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Fabrication and Structure-Property Relation of Squeeze Cast Lithium Containing AA5025 Alloy

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Abstract
Microstructure control always plays a key role in enhancing properties in high strength aluminium alloys. Designers of aircraft desire materials which will allow them to design lightweight, cost-effective structures which have the performance characteristics of durability and damage tolerance. Their needs are being met by new and emerging materials like aluminium-lithium alloys. Increase in fuel economy because of lighter weight structure is the driving force for aluminum alloys in the automotive market and cost is extremely important. Mechanical properties for automotive use also depend on the application, and corrosion resistance must. The desire for more efficient aircraft materials has fueled research of aluminum lithium alloys. The addition of lithium results in beneficial characteristics but also presents undesirable properties. However the binary alloys suffer from problems of poor ductility and toughness. The objective is to develop and study the microstructural features of lithium-containing AA5025 alloy through squeeze casting and followed by heat treatment.

In this present work lithium (Li) containing AA5025 alloy was prepared by squeeze casting and solutionized at 460ºC and aged at 145ºC hot rolled at 450ºC. Grain refinement was done by the application of squeeze pressure. The Optical micrograph analysis revealed that all of the grain structures are not obviously different and consist of a band of thick columnar grains surrounding some large equiaxed grains in the center under the same application of squeeze pressure & obtained microstructures after hot rolling at 450ºC consisted of elongated grains along with nucleation of new fine grains. Recrystallized grains with higher fraction area are evident in the microstructure of the specimen after hot rolling at 450 ºC. Potentio dynamic polarization test shows that the corrosion rate tend to decrease with decreasing grain size.

Keywords: Aluminum-Lithium alloys, Squeeze Casting, Precipitation hardening, Corrosion resistance, XRD analysis.

1. Introduction
The desire for more efficient aircraft materials has research of aluminum lithium alloys. There have been, and still are, obstacles in the development of these alloys [1]. The addition of lithium results in beneficial characteristics but also presents undesirable properties.

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Interest in Al-Li alloys diminished for several decades until the oil crisis, when high fuel prices forced the airline industries to purchase fuel-efficient aircraft [2]. Again the possibilities of aluminum-lithium alloys were researched. Al-Li alloys research led to the second generation of alloys, including 2090, 2091, and 8090, among others [3]. The second generation alloys certainly had improved mechanical properties when compared to the first generation alloys [4]. Cindie giummarra et al. This paper discusses two aluminum lithium alloys for aerospace applications, 2099 and 2199, including the relationship between their alloying elements and thermal-mechanical processing, to the alloy's properties [5]. The paper also includes selected properties of these alloys in sheet, plate and extrusion forms. B.T. Gibson et al. Lap joints of 2198-T8 Al–Li alloy in 0.063 in. sheet thickness were friction stir welded to investigate the combination of this material and assembly method for the manufacturing of aerospace structures [6]. Along with conventional friction stir welding (FSW), weaved FSW and pulsed FSW (PFSW) were evaluated to determine the potential impact of these variant technologies on weld strength.

2. Experimental Details

AA5025 alloy was prepared by squeeze casting method with controlled process parameters. Similarly the lithium containing AA5025 alloy was prepared by the addition of lithium into the melt was carried out by the use of 10cm long aluminium capsules filled with lithium billets at 800ºC. Before pouring the molten metal into squeeze casting, the molten metal was treated with flux and suitable 5Ti-1B grain refiner. The liquid metal was pressed at 30MPa in a hydraulic press. The cross Sectional area of the die was 350mm x 50mm. The die was preheated at 300ºC with help of heating rod.

Table 1 Chemical composition of Li containing AA5025 alloy

Element	Mg	Cu	Zn	Si	Li	Al
AA5025 wt%	2.5	2	1	0.3	-	Bal
Al-1%Li Wt%	2.5	2	1	0.3	1	Bal
Al-3%Li Wt%	2.5	2	1	0.3	3	Bal

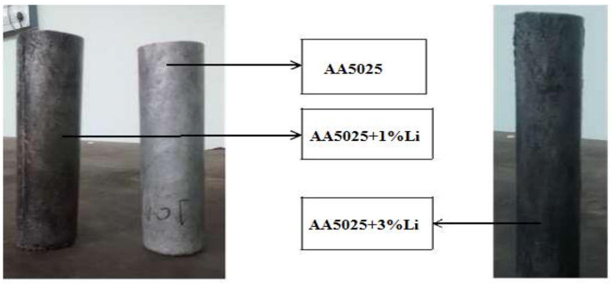

Fig. 1 Casting Billets of AA5025 Different Conditions

2.1 Rolling

- ❖ The procured sheets were cut into strips of 50mm x 30mm x 5mm. The samples were heat treated (solutionized) samples are further used as base sample for rolling.
- ❖ Solutionizing include heating the samples at 450º C for 2 hours. This treatment ensure that the dissolution of coarse precipitate in the matrix
- ❖ Rolling was performed in a custom built 2-high rolling with rolling diameters

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75 mm. The solutionized samples were rolled to different reduction such as 50%,75% & 95% in hot condition only.

Fig. 2 AA 5025 Rolling Different conditions

2.2 Corrosion

Corrosion behaviour of the material was investigated using potentiodynamic polarization technique. Potentiodynamic polarization test was conducted on as casted with comparison of heat treated samples shows the representative PDP curves of as casted and after aging samples respectively. Tested in aera 3.5 wt% NaCl solution and curves of Ecorr vs Icorr is projected in the range of -1500mV to 1500 mV is indicated. The Ecorr and icorr values are obtained from the respective polarization curves using Tafel extrapolation method.

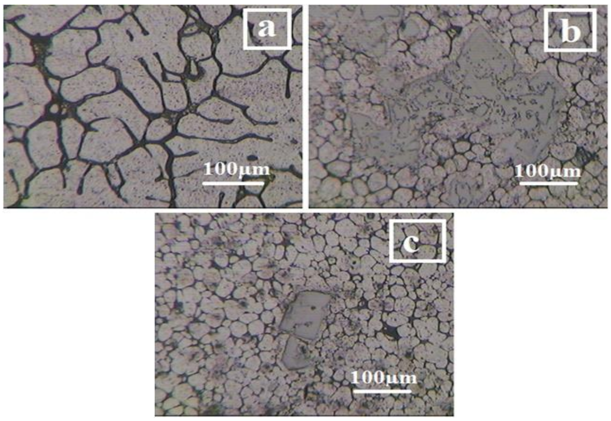
3. Results and Discussion

3.1 Comparison of density values with and without Lithium

Alloy	Theoretical Density g/cm³	Actual Density g/cm³
AA5025 Alloy	2.8 g/cm³	2.5 g/cm³
Al-1%Li Alloy	2.7 g/cm³	2.2 g/cm³
Al-3%Li Alloy	2.5 g/cm³	1.5 g/cm³

It is clearly observed that the density values by the increase addition of Lithium shown decreasing in density values compared to AA5025. A lithium atom is lighter than an aluminium atom; each lithium atom then displaces one aluminium atom from the crystal lattice while maintaining the lattice structure. Every 1% by weight of lithium added to aluminium reduces the density of the resulting alloy by 3% and increases.

3.2 Micro Structure Analysis of Lithium Alloy



The microstructures of the Li containing squeeze-casted AA5025 alloy solidified under the 30MPa applied pressure with the pouring and die temperatures of 820ºC and 300ºC, respectively. The microstructures of as casted the samples consist of thick columnar grains surrounding some equiaxed grains in the center, and the applied pressure leads to finer columnar grains as well as equiaxed grains and limits the extent of the columnar growth from the die surface. The grain structure of the samples having 1%Li has no much difference from the samples having 3%Li under same applied pressure. All of the grain structures are not obviously different and consist of a band of thick columnar grains surrounding some large equiaxed grains in the center.

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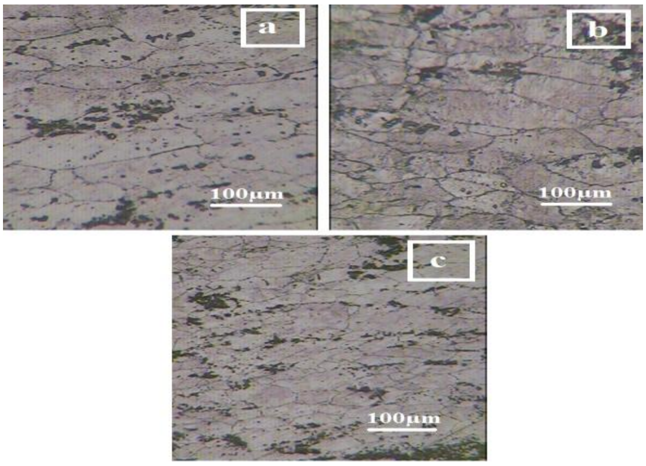
Rolling Microstructural Analysis



From above fig shows that the obtained microstructures after hot rolling at 450ºC consisted of elongated grains along with nucleation of new fine grains. Recrystallized grains with higher fraction area are evident in the microstructure of the specimen after hot rolling at 450ºC. The grains at this temperature are almost equiaxed along with formation of new dynamically recrystallized grains. This is rationalized as effect of deformation temperature on the restoration processes microstructures of hot rolled to 95% reduction of AA5025,AL-1%Li,Al-3%Li alloys resulted as fine elongated grains in the rolling direction. It is observed that there no is much difference between them.

3.3 Mechanical Properties of AA5025 Different Conditions

Alloy	**As casted**	**Solutionized(460°C)**	**Aging (145°C)**
AA5025	120 Hv	108 Hv	138 Hv
Al-1%Li Alloy	126 Hv	115 Hv	142 Hv
Al-3%Li Alloy	148 Hv	125 Hv	167 Hv

Alloy condition	**Hot rolling to50% reduction**	**Hot rolling to75% reduction**	**Hot rolling to 95% reduction**
AA5025 alloy	137 Hv	138 Hv	155 Hv
Al-1%Li alloy	145 Hv	164 Hv	168 Hv
Al-3%Li alloy	175 Hv	188 Hv	195 Hv

In as casted samples, the improvement of mechanical properties is attributed to eliminating of micro-pores in the as casted alloys caused by applied pressure during Squeeze casting. The increase in the hardness of squeeze cast products is brought about by the faster cooling rates giving rise to grain refinement and elimination of porosity and hence increased hardness of squeeze cast products.

The comparison of micro hardness values for the base material and the rolling materials shown in graph .It is observed that the rolling operation has increased the hardness values of deformed material from that of the solutionized base material by 50%,75% and 95% reduction of thickness rolling at cryogenic temperature causes the

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accumulation of dislocations and reaches higher density level than sampled at room temperature due to suppression of dynamic recovery .As rolling direction increase grains become fine .So grain boundary strengthening is more for high stained sample .So that 95% reduced samples have more hardness than 75 and 50% reduced samples at all the conditions.

Tensile properties of AA5025 alloy

Processing condition	UTS (MPa)	Yield strength (MPa)	% Elongation
Base sample	158	124	4.4
Aged	182	151	6.8
Hot-Rolled to 95% reduction	248	192	9.8

Tensile properties of Al-1%Li alloy

Processing condition	UTS (MPa)	Yield strength (MPa)	% Elongation
Base sample	145	121	5.2
Aged	162	143	8.9
Hot-Rolled to 95% reduction	195	148	7.5

Tensile properties of Al-3%Li alloy

Processing condition	UTS (MPa)	Yield strength (MPa)	% Elongation
Base sample	156	124	5.2
Aged	175	121	8.9
Hot-Rolled to 95% reduction	234	202	7.5

From above table we can see that the as cast samples are exhibited a yield stress of: maximum as 124MPa and ultimate tensile stress of 158 MPa. At constant rolling temperature, increasing the strain rate resulted in lower yield strength. Therefore, the rate of increase of the strengths versus increase of the rolling temperature is decreased with increasing strain rate[The effects of rolling parameters on the mechanical behavior of aluminum alloys. The precipitates would be relatively soft at 450ºC for 1hr as this temperature is close to the solutionizing temperature range of the experimental alloy and might be easier to be cut through by dislocations during the deformation under higher strain rate. Consequently, the barrier to dislocation motion is less strong with increasing strain rate there by the yield stress would reduce.

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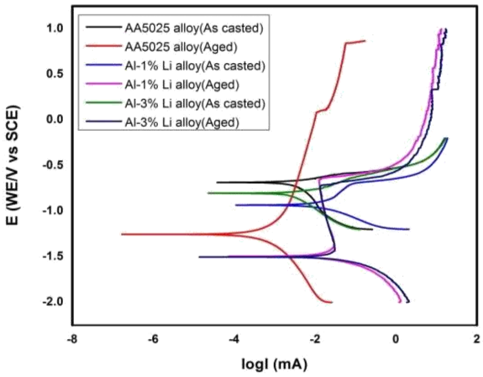
3.4 Corrosion Properties

Alloy	Ecorr (mV)	Icorr (μA)	Corrosion Rate (mm/y)
AA5025	-683.555	1.814	0.028
Al-1% Li Alloy	-932.688	15.292	0.767
Al-1% Li Aged Alloy	922.15	18.92	0.83
Al-3% Li Alloy	-802.795	21.36	0.94
Al-3Li Aged Alloy	966.52	29.58	1.08

The alloy AA5025 has fine grain size hence as grain size decreases corrosion resistance increases because of greatly increase the number of grain boundaries ,which turn decreased the chloride concentration per grain boundary resulting in decreased current density but the addition of 1% Li AA5025 shows higher current density icorr 15.2mV values and addition of 3%Li shows icorr 2.1mV and it is due to the depletion of oxide film in reducing atmosphere by the presence of intermetallic compounds causes large potential difference between Al and grain boudaries or with intermetallic compounds. After aging condition the corrosion rate much increased than as casted due to the presence of reappearance of precipitates led to large difference between -Al and precipitates. From graph & table shows PDP curves and corrosion data of hot rolled samples



Alloy condition	E corr (mV)	Icorr (μA)	Corrosion rate(mpy)
Hot rolled 95% reduction AA5025 alloy	-1253	11.687	0.780
Hot rolled 95% reduction Al-1%Li alloy	-1494	15.10	1.24
Hot rolled 95% reduction Al-3%Li alloy	-1502	29.150	3..42

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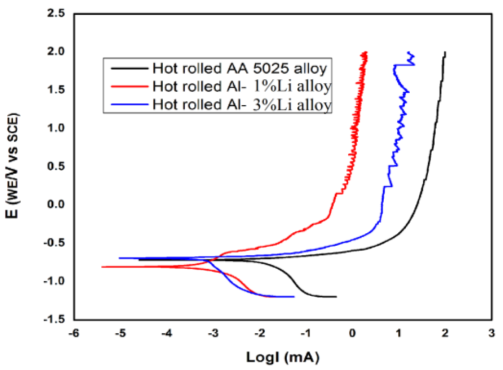

4. Conclusions

In the present work, lithium containing AA5025 was fabricated using squeeze casting. The density, microstructure, hardness and corrosion behaviour, tensile strength, were compared before and after heat treatment.

- ❖ Grain refinement was done by the application of pressure during squeeze casting and less wastage of material, good surface finish is obtained.
- ❖ By the increasing addition of lithium to AA5025 alloy results decreasing density values.
- ❖ In XRD analysis, peaks of aluminium and intermetallics like Mg2Si, Al-Li-Si, Al-Cu-Mg, Al2-Cu-Mg4, A6-Cu-Mg4 can seen. It is evident and confirmed that a phase of lithium is appeared in XRD patterns. It was the reason for the increase in hardness values

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