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DEVELOPMENT OF ULTRA FINE GRAIN STRUCTURE IN ALUMINIUM ALLOY BY ROLLING

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Abstract:* Efforts were constantly made to increase the strength related to the application either by alloying, coupling, forming and forging. Cryorolling is one more adding to this list, perhaps it lies in the domain of forging in the nano scale. This method is used to change the internal coarse grain structure of metals and alloys into ultrafine grained (UFG) materials to gain unpredictable strength in real for different application. Aluminium 2024 was the chosen material and was dipped in liquid nitrogen solution and was then subjected to Cryorolling processing. Mechanical properties testing was done and processed alloy come out with both high strength and high ductility. The combination of UFG size and high-density dislocations appears to enable deformation by new mechanisms not active in coarse-grained metals and alloys. These results express the possibility of tailoring the microstructures of metals and alloys by Cryorolling to obtain superior mechanical properties.
Keywords: Cryorolling, Ultrafined grain, Aluminum 2024.

I. INTRODUCTION

In the current times, efforts have been taken to refine grains or sub grains of metals into nanocrystalline system to have high strength, but their inadequate ductility has become a major issue in their practical application. A number of techniques have been developed to improve the tensile ductility . While most of the approaches improved strength at the expense of ductility or vice versa, a few more recent approaches have succeeded in simultaneously achieving high strength and ductility. One such successful approach is achieving bi modal structure and Nano precipitation. Ultrafine grained and nano structured bulk materials were produced through severe plastic deformation (SPD) processes such as equal channel angular pressing (ECAP), multiple compression, and severe torsional straining [1].Severe plastic deformation (SPD) is an approach being used to realize the UFG/nanocrystalline structure in the material by imparting severe strains. SPD techniques involve heavy tooling and it is expensive. Alternative to the SPD process is deforming the material at very low temperatures (near or at the liquid nitrogen temperature), the so called cryorolling[2]. Recently, Cryo rolling has been identified as one of the potential routes to produce nanostructured /ultrafine grained pure metals Cu, Al, Ni and its alloys from its bulk counter part by deforming them at cryogenic temperature. Rolling relatively requires less force due to less friction. In addition the low temperature (Cryo) suppresses dynamic recovery during deformation and hence Cryorolling preserve a high density of defects generated by deformation, which can act as the potential recrystallisation sites for precipitates at relatively low strain and stress as compared to other processes[3,4]. The processing steps in this approach include:(i)solid solution-treating the Al alloy to dissolve partially the second phase particles and to produce an oversaturated solid solution; (ii) cryo-rolling at cryogenic temperature to produce ultrafine-grained (UFG) microstructures, and (iii) aging to produce highly dispersed second- phase nano-size particles. In this study 2024 Al alloy was solid solution treated (SST) for 55 min at 495oC to partially dissolve the precipitates and cryo rolled at -193oC to accumulate the dislocations, then aged at 160oC for 10 hour to achieve ductility and strength[5]. Proper heat treatment of the cryorolled samples results in the development of UFG structure in the material. The present study aims to obtain UFG structure, improvement of strength and ductility using Cryorolling to achieve 30% and 50% thickness reduction in alloy plates which were subjected to rolling in an aluminium alloy using Cryorolling Technique.

II. EXPERIMENTAL DETAILS

A commercial aluminium alloy 2024 was chosen for this experiment. The chemical composition of the material is given in Chemical composition is shown in Table 1.

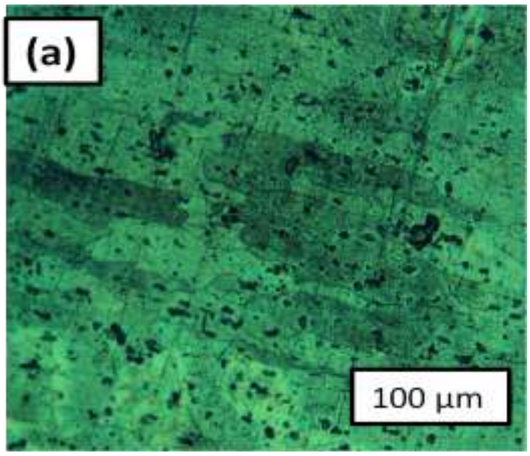
Al	Cu	Mg	Si	Mn
1159,0 KCps	1063,1 KCps	29,1 KCps	6,2 KCps	59,5 KCps
89,32 %	5,09 %	1,56 %	1,26 %	0,90 %

Table 1. Chemical composition of Al 2024 weight%

The samples for cryo-rolling was cut by shear cutting with dimensions of 80mm (length) × 40mm (breadth) × 10mm (thickness). Samples sides were well polished to avoid the cracking during cryo-rolling. The as-received alloy samples were first solid-solution treated at a temperature 495oC for 1hour 50 minutes and then quenched in water to room-temperature. The solution heat treatment in which all solute atoms are dissolved to form a single phase solid solution. In ST involve the heating of an alloy to a suitable temperature, holding at the temperature for sufficient time to induce one or more of the constituents to enter into solid solution and cooling rapidly enough to hold these constituent in solution. Solutionized samples were immersed in a cryo-bath. Cryobath contains isopropyl alcohol. The cryo-bath temperature was maintained at -193oC throughout the experiment. The microstructural evolution of the solution treated (ST), cryorolled (CR), and annealed CR samples was examined through optical microscopy. The solid solution treated samples were soaked for 1hour at -193oC before rolling. Samples were rolled along the longitudinal and transverse directions to avoid severe grain elongation in one direction. Between each pass also samples were immersed in cryo-bath for 1 hour. For the purpose of comparison, solid solution treated samples were also rolled at room temperature. The room temperature rolled samples were aged at 190oC for 12 hours. In contrast, cryo-rolled samples were aged at 160oC for 12 hours. Vickers hardness was measured to keep track of the hardness variation. Uniaxial tensile tests were conducted and the specimen was machined as per ASTM E-8 specifications. The tests were performed at room temperature. Samples for metallography were polished, etched and examined using standard metallographic techniques. Etching were done using keller reagent (1.5% HCL+ 2.5% HNO3 +1% HFL + 95% water). X-Ray Diffraction profile were obtained at 40kV and 20mA using monochromated Cu Kα raditation. The samples were Scanned in the 2θ range of 20o -90o. The grain size were calculated using Scherrer formula.

III. RESULTS AND DISCUSSION

A. Microstructure: The microstructure of the 2024 in the Fig 1(a) shows the solution treatment firstly we heated the alloy at 495o C for 1 hour 55 minutes them after the set of time. The procedure is followed by rapid cooling or quenching temperature in water. In the part (b) and (c) the elongated grains observed in the micrograph reveals that the samples are in as rolled condition. According to standard literature and hand books, precipitates (black spots) formed along the grain boundaries are Al2CuMg precipitates. The optical micrographs of the starting material and cryorolled samples after 30%, 50%.After solution treatment, the material possesses equiaxed grains with the average grain size. After subjecting to rolling up to 50% reduction, the grains were elongated in the rolling direction shown in Fig 1.(b). As the percentage deformation increases, the grains are more elongated in the rolling direction, and they became denser, as seen in Fig. 1(c). The Cryorolled sample is reached at reduction of 30%. The initial microstructure of the Al 2024 sample after annealing at 495oC for 1hour 50 mintues exhibits high density of fine second phase particles with very low density of dislocations at Fig1(a). During cryorolling, the dislocation density is increased with increasing percentage of reduction.



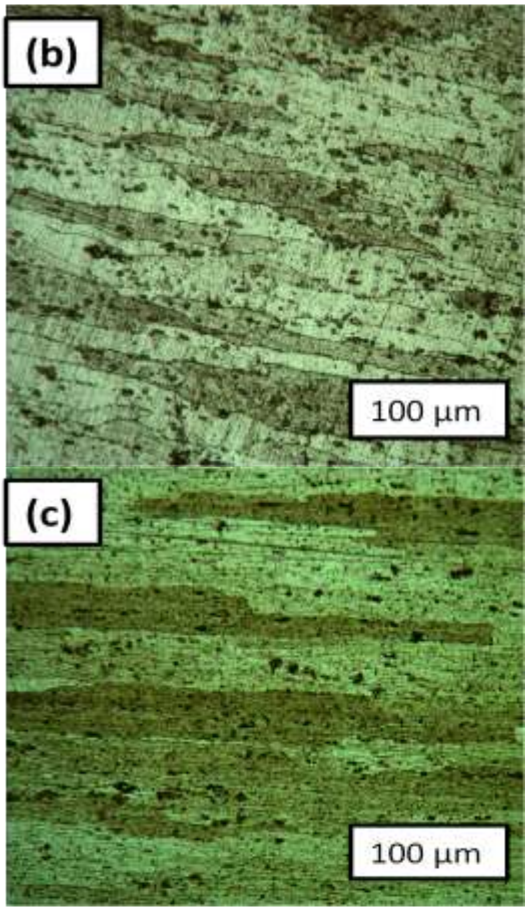


Figure 1: Optical micrographs of Al 2024 alloy; (a) Initial material (ST), (b)cold rolled sample, (c) Cryorolled Sample

B. Mechanical Properties

The Vickers hardness values of initial solution treated, cold roling, and cryorolling condition samples.The observed hardness of intial maerial is 134 Hv. After rolling up to 50% reduction , the hardness of material has increased to 154 Hv in room rolling and 164Hv in cryorolling.

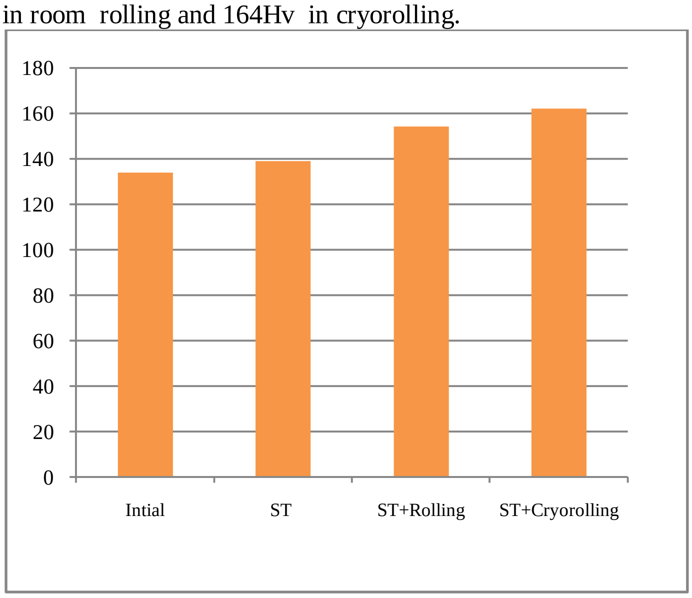


Fig 2. Vicker hardness of Al 2024

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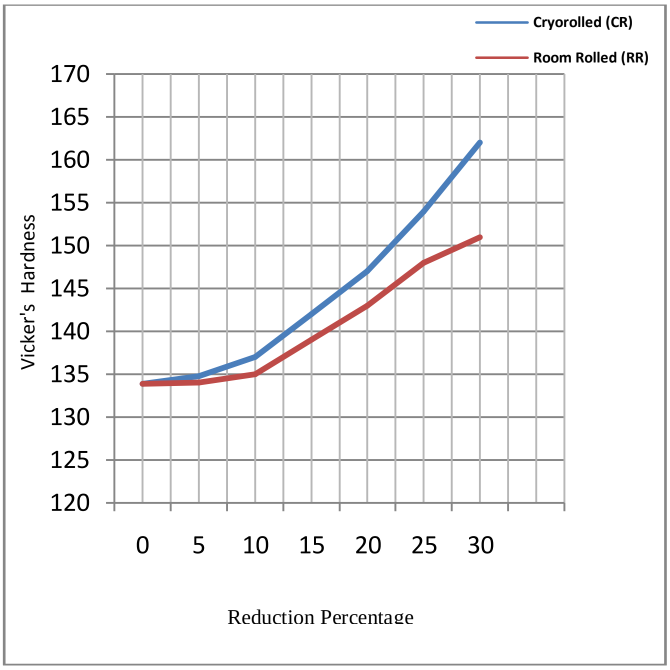

Fig 3. Comparsion between Vicker's Hardness and increasing in Reduction

C. Tensile test

The tensile strength increased about 1.25 times and increased with reduction in ductility of 0.52 times as compared solutionised samples in Table 2 shows the tensile properties of Al2024.

Condition	Reduction	UTS (Mpa)	Elongation %
Initial unrolled	Nil	409	8.2
Rolled sample	25%	423	13.80
Cryorolled	30%	434	1.52

Table 2: Tensile properties of 2024 Al alloy

D. XRD analysis

XRD analysis of ST(solution treated), rolled and Cryorolled Al 2024 alloy is shown in Fig 3. Cu are the major elements in Al 2024 alloy, which impart strength to Al matrix by forming Al2CuMg precipitates during ageing. Fig.3 corresponds to starting solution treated material after quenching and cryorolled material, respectively. Super saturated solid solution of Al 2024 alloy obtained after solution treatment and water quenching contains Mg and Si in the dissolved state. It is evident in Fig 3. Since solution treated and water quenched material was selected as starting material for cryorolling, there is no peak corresponding to AlCu precipitate after reduction. XRD analysis (Fig. 4) suggests that Al2CuMg, AlCu2Mn and Al2Cu precipitates are present in the Cryo rolled. Out of these three precipitates AI2CuMg is responsible for the strengthening of the Al 2024 alloy. The precipitate sizes after cryo rolling are show in the Table 3.

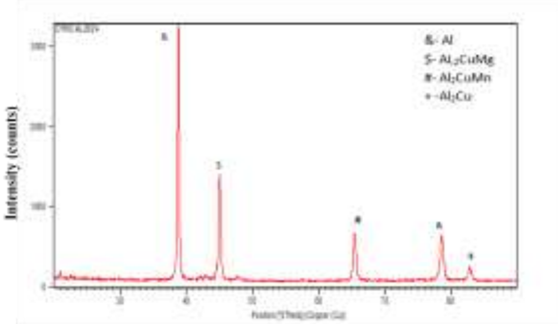

Fig.4 XRD Analysis

Precipitate	Size
Al	35.98
Al_2CuMg	38.45
$AlCu_2Mn$	34.8
Al_2Cu	21.6

Table 3: Precipitate size Al2024 after cryo-rolled

IV. CONCLUSIONS

The effect rolling on the mechanical properties and micro structural characteristics of Al alloy subjected to room temperature and liquid N2 temperature rolling was investigated in the present work. The cryorolled 2024 Al alloy has shown an improved strength of (434MPa) as compared to the room temperature rolled samples. The tensile properties of as cryorolled 2024 Al alloy and the samples subjected t were investigated and compared with that of its room temperature rolled alloys. It is found that the cryorolled Al alloy with showed a high strength and ductility as compared to room temperature rolled alloys.

- In the Cryo rolling (CR) their is 25% increase in hardness.
- In the Cryo rolling(CR) their increase in strength (434Mpa) and elongation also shows the increase in strength.
- Cryo-rolling increase the strength of processed material.
- Rolling forms the ultrafine grain structure that strengthen the material.
- In CR material, the precipitate features are coarser than Rolled material.

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