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PURIFICATION OF HYPOEUTECTIC ALUMINIUM ALLOYS THROUGH FRACTIONAL SOLIDIFICATION

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INTRODUCTION

Aluminium recycling is an up-to-date topic nowadays and considering that the amount of automobile and aircraft dismantling is going to increase in the next year, new ways of recycling need to be found. A novel technology for purification of Al alloys based on the principles of fractional solidification, is described in the present work. Fractional solidification is a separating technique in which an alloy is processed in the semisolid state with its solutes partitioned between the solid and liquid phases. In fact during the crystallization process, there is always a distribution of solutes atoms that differ from the homogenous distribution in the initial liquid even if the total amount of them does not change. In the case of those elements that have a partition coefficient less the one (e.g. Fe, Si, Cu, Mg), while the solidification proceeds, the crystal structure of the forming solid cannot accommodate solute atoms, and these are rejected at the interface enriching the liquid phase. If it could be possible to get rid of the solute-enriched liquid fraction in the middle of the solidification process, the purified solid fraction could be extracted. Based on an idea developed by Flemings (Lux & Flemings, 1978) but tested only on Sn-Pb alloys and on a small scale, an isothermal compression of an aluminium alloy slurry towards a filter is described. Figure 1 shows a schematic representation and an image of the set-up. Each experiment was conducted using 1500 g of the prepared alloys molten in clay-graphite crucibles in a standalone electric furnace. Once molten and superheated to 750°C, the alloys were taken out of the furnace and cooled in air until reaching a desired temperature reflecting 50% of the solid phase as estimated by Thermocalc software using the Scheil equation. Once this semisolid temperature was reached, the slurry was poured into the cylindrical furnace on top of the heated filter (set to the same temperature) and squeezed by a pre-heated steel piston. The purer fraction solidified on top of the filter, while a liquid fraction enriched in the impurities went through it and was collected in the reservoir.

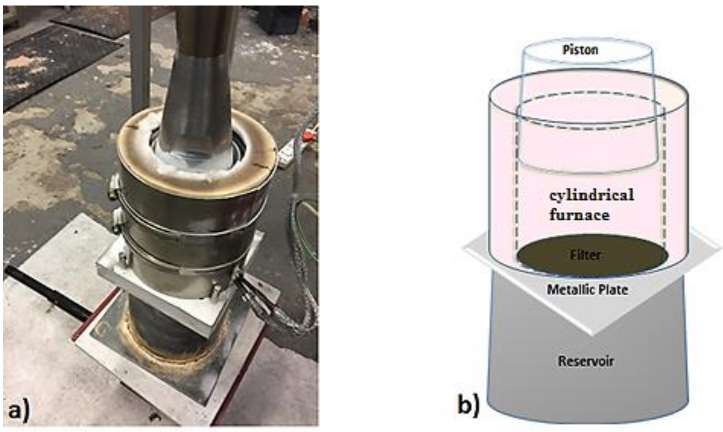

Figure 1. Experimental setup: (a) Assembled set-up and (b) schematic.

The purified fraction was cut from the filter and ground with SiC abrasive paper to get a clean and flat surface to be analysed by an optical emission spectroscope FoundryMaster. Optical microscope images were taken on the cross section of the purified fraction along its height after being polished following the standard polishing procedure. Table I shows the composition of the model alloys prepared for the purpose of being tested on the set-up and Table 2 displays the results after the isothermal squeezing happened. It is clear that the purification process happened successfully. The level of purification between 40% for Si and Cu and 50% for Fe were achieved. The different level of purification for different alloying elements can be related to the different values of the partition coefficient and the primary solidification range.

The main challenge is to allow the liquid to flow through the mush avoiding its entrapment inside, which contributes to a higher composition. One of the known ways to improve the permeability of the mush is grain refinement. Choosing the Al- 6wt% Cu system as an example, an Al5Ti1B grain refiner (4 kg/t) was added to it. Table 2 shows that actually there is an improvement in the final purification achieved. Moreover from the optical microscope images it was possible to calculate the area of eutectic phase entrapped at the grain boundaries. In the case of the sample treated without grain refiner a eutectic volume fraction of 0.5 was obtained, while a volume fraction of 0.6 was measured in the case of a sample with grain refiner.

Table 1. Average chemical composition of the model alloys prior to purification

	Al, wt%	Si, wt%	Fe, wt%	Cu, wt%
Al- 7% Si	**92.8**±0.08	**7.0**±0.8	**0.012**±0.01	-
Al- 2% Si- 2% Fe	**96.1**±0.05	**2.0**±0.02	**1.8**±0.02	-
Al- 6% Cu	**92.5**±0.1	**0.03**±0.01	**0.1**±0.01	**6.2**±0.1

Table 2. Average chemical composition of the purified fraction and the scrap fraction of the alloys tested.

	Al	**Si**	**Fe**	**Cu**
Al- 7wt% Si				
Purified	**95.87**±0.4	**3.99**±0.4	**0.010**±0.01	**-**
Residue	**92.0**±0.09	**7.8** ± 0.10	**0.012±0.01**	**-**
Al- 2% Si -2% Fe				
Purified	**97.6**±0.1	**1.2**±0.04	**0.9**±0.07	**-**
Residue	**95.7**±0.1	**2.14**±0.07	**1.98**±0.09	**-**
Al- 6 wt% Cu				
Purified	**95.9**±0.1	**0.01**±0.01	**0.1**±0.01	**3.77**±0.07
Residue	**92.7**±0.1	**0.03**±0.01	**0.02**±0.01	**6.92**±0.12
Purified(Grain refiner)	**96.1**±0.1	**0.01**±0.01	**0.1**±0.01	**3.58**±0.08

Fractional solidification, performed as an isothermal squeezing, is working successfully to purify Al alloys. It is necessary to process the material in the semisolid state and for this reason controlling the temperature is a key aspect of the method. In order to improve the purification efficiency, more process parameters along with the permeability of the mush need to be studied and optimized.

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KEYWORDS

Fractional solidification, hypoeutectic alloys, purification, recycling, semisolid processing.

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