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ScienceDirect

Procedia Engineering 207 (2017) 13–18

Procedia Engineering

www.elsevier.com/locate/procedia

International Conference on the Technology of Plasticity, ICTP 2017, 17-22 September 2017, Cambridge, United Kingdom

Experimental investigation of tensile properties and anisotropy of 1420, 8090 and 2060 Al-Li alloys sheet undergoing different strain rates and fibre orientation: a comparative study

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Abstract

Al-Li alloys have gained great attention for military, aerospace, and commercial applications because of their outstanding properties compared to commercial Al alloys. However, the tensile properties of former Al-Li alloys cannot fulfil most of the design and manufacturing characteristics because of their poor formability, and anisotropy in tensile properties. Therefore, the third generation of Al-Li alloys was developed to overcome the shortcoming of the former Al-Li alloys. The sensitivity of tensile properties and anisotropy behavior of Al-Li alloys to fibre orientation (sample orientation) and strain rate is vitally important from the aspects of formability improvements and developing material models for formability prediction. Therefore, this paper aims at investigating the influence of sample orientation and strain rates on the tensile properties and anisotropy behavior of Al-Li alloys sheet through quasi-static and dynamic uniaxial tensile tests. AA1420 and AA8090 sheets were selected from first and second generations of Al-Li alloys respectively because of their outstanding properties. Moreover, AA2060 is a new third generation Al-Li alloy launched at 2011 by Alcao Inc. The results showed that AA2060 alloy offers superior tensile properties compared with former Al-Li alloys, notably along the rolling direction and at high rates of deformation. For instance, the elongation to fracture of AA2060 was increased to 21.9 % at a strain rate of 2000 s-1. However, it's formability at room temperature and quasi-static strain rate is very poor. Additionally, AA2060 is still suffering from anisotropic tensile properties, but the degree of anisotropy in less than the former Al-Li alloy. It is concluded that the quasi-static and dynamic tensile properties and formability for Al-Li alloy sheets show a dependable tendency in reference to sample orientation and don't display the constant trend with the increasing of the strain rate.

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Peer-review under responsibility of the scientific committee of the International Conference on the Technology of Plasticity.
10.1016/j.proeng.2017.10.730

Keywords: Al-Li alloys, tensile properties, anisotropy behaviour, quasi-static and dynamic tensile tests, formability,.

1. Introduction

Al-Li alloys have gained great attention for military, aircraft, space, and commercial applications because of their outstanding properties, such as high elastic modulus, high specific strength, low density and good weldability and corrosion properties compared to commercial Al alloys. Based on the production date, Al-Li alloys are classified into three generations denoted as; first (1^{st}), second (2^{nd}) and third (3^{rd}) generations Al-Li alloys. Although the former Al-Li alloys (1^{st} and 2^{nd} generations) exhibit as the aforementioned properties, they did not fulfil the requirements of manufacturers and designers for modern aircraft and space applications due to various issues [1,2].

Anisotropy in tensile properties is the main issue of the former Al-Li alloys (especially those containing predominantly un-recrystallized grains) because it leads to serious problems in products manufacturing and quality. Therefore, the 3^{rd} generation of Al-Li alloys was improved to overcome the shortcomings of the former generations and fulfil the requirements of manufacturers and designers [3].Indeed, the anisotropy in tensile properties of Al-Li alloys sheet is very complex because these alloys are affected not only by crystallographic texture but also by many other factors such as the sizes, shapes and orientation of the grain and sub-grains (fibre orientation) [4]. Furthermore, the sensitivity of tensile properties of these alloys to the strain rate is vitally important from the aspects of formability improvements and developing material models for formability prediction [1,3]. With reference to formability development and anisotropy in tensile properties, most of the previous investigations explored the phenomena occurred on the former Al-Li alloy sheets under a quasi-static or static deformation conditions, while, the phenomena existing under high strain rate (dynamic) conditions are rarely investigated on Al-Li alloy sheets.

Accordingly, this study aims at investigating the influences of sample orientations and strain rates in the range of 0.001 to 2000 s-1 on AA1420, AA8090 and AA2060 alloy sheets through uniaxial tensile tests, at room temperature to compare the tensile properties, formability, and degree of anisotropy of these alloys to determine the optimum alloy and working conditions to form and manufacture a complex aircraft component using either sheet hydroforming or impact hydroforming technologies. We selected AA1420 and AA8090 sheets to from 1st and 2nd generations of Al-Li alloy respectively because their outstanding tensile properties compared to their counterparts of Al-Li alloys. Moreover, AA2060 was a new 3^{rd} generation Al-Li alloy launched at 2011 by Alcao Inc. to overcome the shortcoming of the former Al-Li alloys and replace the conventional Al alloy in aircraft and space applications.

Nomenclature	
σ_e, σ_y	Elastic stress and yield stress respectively.
$\varepsilon_e, \varepsilon_0, \varepsilon_p, \varepsilon_l, \varepsilon_w, \varepsilon_t$	Elastic strain, strain offset constant, plastic strain, longitudinal strain, width strain and transverse strain respectively.
E, K, n	Young's modulus, linear hardening parameter, strain hardening exponent respectively.
x_1, y_1, x_2, y_2,	Length of the rectangle grid on x and y-directions before and after tensile test respectively
RD, DD, TD	rolling (0°), diagonal (45°), and transverse directions (90°) to rolling direction

2. Experimental Programme

2.1. Materials description

The thickness, density, nominal chemical composition, and the developers of AA1420, AA8090 and AA2060-T8 Al-Li alloy sheets are listed in table 1.

2.2. Quasi-static and dynamic tensile tests

A 100 KN Instron 5980 Floor Model was used to accomplish the quasi-static uniaxial tensile test according to the Chinese Standard GB/T 228.2-2015. The quasi-static tensile tests were performed at room temperature and various conditions as described in table 2. The samples used for quasi-static tensile tests were machined (according to the Chinese Standard) from AA1420, AA8090 and AA2060 rolled sheets in different angles to the rolling direction (RD). The geometrical details of the quasi-static tensile test sample are depicted in Fig. 1a.