Research article

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Effect of heat treatment on proportion of duplex fiber texture of aluminium magnesium silicon alloy

Abstract

In the present study, an attempt has been made to understand the texture evolution of Aluminium alloy 6082–T6 after different aging heat treatment process. Effects of heat treatment in controlling the variation and domination of one fiber texture over the other in a duplex fiber texture have been observed. Texture studies were carried out with ND direction parallel to direction of extrusion. Solutionised and aged samples have shown the variations in volume fraction of <100> and <111> fibre due to effect of re–crystallization and precipitation. The presence of clusters of solutes and β″ precipitates alters the proportion of volume fraction of <100> and <111> duplex fibers. Peak aged samples showed significant strengthening of <100> fiber as compared to solutionised and aged samples.

Keywords: texture, aluminum alloy 6082, heat treatment, volume fraction of fibers

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Manoj Chopkar, Shailesh Tiwari
Department of Metallurgical Engineering, National Institute of Technology, India

Correspondence: Manoj Chopkar, Department of Metallurgical Engineering, National Institute of Technology, India, Email mchopkar.met@nitrr.ac.in

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Introduction

The strength–to–weight ratio offered by AA6XXX alloys and their enhanced mechanical properties have become crucial criteria for their use in light weight military vehicles, rockets, missiles, aircrafts, and cars, used for both defence and civil purpose.[1] Heat treatment changes the microstructure and mechanical properties of material and it also contributes to important effects on evolution of re–crystallization and deformation textures. The alloys AA6082–T6 is high strength Al–Mg–Si alloys that contain manganese to increase ductility and toughness.[2] Cuniberti et al.[3] have reported that, artificial aging of Al–Mg–Si alloy for 30min at 180°C after solution treatment resulted in a significant increase in yield strength and loss of ductility, due to the rapid precipitation of the β″ intermediate phase.[3] The β″ precipitates have fine needle type morphology, with the major axis in the <100> directions of the aluminum matrix.[3] The β″ phase has a composition of Mg_5Si_6 and has monoclinic C–centred structure and is fully coherent in <100> direction.[4] The texture of an extruded face centred cubic material is of <100> and <111> duplex fibre texture parallel to the direction of extrusion.[5] The study of dependence of the proportion of <111> and <100> fibre on heat treatment by Demakov et al.[6] exhibited changes in volume fraction of fibres radially and with annealing temperature in copper wires.[6] Gerber et al.[7] have also shown the significant variation in proportion of cube texture in cold rolled copper above annealing temperature of 130°C.[7]

The deformation texture in FCC metals and alloys is strongly dependent on the stacking fault energy.[8] All Face centred cubic (FCC) material under axisymmetric deformation like wire drawing and extrusion produce duplex fiber texture of <111> and <100> parallel to the direction of drawing or extrusion. The proportion of volume fraction of <111> as compared to <100> varies depending on the mode of deformation (drawing or extrusion) and also on the stacking fault energy of the material.[9] Waryoba et al.[10] studied the effect of annealing temperature on the texture of OFHC copper wire. The strong <111> fiber first decreases with annealing temperature but then increases again.[10]

However, there is no literature available on effect of ageing on the duplex fiber texture of high stacking fault energy face centered cubic materials. Therefore, in the present study an attempt has been made to understand the texture evolution of Aluminium alloy 6082–T6 after different ageing process. This study can be utilized to control the pre–deformation initial texture of aluminum alloy 6082–T6.

Material and methodology

The Aluminum Alloy 6082–T6 in extruded form was procured and cylindrical samples were prepared with 10mm diameter and 5mm height. Table 1 shows the composition of the alloy. The AA6082–T6 was in the form of hot extruded bar of 25.4mm diameter and cylindrical samples were cut with axis parallel to the direction of extrusion. Texture studies were done on face normal to the direction of extrusion.

These samples were solutionised at 560°C for two hours and water quenched. Some of the solutionsed samples were aged at 170°C for four hours and some were aged at same temperature for 16 hours. Texture studies were done using Rigaku Ultima IV four circle goniometer diffractometer and analysis done using ResMat–TexTools. All texture studies were done with the ND direction parallel to the direction of extrusion.

Table 1 Chemical composition of AA 6082

Elements	Mg	Si	Cu	Fe	Mn	Cr	Al
Wt %	1.2	0.8	0.1	0.2	0.5	0.17	Bal

Results and discussion

The heat treatment of precipitation harden able AA6082 alloy affects the volume fraction of <111> and <100> duplex fibre through planarity of slip and recrystallization due to combined effect of stacking fault energy, deformation stage, ageing condition and precipitation state. An attempt has been made to explain the possible reasons for the variations of ratio of duplex fiber due to of heat treatment and presence of types of precipitates, in the following section.

The volume fraction of various fibers observed in extruded, solutionised and aged samples has been listed in Table 2. The same has been calculated using the Resmat–Textool.

Texture of the initial material

The texture of an extruded AA6082 is typical round extruded face centred cubic texture of <111> and <100> duplex fibre texture parallel to the direction of extrusion. It had strong <100> fiber with comparable <111> fiber (Figure 1). The volume fraction of <100> was 38.24% as compared to <111> at 31.57%. The maximum intensity was at 11.0. The {111} pole figure showed strong cube texture with maximum intensity of 8.1units (Figure 1). The contour lines in the IPF show the frequency with which various <uvw> directions in the crystal coincide with the normal direction which is the direction of the extrusion in current study. In FCC materials, axisymmetric deformation like extrusion has higher order of symmetry and produces <100> and <111> fiber texture. During deformation the plastic strain is accommodated by dislocation motion and by realignment of grains.

Table 2 Volume fraction (%) of 100, 110 and 111 fibers in all four samples

Volume fraction (%)	100 Fiber	111 Fiber	110 Fiber	Random fiber	100/111 Ratio
6082 EXTRUDED T6	38.24	31.37	8.9	21.29	1.211277
6082 SOLUTIONISED	28.72	29.72	11.38	30.2	0.966353
6082 AGE 4HR	25.15	28.23	11.38	35.24	0.890896
6082 AGE 16HR	36.24	28.83	10.21	24.7	1.257024

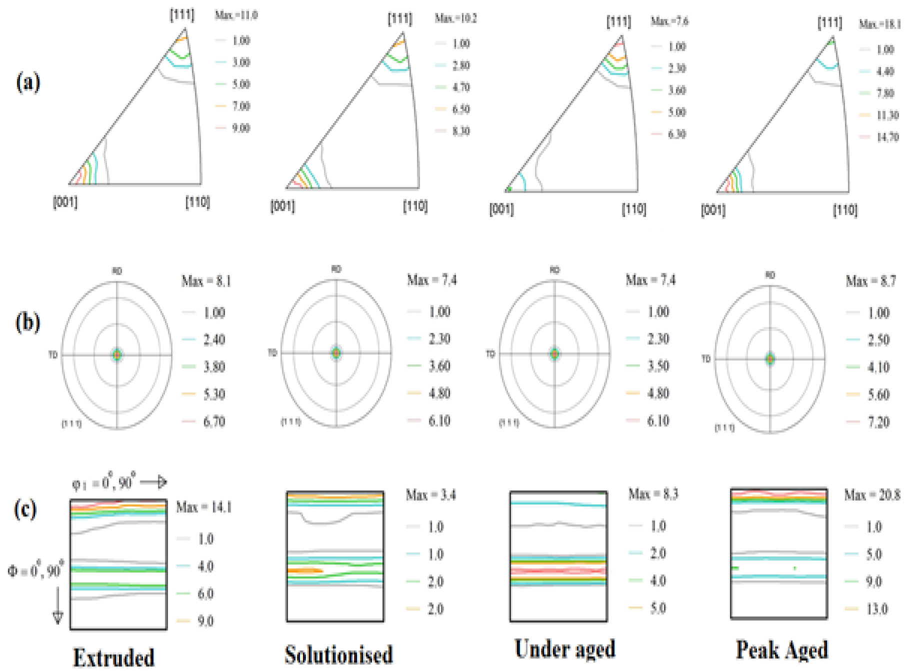

Figure 1 (a) ND-Inverse Pole Figure, (b) 111 Pole Figure and (c) ODF φ_2=45° section of extruded, Solutionised, 4hr aged and 16 hr aged AA6082.

Texture of solutionised sample

Samples were heated at a temperature of 560°C for two hours and water quenched. Immediately after quenching, solute atoms are randomly distributed in solid solution in the Aluminium matrix. The solutionised samples showed slight drop in the volume fraction of <111> fiber while the drop in <100> was significant. The volume fraction of <100> dropped from 38.24% to 28.72% whereas the <110> fiber fraction increased from 8.9% to 11.38% (Figure 2). The {111} pole figure showed strong cube texture with max intensity of 7.4 units.

Texture of aged samples

Solutionised samples were aged at 170°C for 4 hours and 16 hours to get variation in the extent of precipitation. The texture of the sample aged for 4 hours displayed a further reduction of fraction of <100> fiber from 28.72% to 25.15%. The volume fraction of <111> further dropped marginally to 28.23%. The {111} pole figure showed strong cube texture with 7.4 maximum intensity. The observed change may be due to the formation of individual clusters of Silicon and Magnesium and also clusters containing both of random sizes and shapes. These clusters do not favor any particular orientation hence no significant change in any orientation is observed.

The texture of the sample aged for 16 hours displayed a recovery of fraction of <100> fiber from 28.72% back to the range of the extruded texture i.e. at 36.24%. The volume fraction of <111> further dropped marginally to 28.83%. The {111} pole figure showed strong cube texture with 8.7 maximum intensity. The increase in the <100> fiber fraction is due to the increased volume of elongated β′′ precipitates with prolonged ageing. Similar observations of β′′ precipitates affecting the <100> fiber favorably during annealing has been made by Demakov et al.[6] & Wayroba et al.[10] The ultrathin and elongated

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β″ precipitated favor strengthening of <100> fiber as their axis is coherent to only 100 directions.[7]

The orientation distribution plot shows the variation of <100> fiber intensity at $\Phi=0^{\circ}$ and $\Phi_2=45°C$ (Figure 3). The intensity of the <100> fiber decreases marginally on solutionising and further on under ageing while it significantly increases manifold for 16 hours peak aged sample.

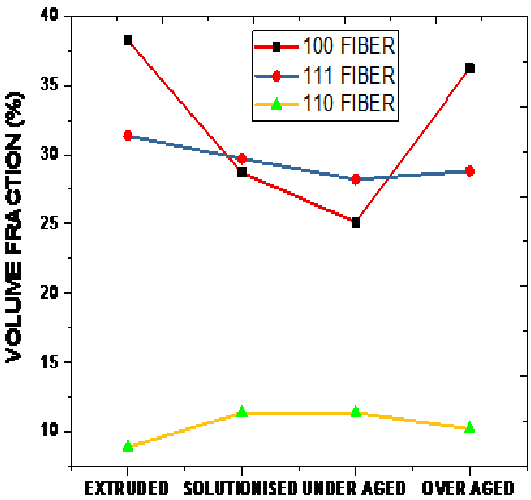

Figure 2 Volume fraction of <100>, <111> and <110> fibers for different heat treated AA6082.

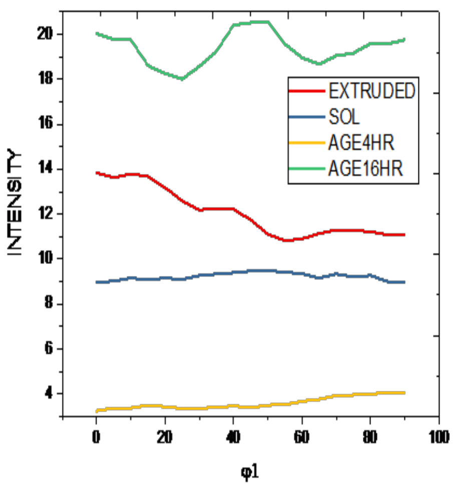

Figure 3 Intensity of <100> fiber at Φ=0o and Φ_2=45° for sample at all four conditions.

Conclusion

The volume fraction of <100> fiber of extruded AA6082 decreases significantly (24.89% of original fraction) on solutionising while the fraction of <111> reduces marginally (5.86%). This is due to secondary recrystallization/grain growth and dissolution of β″ Mg_5Si_6 precipitates which favor <111> fiber formation. On Ageing, initially the fraction of all fiber change marginally. On further ageing to 16 hours the fraction of <100> fiber increases significantly to 36.24% due to intensive β″ precipitation favoring only <100> fiber formation. The presence of β″ precipitates alters the proportion of volume fraction of <100> and <111> duplex fibers and can be utilized favorably in the evolution of deformation texture of materials by controlling the initial texture before deformation. <100> dominated over <111> for initial deformed sample and for sample aged for 16 hours, whereas <111> dominated marginally for solutionised and four hour aged sample. Heat treatment can be used to control the fraction and domination of one fiber texture over the other in a duplex fiber texture.

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Conflict of interest

The author declares no conflict of interest.

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