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PREPARATION OF Al-Ni COMPOSITE AND ITS CREEP BEHAVIOUR

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Friction stir processing (FSP) is an emerging solid state thermo-mechanical metal working process that changes the local properties of the material without influencing the properties of the bulk material. FSP was developed based on the concept of Friction stir welding [1]. In this study, FSP was used to investigate the feasibility of producing Al-Ni intermetallic composites on the surface of commercial aluminium alloy. The process was simplified by opting for incorporation of Ni powder using a groove in the substrate and stirring was done with a friction tool made from tool steel. Table 1 shows processing parameters used for producing Al-Ni composite layer on the aluminium alloy. The processed zone was cut perpendicular to its length and using standard metallographic techniques samples were prepared. Using scanning electron microscope macrostructure and microstructures were studied. Figure 1 shows the macrostructure and it reveals two distinct zones, namely, friction stirred zone and base metal zone.

Table 1: FSP processing parameters

1. Normal force	8kN	4. Pin depth	3mm
2. Shoulder diameter	20mm	5. Rotation speed	2000rpm
3. Pin diameter	6mm	6. Transfer speed	18cm/min

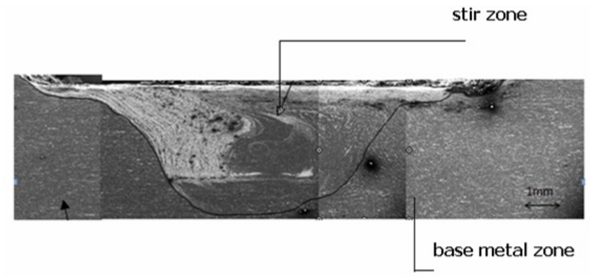

Figure 1. Macroview of a FSP sample

Microstructure study along with the EDS analysis in the friction stirred zone reveals the presence of Ni particles of varying size. The coarse particles were pure Ni. Matrix in some regions showed pure Al where as some regions indicated presence of both Ni and Al. A few regions in the matrix indicated Al/Ni ratio as approximately 3: 1 indicating the possibility of Al_3Ni. Formation of

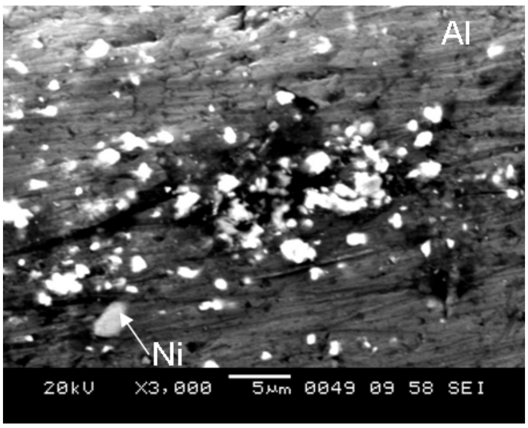

Figure 2. Microstructure in the friction stir processed zone.

intermetallics during friction stirring is reported by Liming Ke et.al [2]. But it must be reported that XRD analysis of this sample did not show any noticeable peaks for Al_3Ni. We conclude that Ni in the FSP zone existed both in dissolved form and undissolved form. It is to be noted that equilibrium solubility of Ni in Al does not exceed 0.04at% [3]. The large extent of Ni dissolution in Al was attributed to non-equilibrium nature of friction stir processing. Non-equilibrium phenomena during friction stir welding is reported by many investigators [4].

To compare the creep behaviour of FSP zone with the base material, impression creep experiments were conducted with a tungsten carbide indenter. The stress employed during creep experiments was 28MPa. Creep experiments were conducted at 30, 100 and 200°C at both FSP and base metal zone. Plots of creep strain vs time (i.e. creep curve) were drawn and from that steady state creep rates were estimated. Table 2. shows values of steady state creep rates (value/ min) both for FSP and base material.

Table 2. Steady state creep rates at various temperatures and zones

Temperature (°C)	Steady state creep rate (value/min)	
	Base metal	FSP zone
30	0.7 x 10-5	0.02 x 10-5
100	94 x 10-5	2.5 x 10-5
200	250 x 10-5	133 x 10-5

From the creep curves activation energy (Q*) for creep is calculated using the formula [5]

$$(Q^*) = R \ln(\varepsilon_1 - \varepsilon_2) / \left(\frac{1}{T2} - \frac{1}{T1}\right)$$

Where ε_1 and ε_2 are steady state creep rates (SSCR) at T_1 and T_2 temperatures respectively. The activation energy (for both zones) are found to be in the range of 55-65kJ/mol. The reported activation energy value for self-diffusion of aluminium is 140kJ/mol). From activation energy values, it could be inferred that the underlying creep mechanism is dislocation creep in both the regions [6]. The temperature variation of the creep rate is related to thermally assisted force required to overcome the obstacles lying in the plane of dislocation glide. Recovery processes during creep phenomena is assisted by non-conservative motion of dislocations, like climb. However in lower temperature regimes (30-100°C), velocity of dislocation climb is less than that of dislocation glide. Thus, it is arguably inferred that dislocation glide dominates the mechanism of creep in both zones. The dislocation glide in the processed zone is resisted more, resulting in the zone registering a higher creep resistance. The resistance is due to:

(i) Dissolution of Ni atoms into Al matrix by mechanical forces.
(ii) Precipitation of second phase particles, both having stable and metastable nature.

From the results and discussion following conclusions can be drawn.

1. Stir processed zone of Al with Ni particles exhibits higher creep resistance by an order compared to unprocessed Al base metal in the temperature of 30-100°C.
2. The values of experimentally determined activation energy, being in the range of 55 kJ/mol to 65 kJ/mol, suggest that creep mechanism is dislocation creep.

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