Mechanical Performance and Fracture Behavior of Recycled AA6061-T6 Alloy Melted from Aluminium Chips

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ABSTRACT

Aluminium chips were re-melted under the molten bath in a gas fired reverberatory furnace and superior quality recycled AA6061-T6 alloy was synthesized. The chips were added 5 to 20% by weight in the recycled alloy. The furnace charge included clean scrap of the same alloy (AA6061) along with the machining chips or tunings of mixed nature. The chips used in this study were mostly generated from lath/bore operations carried on homogenized billets. The fabricated alloy of each heat was characterized for microstructures, mechanical properties and fracture behavior. The results showed that the metallurgical and mechanical performance of the recycled alloy was comparable to the primary alloy. However, SEM analysis of the recycled alloy revealed a sizeable amount of Fe and Si containing intermetallic compounds such as AlFeSi, AlFeMg, and AlSiMg phases.

KEYWORDS
AA6061-T6, Aluminium Chips, Impurity Phases, Intermetallic, Mechanical Performance, Melting, Microstructure, Recycled Alloy

INTRODUCTION

The usage of aluminium material in diversified engineering applications has been growing exponentially during the past few decades. Primarily, the property enhancement in conventional aluminium as well as the development of new grades of aluminium with superior properties has widened their engineering scope (N. Akhtar, Wu, & Akhtar, 2014; W. Akhtar, Akhtar, & SuJun, 2014). Today, huge volume of aluminium is being consumed in construction, automobile, packaging, aerospace, defense, and miscellaneous hi-tech applications. The rising demand of aluminium has triggered the ‘production capacity’, and also introduced new dimensions in scrap recycling. Scrap is produced at various stages during the fabrication of targeted alloys from primary aluminium i.e. melting and casting waste, billet cuts ends, machining waste, extrusion waste, sizing waste etc. Moreover, components and machinery which finished their service life also add up in scrap.

Aluminium scrap/waste may be classified in two categories i.e. in-house scrap and external scrap. In-house scrap is mainly the ‘returns’ from different processes, and usually it is considered as clean scrap because of its known constituents and low impurities. External scrap is obtained from some outsource, and it may or may not be of one source. Mostly, it is of mixed nature and contains different classes of aluminium alloys. Aluminium scrap may also be categorized on the basis of impurity level.
and product form e.g. solid profiles, powdered waste, chips/turnings, painted or lacquered aluminium, oily scrap etc. Such type of classification is necessary to know the cleanliness, alloy type, morphology and size, contamination, thermal history etc.

Machining process play a key role in the fabrication of semi-finished, or finished aluminium products. However, machining process generates a lot of waste in the form of turnings or chips. This type of waste is difficult to recycle due to its low density and large surface area. Furthermore, if the turnings come from two or more alloys, it’s almost impossible to sort such type of scrap.

Aluminium scrap has been utilized to produce high quality products for a number of industrial applications (Jirang & Roven, 2010; Varužan Kevorkijan, 2010; Kevorkjjan, 2010), and their performance was found quite satisfactory in many applications such as piping of plant, heat exchanger tubing and cast engine parts etc. However, aluminium scrap is not recommended in those applications, which require high fracture toughness and superior fatigue life such as the wings of an aircraft.

Recycling of Aluminium Scrap

It is believed that in-house aluminium scrap is easy to recycle due to its known contents and predictable behavior. Recycling of in-house scrap offers significant benefits over outsource scrap, and some are listed in Table 1. A comparison between scrap and primary aluminium is also included to record some of the limitations in scrap use.

Recycling of in-house scrap is very crucial for the maximization of resources. The in-house scrap is easy to categorize/sort, and normally do not require any pretreatment/purification step before their use. The only concern in their use is the contamination and control of impurities (Gaustad, Olivetti, & Kirchain, 2012) such as Cu, Mg, Fe, and Si. As aforementioned, usually the in-house scrap is not pretreated, as anticipated low level of impurities, though, it may raise the level of Fe (Belov, Aksenov, & Eskin, 2002) and Si in the final composition.

In the recycling of metallurgical clean scrap, there are two fundamental requirements that must be met to produce low cost, high quality recycled alloy, comparable to the one manufactured from primary ingots. First, achieving the required chemical composition with minimal additions of primary aluminium and master alloys. Second, strict control of impurities such as alkali metals, hydrogen contents and inclusions (Damoah & Zhang, 2010; Dewan et al., 2011). Similarly, the allowable quantity of scrap in a particular alloy depends on a number of factors e.g. scrap morphology and cleanliness level, melting practices, desired quality, and the area of use. In conclusion, one may add scrap until the material perform satisfactory in certain properties e.g. ductility, hardness, malleability, elasticity, fracture toughness, brittleness, conductivity, corrosion resistance and density.

Table 1. Characteristics of aluminium scrap recycling (Al Mehedi, 2014; Das, 2006; Green, 2007; Schlesinger, 2013)

<table>
<thead>
<tr>
<th>Sr #</th>
<th>In-house versus outsource scrap</th>
<th>Scrap versus primary aluminium</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Reduction in raw material cost</td>
<td>Low metal recovery rate</td>
</tr>
<tr>
<td>2</td>
<td>Easy sorting/categorization of waste from various sources on the base of geometry and alloy type</td>
<td>Low quality of the final products (non-metallic inclusions, gas porosity, poor mechanical properties)</td>
</tr>
<tr>
<td>3</td>
<td>Less impurities</td>
<td>High smoke and gases generation</td>
</tr>
<tr>
<td>4</td>
<td>Elimination of transport cost</td>
<td>Stringent requirement of molten metal treatment</td>
</tr>
<tr>
<td>5</td>
<td>Energy savings</td>
<td>Dangerous residues</td>
</tr>
<tr>
<td>6</td>
<td>Clean environment</td>
<td>Human health issues</td>
</tr>
</tbody>
</table>
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