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Tensile behavior and impact toughness of an AlSi3MgCr alloy

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Abstract

Recently, an innovative AlSi3Mg alloy with Cr and Mn additions was developed for the production of truck wheels by means of a non-conventional hybrid technique, which combines features of both low pressure die casting and forging processes. The presence of both Cr and Mn leads to the formation of an intermetallic phase rich in Cr, Mn and Fe with a globular or dendritic morphology. Furthermore, proper solution treatments cause the formation of dispersoids in the aluminium matrix. These dispersoids are responsible of enhancing the alloy performance due to dispersion hardening mechanism. In the present work, the tensile properties and the impact toughness of the alloy in as-cast and different heat-treated conditions were studied. Moreover, tensile and impact strength tests were performed on A356 samples in T6 condition machined from traditional LPDC wheels, whose results were compared with the performance of the innovative alloy. Fracture surfaces of tensile and Charpy specimens were observed by Scanning Electron Microscopy (SEM) in order to identify the role of the Cr-Mn containing intermetallic particles in the failure mechanism and the influence of the heat treatment parameters. Considering the static properties, the innovative alloy showed remarkable values of tensile strength, while ductility was improved only after heat treatment optimization. Poor impact toughness values were measured and the microstructural analysis confirmed the presence of coarse intermetallic secondary phases, acting as crack initiation and propagation particles, on the fracture surfaces.

Keywords: Al-Si-Mg alloys; tensile test; impact test; fracture surface

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1. Introduction

Al-Si-Mg alloys are the most common aluminum alloys used for automotive castings (Zapp et al. (2002); Miller et al. (2000)). These materials are characterised by excellent castability, good corrosion resistance, high elongation and significant strength, particularly after proper heat treatments. In the last decades, the light weighting of cars and trucks has become a very widely discussed theme (European Aluminium Association (2013)) and the object of several researches performed by both the academic and the industrial world. The design of more efficient processes and the development of stronger and lighter materials enhance the reduction of weight of cars and trucks components, allowing the reduction of fuel consumption and toxic emissions in atmosphere. For these reasons, an innovative AlSi3Mg alloy with Cr and Mn addition was developed for the production of truck wheels by means of a non-conventional hybrid technique, which combines features of both low pressure die casting and forging processes (Tocci et al. (2015)). The aim is the light-weighting of this component by enhancing the mechanical properties of the alloy due to a particular efficient casting technology and the presence of Cr and Mn as strengthening elements. In fact, in Al-Si alloys, Fe is a common impurity which forms brittle needle-like intermetallics, known as β-Al_5FeSi, which are harmful for mechanical properties, particularly for tensile and fatigue behaviors (Seifeddine et al. (2008); Mahta et al. (2005); Kim et al. (2006)). Instead, Cr and Mn additions lead to the formation of globular or polygonal intermetallics (Mahta et al. (2005); Shabestari (2004); Taylor (2012)) that are less detrimental for mechanical properties than the acicular β-Al_5FeSi phase. Nevertheless, the presence of a significant amount of intermetallic phase can still represent a limit to the mechanical performance of the Cr-containing alloy and deeper investigations are needed to evaluate its effect.

In addition, heat treatment is also a key factor to consider in order to optimise the performance of any Al-Si-Mg alloy and several authors examined the effect of heat treatment parameters and chemical composition on microstructure, mechanical properties and precipitation sequence for Al-Si-Mg alloys (Sjolander and Seifeddine (2010)). For instance, Wang et al. (Wang and Davidson (2001)) studied the effect of Mg content on both solidification and precipitation behaviour of AlSi7Mg casting alloy, while Li et al. (Li et al. (2004)) investigated the ageing behaviour of Al-Si alloys with Mg and Cu addition with particular attention to the precipitation sequence. Conversely, when Cr and Mn are present in the alloy composition it was found that they do not interact significantly with Mg during ageing treatment. In fact, it was recently demonstrated that Cr-containing dispersoids already form in AlSi3Cr alloy during the solution treatment and that they contribute to the dispersion hardening of the material (Tocci et al. (2017)).

Despite the abundant information in scientific literature about this topic, heat treatment optimization is a constant issue for industrial production in order to reach a good compromise between strength and ductility. For these reasons, in the present paper tensile properties and impact toughness were investigated for the innovative AlSi3Cr alloy by changing time and temperature of the ageing treatment. Particular attention was paid to the role of intermetallic particles and the effect of ageing treatment parameters. Furthermore, the optimised performance of this alloy was compared with the properties of the commercial A356 casting alloy, currently used for the production of car wheels, in order to better evaluate the suitability of the alloy for this application.

2. Materials and methods

The alloy under investigation is an Al-Si-Mg alloy developed for the production of truck wheels by a non-conventional hybrid technique (Tocci et al. (2015)), combining features of both low pressure die casting (LPDC) and forging processes. The chemical composition is among those of the conventional alloys for LPDC and forging. In particular, the concentration of the main alloying elements is shown in Table 1.

Table 1. Main alloying elements (wt. %) for the studied alloy.

	Si	**Mg**	**Cr**	**Mn**	**Fe**	**Al**
AlSi3Cr	3.158	0.558	0.276	0.120	0.123	Balance

All the samples were drawn from the same position of the wheel (rim). Samples to be tested in as cast condition were directly machined to the proper shape for tensile and Charpy impact tests, while other samples were first machined as cylinders, heat treated and then machined to the final shape.