

## THE INFLUENCE OF MICROSTRUCTURE ON THE FRACTURE RESISTANCE OF 6XXX ALLOY SHEET

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### INTRODUCTION

The fracture behavior of 6xxx alloy aluminum sheet is affected by alloy composition, heat treatment, and aging practices. Two alloys, 6014 and 6016, were quenched at different rates and artificially aged to a range of strength levels. Testing of bend samples and notched coupons was used to measure the fracture resistance of the alloys. The fracture behavior observed by SEM varied from mostly transgranular to highly intergranular. TEM was used to examine the extent of intergranular precipitation of Si and Mg<sub>2</sub>Si particles and the size of precipitate-free zones adjacent to the grain boundaries. The toughness results were related to the degree of strain localization within the grains and the grain boundary microstructures.

### EXPERIMENTS AND SOME RESULTS

Cold-rolled AA6014-F aluminum sheet samples were supplied by Novelis Inc., and AA6016-T4 aluminum sheet was supplied by Aleris, Inc. The chemical compositions of the experimental materials are given in Table 1.

Table 1 Chemical composition (wt. %) of AA6014 and AA6016 aluminum alloys

|        | Mg       | Si       | Cu   | Mn       | Fe   | Cr   | Zn   | Ti   | V        |
|--------|----------|----------|------|----------|------|------|------|------|----------|
| AA6014 | 0.40-0.8 | 0.30-0.6 | 0.25 | 0.05-0.2 | 0.35 | 0.20 | 0.10 | 0.10 | 0.05-0.2 |
| AA6016 | 0.25-0.6 | 1.0-1.5  | 0.2  | 0.2      | 0.5  | 0.1  | 0.20 | 0.15 | --       |

A series of samples (25x30x(1.25/1.05)mm<sup>3</sup>) was soaked for 5 minutes at 560°C in a sand bath furnace, then quenched at 25°C cold water (Fast quenching rate, “W”) and air (Slow quenching rate, “A”). Samples were artificially aged at 180 and 200°C (abbreviation is “180/200”) in an oil bath (Figure 1a). Aging curves obtained from microhardness values are shown in Figure 1b. For now, we have selected the T6 condition at 180°C and performed further testing. Underaged and overaged tempers will be studied in the following work.

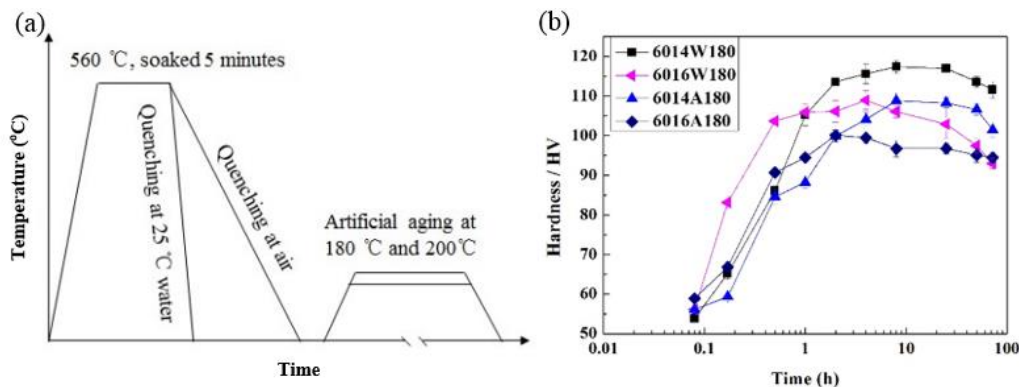


Figure 1. (a) Experimental procedures arrangement; (b) Vickers hardness of the alloys after solution heat treatment

Standard tensile samples were cut in the transverse direction ( $90^\circ$  to the rolling direction), after artificial aging at  $180^\circ\text{C}$  to the T6 temper. Tensile tests were conducted at a constant speed of 3 mm/min. The tensile test results are shown in Figure 2a. The W samples of both alloys showed higher strength and elongation. Samples of the AA6014 alloy had higher strength and lower elongation compared to AA6016.  $30\text{ mm} \times 50\text{ mm}$  coupons were mechanically polished and observed after three-point bending tests with the bend line parallel to the rolling direction of the sheet. Samples were bent until the onset of fracture. Minimum bend angles for the different alloy/heat treat conditions are shown in Figure 2b. The AA6016-T6 W sample was bent completely to a  $0^\circ$  angle without fracture.

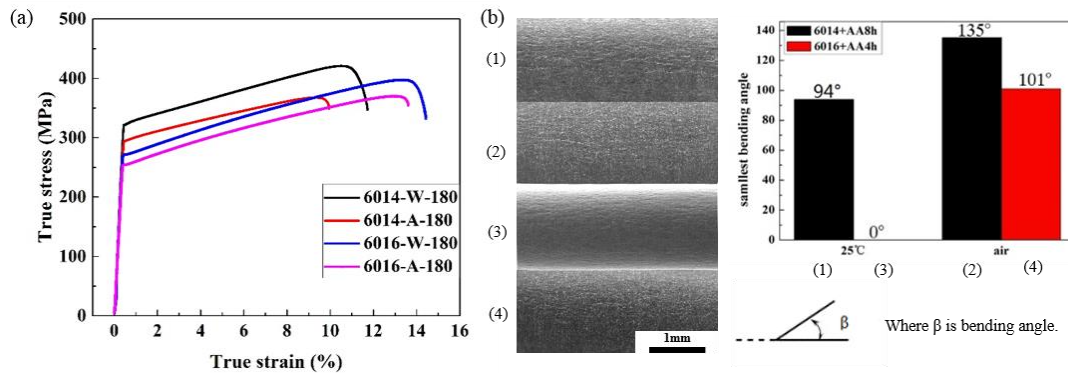


Figure 2. (a) Stress strain curves in TD direction; (b) SEM micrographs of fracture surface of samples aging to T6 at  $180^\circ\text{C}$  and minimum bending angle of alloys

SEM observations (Figure 3) were made of samples bent completely to failure. Grain boundary debonding and rupture occurred for the slowly-quenched A samples while water-quenched W samples showed ductile transgranular fracture. The brittle fracture character, shown in Figures 3b and 3c, resulted in the larger bending angles for the A samples shown in Figure 2b.

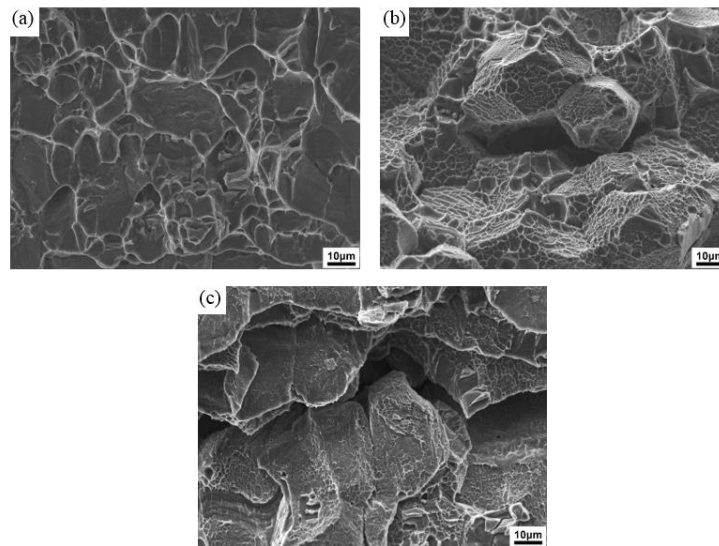


Figure 3. SEM micrographs of fracture of samples aging to T6 at  $180^\circ\text{C}$  (a) 6014-W; (b) 6014-A; (c) 6016-A.

#### KEYWORDS

Bendability, Three-point bending test, Fracture behavior