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Effect of heat treatments on mechanical properties and damage evolution of thixoformed aluminium alloys

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Abstract

In the present work, the effects of heat treatments on mechanical properties, microstructure evolution and damage resulting from plastic deformation of thixoformed A319 and A356 aluminium alloys, are studied. The thixoforming process can lead to the production of components that are characterized by very good mechanical properties and low porosity with a globular microstructure which is fine and uniform. The mechanical properties can be further improved through heat treatments such as T5 and T6. The prime factor influencing the damage in the alloys belonging to the Al–Si system is represented by decohesion of silicon particles resulting from the stress concentration at the particle–matrix interfaces. A statistical analysis of fractured particles after tensile tests in the as-cast and as-treated condition has been carried out in the present work; optical and scanning electron microscopy techniques have been used to characterize the microstructure and fracture surfaces of the specimens and the results are fully presented.

Keywords: Al–Si; Thixocasting; Heat treatments; Fracture behaviour; Damage

1. Introduction

The interest devoted to the study of thixoformed aluminium alloys and the effect of heat treatments on the improvement of their mechanical properties depends on the extensive use of these materials and the related technology in modern industries in particular in automotive and aerospace. One of the major reasons is that it permits the design of products characterized by lower weight and very complex geometries in a single step cycle compared to traditional techniques and materials. By using thixoforming, it is also possible to improve the tool life, the mechanical properties of the components and realize net shape products [1–3]. The extensive use of thixoformed aluminium alloys belonging to the Al–Si system is related to the possibility of obtaining defect free components in terms of void formation during casting operations. The alloys from the Al–Si system

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Table 1
Semisolid process parameters for the materials of the present study

Alloy	Reheating temperature (°C)	Reheating time (min)	Solid fraction (%)
A356	583	15	50
A319	578	15	50

are the most widely used in the foundry industry thanks to their good castability and high strength-to-weight ratio; the microstructure of such materials consists of a primary phase, aluminium or silicon, and an eutectic mixture of these two elements. The aluminium alloys A319 and A356 exhibit mechanical properties higher in the thixocast condition than showed by alloys produced with traditional casting techniques [4,5]. Aluminium alloy thixoformed at a liquid fraction of around 50% presents, with respect to its 100% liquid homologue used in conventional high pressure die casting, three major differences [4]: (i) a much higher viscosity, that permits the injection of the material at relatively high speeds; (ii) a lower heat content allowing a considerable increase in production rate and (iii) less contraction during solidification reducing porosity formation. Moreover, the solidification structure is uniformly fine throughout the part and independent of local thickness. The industrial process comprises two steps after the production of the thixotropic alloy: reheating of feedstock slugs to the semisolid state and injection of the semisolid metal into a die by a process similar to high pressure die casting. The excellent mechanical properties are due to the globular microstructure which is very fine and homogeneous and is accompanied by very low levels of porosity produced

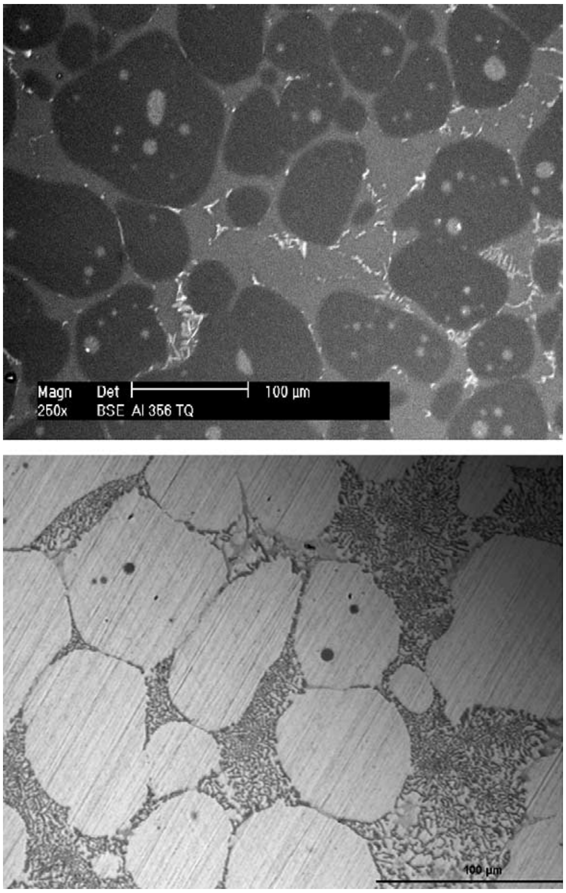

Fig. 1. Microstructure of the as-thixo A356 and A319 aluminium alloys showing the semisolid structure of the material.

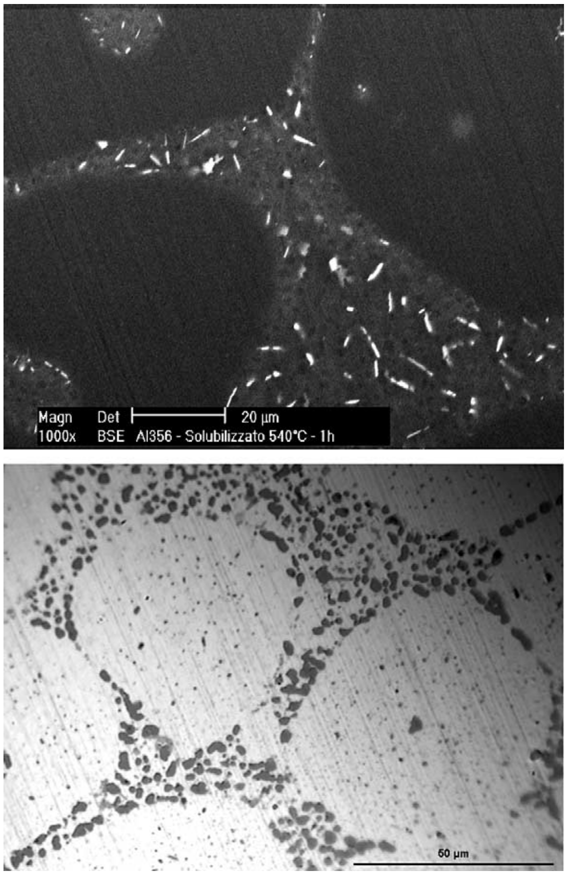

Fig. 2. Microstructure of A356 and A319 aluminium alloys after solution treatment showing the spheroidization of silicon particles.