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Semi-Solid Processing of Aluminium A201 – expectations and fulfilment

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Semi-Solid Metal Processing (SSM) or Thixoforming is the near net shaping of metals in the semi-solid state, i.e. within the freezing or melting range between the fully solid and fully liquid states. A201 is a copper containing casting alloy with additional small quantities of magnesium, silicon and silver. Although this alloy is difficult to cast, it has a particularly high response to age-hardening and therefore offers mechanical properties close to the wrought 2014 alloy. Alloy development experiments carried out at the University of Sheffield on A201 alloy have shown that feedstock of this alloy can be produced having uniform non-dendritic microstructures amenable to thixoforming, exhibits thixotropic properties under these conditions, can be shaped into complex near net-shape parts and develops impressive mechanical properties after appropriate heat treatment. A201 alloy billets thixoformed in the semi-solid state, heat treated with a T7 followed by T6 heat treatment before being mechanically tested with properties approaching these of wrought alloys. Here follows a review of work done to date on shaping the A201 aluminium alloy in the semi-solid state describing the hopes, expectations and fulfilment of researchers in the field.

Keywords: *A201 aluminum alloy; Non-dendritic feedstock; Thixoforming; Semi-Solid Metal Processing; Mechanical Properties*

1. Introduction

Thixoforming, the near net shaping of metals in the semi-solid state, relies on material that has a non-dendritic microstructure that exhibits thixotropic properties, i.e. when undisturbed the material remains stiff and holds its shape so it can be readily handled, but rapidly thinning and behaving like a liquid when put under shear. This behavior is the key to the thixoforming process where material flows as a semi-solid slurry into a die, as in conventional die-casting. This behavior is exhibited in all metal alloys that possess a microstructure that consists of metal spheroids e.g. α-Al in aluminum alloys, surrounded by a contiguous layer of eutectic liquid when heated to the semi-solid state.

The thixoforming process offers a number of advantages over both the casting and forging processes, such as fine, uniform and virtually free of porosity microstructures, products that may be heat-treated to give mechanical properties superior to those of casting, reduced energy consumption and reduced die thermal shock and therefore longer die-lives, due to the lower heat content of the semi-solid material. In addition, higher melting point alloys, such as hypereutectic aluminum-silicon alloys with very high silicon contents (~25-40%), superalloys or tool steels, which cannot be easily be die cast, may nevertheless, be thixoformed.

However, even though the potential of the process is clear to see and through its long history had numerous attempts to full commercialization, it has only been successfully exploited in a limited number of cases [1], using mainly conventional aluminum casting alloys of the AlSi7Mg type (A356 and 357).

At Sheffield we looked at the A201 copper containing casting alloy with additional small quantities of magnesium, silicon and silver and although this alloy is difficult to cast, it has a particularly high response to age-hardening and therefore offers mechanical properties close to the wrought 2014 alloy, therefore making it an idea candidate for thixoforming applications with potential to be used in aerospace.

1.1 Work on Aluminum A201

Although A201 is castable, it suffers from hot-shortness. However, better casting procedures and process control approved by the Casting Technology International has improved the situation. A201 is sand cast, permanent mold and investment cast into parts such as structural castings members, aerospace housings, electrical transmission line fittings, insulator caps, truck and trailer castings, and applications

requiring highest tensile and yield strengths with moderate elongation. A201 castings also find applications in gasoline engine cylinders heads and pistons, turbine and supercharger impellers, rocker arms, connecting rods, missile fins, and other applications where elevated temperatures are important, as well as structural gear housings, aircraft landing gear castings, ordnance castings, pump housings and other applications where high strength and high energy- absorption capacity are required.

A factor that has kept the A201 cast alloy products from being widely used in aerospace applications has been its low elongation and the lack of fatigue property data. Thixoforming A201 has provided some evidence of good mechanical properties, almost doubled the elongation over conventional castings and encouraging data on fatigue behavior [2,3] showing that the alloy holds considerable promise if the data can be reproduced and the manufacturing route optimized both for its technical as well as its commercial aspects. The fact that the fatigue data were impressive, triggered thixoforming trials on the A201, conducted at the University of Sheffield's Advanced Manufacturing Research Centre producing a quite favorable comparison between the mechanical test results for the thixoformed and heat-treated A201 and a similar wrought alloy, 2014. These results were encouraging and showed that the target values for ultimate tensile strength and elongation of the standard as cast A201 (480 MPa UTS and 7% E), have been matched and bettered by the thixoformed alternative (480 MPa UTS and 13% E) and that these values are quite well compared to those of the wrought 2014 at 480 MPa UTS and 13%E [3].

2.1 Thixoformed products

Successful thixoforming of aluminum alloys has been carried out over the years in a number of applications, especially of automotive parts and these have been publicized in the wider literature [1, 4].

A commercial application of thixoforming the high strength casting alloy 201 into impeller shapes has been recently published [5]. The same authors have shown that heat treatment trials on material cut from the impeller were carried out to compare T7, T71 and T71* conditions and their hardness results suggest that T71 with an ageing time of just under 3 hours give the optimum behavior and their results also show an enhancement relative to the ASM Handbook recommended value for T7 treatment.

3. Discussion & Conclusions

Work carried out on the high strength A201 casting alloy has provided us with a lot of useful information as well as data of mechanical properties that are very encouraging.

- ✓ A201 aluminum alloy can be shaped into near net-shapes by Semi-Solid Metal Processing.
- ✓ The mechanical properties of thixoformed A201 alloy parts are better than conventional castings and can approach those of wrought alloys if the process and heat treatments are optimized and appropriately controlled.
- ✓ Consistency of mechanical properties is dictated by large extent by the feedstock material used.
- ✓ The suitability of feedstock material and in effect the commercial success of this process will be cost and market driven.

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