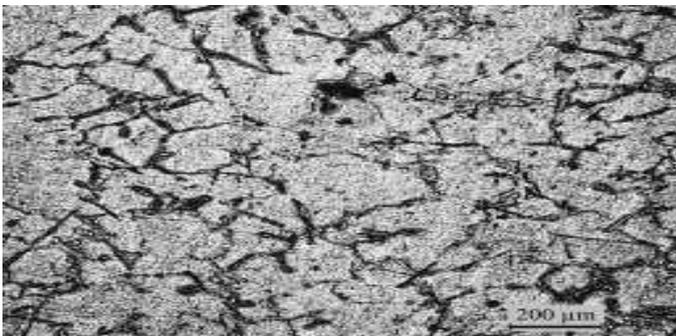


Fig -11: 20% Reduced Forged Sample at 10x Magnification

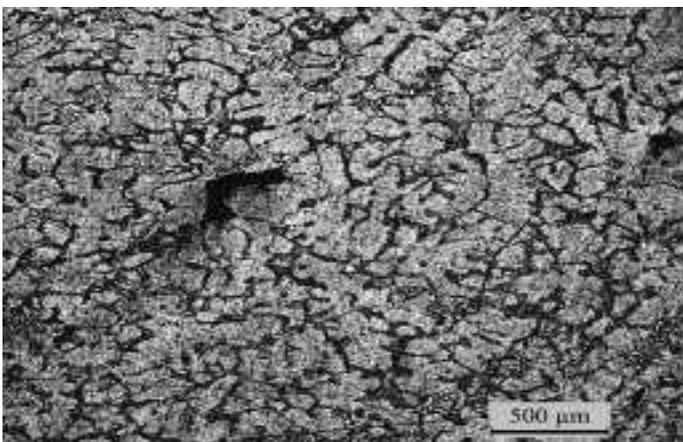


Fig -12: 20% Reduced Forged Sample at 5x Magnification

4. CONCLUSIONS

The present study shows the enhancement of mechanical properties due to microstructural evolution in cast Al3003 alloy after uniaxial forging. The results show that the uniaxial forging generally results in the increased strength and hardness of the alloy. It will also change the microstructure of the aluminium alloy.

- a) After forging with different reduction ratio, the grains were broken up to fine block of grains and the reduction ratio increases the grains broke into more fine blocks and uniformly distributed.
- b) The alloy tends to increase in hardness from 65.12VHN to 74.55 VHN after the subsequent reductions under forging operations. The increase in hardness is the result of the increasing reduction ratios.

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BIOGRAPHIES



My name is Prince Kumar Gupta and I have done my B. tech Mechanical Engineering from SRM Institute of Science & Technology, India. I have always been passionate about the recent trends in the engineering and been trying to bring the change using my knowledge and skills.



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