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EFFECTS OF INCLUSIONS ON AN Al-Cu 4-Mg1.5 ALLOY

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ABSTRACT

Filtering through refractory material is accepted as an efficient method for the removal of inclusions from the structure of aluminum-base alloys. The effects of inclusions are examined in relation to the anisotropy of the wrought aluminum alloy, Al – Cu 4 – Mg 1.5. The experimental variables selected were the filtration technique, casting methods, variations in heat treatments as well as variations in rolling reductions. Reduction in the solid particle inclusion content could be achieved by using sintered filter material. Quite high short transverse ductility could be achieved in rolled plates of commercial high strength aluminum alloy.

Key Words : Inclusion , Filtration

İNKLÜZYONLARIN Al-Cu 4-Mg 1.5 ALAŞIMI ÜZERİNDEKİ ETKİLERİ

ÖZET

Alüminyum esaslı alaşımların yapılarından inklüzyonların giderilmesi için refrakter bir malzeme içerisinden filtrasyon tekniği etkin bir yöntem olarak kabul edilmektedir. İnklüzyonların etkileri şekillendirilmiş Al-Cu4-Mg1.5 alaşımındaki anizotropi ile ilişkili olarak incelenmiştir. Seçilen deney değişkenleri filtrasyon teknikleri, farklı döküm yöntemleri, farklı ısıl işlemler ve şekil değişim oranındaki farklılıklar olmuştur. Sinterlenmiş filtre malzemesi kullanarak katı partikül inklüzyonlarında azalma sağlanmıştır. Ticari kalitede yüksek mukavemetli alüminyum alaşımlarında haddelenmiş yapıda kesitten alınan numunelerde yüksek süneklik değerleri elde edilmiştir.

Anahtar Kelimeler : İnklüzyon , Filtrasyon

1. INTRODUCTION

Aluminum played an essential role in aerospace history from its very inception. The engine crankcase used in the historic first flight of the Wright Flyer in 1903 was an aluminum alloy with 8 % copper (Gayle, 1997). The aluminum industry continues to benefit from technical innovations made in alloy development, product-manufacturing technologies, and processing equipment (Sanders, 2001). Low density and product versatility have been keys thus far in expanding aluminum's fast-growing market. Continuous molten metal is one of the process developments that have shaped the industry's production methods and markets. Different forms of molten metal filtration are routinely employed in all aluminum shape casting processes by many foundries and diecasters. Deep-bed filtration (the Alcoa 94 process) used tabular aluminum balls to trap oxide inclusions as the metal flowed from the holding furnace to the casting pit.

Inclusions are foreign particles mechanically entrapped in the metal. Scrap and remelted alloy charge, melting equipment, melting process, fluxing, deoxidising, grain refinement and pouring practices introduce inclusions into the melt. The most common inclusion in aluminum alloys is aluminum oxide which occurs in two diffrent forms: film type or gamma alumina and particle type or alpha alumina. Intermetallic inclusions, magnesium oxide, spinel, chlorides and carbides are the other common inclusions. The size, shape and distribution of inclusions are governed by their composition, the buoyancy and convective forces in the melt and by the solidification speed.

Removal of inclusions is an important factor in producing sound aluminum castings. Some fluxing and filtration methods such as Alcoa-94 are proposed for this purpose. For an efficient filtering, the most important factors that must be considered are composition, chemical-physical stability, wettability, size, shape and depth of filter material as well as the filter unit design and technique.

Inclusions may greatly affect the mechanical properties of aluminum alloys. They are often the source of cracks or voids which lead to ductile rupture. Directionality problems are often associated with inclusions. Variations in mechanical properties with direction are important in two respects: a) in forming the material to the required shape, b) on the behaviour of the material in service.

Directionality of mechanical properties can be explained by crystallographic and mechanical fibering. Mechanical fibering, the dominant type, arises because the pre-existing pattern of matrix discontinuities is modified by deformation. These modified discontinuities are: a) aligned brittle intermetallic particles, b) aligned foreign matter, oxides etc., c) unhealed porosity, d) aligned precipitated boundaries.

The aim of the experiments was to create a variety of structures showing the effects of inclusions on the mechanical properties of an Al-base 4.1 % Cu, 1.5 % Mg, 0.05 % Si alloy (Dündar, 1976; Dündar and Yılmaz, 1984).

2. EXPERIMENTAL PROCEDURE

Three main variables were thought to give different mechanical properties: a) changes in the amount of inclusions, b) changes in the structure of the matrix in which the inclusions are embedded, c) changes in the direction from which test specimens are taken.

Swarf was added to all the melts in order to introduce a considerable amount of inclusions. Presolidification, fluxing, degassing and filtering treatments were applied to clean one group of melts from the inclusions whereas the other group was intentionally left untreated.

The alloy was cast with and without filtration, using both a semi-continuous casting machine and static cast iron moulds. Filtration was carried out using kalbrite, a pelletised and calcined ball clay, in both the loosely compacted form and after sintering at 1000 C.

Deformation by hot rolling was thought to create stringers of inclusions in the matrix. To show the detrimental effects of inclusions, specimens were prepared from short transverse, transverse and longitudinal directions.

Solution treament at 495 ºC for two hours and artificial aging at 180º for 7.5 hours were employed to obtain structures of differing hardness.

3. RESULTS AND DISCUSSION

In the unfiltered conditions the mechanical properties, (particularly ductility), of the material derived from static castings was distinctly inferior to that from semi-continuous castings (Figure 1).

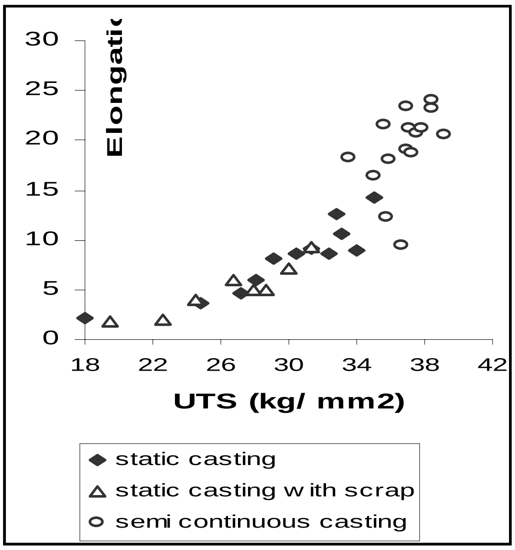
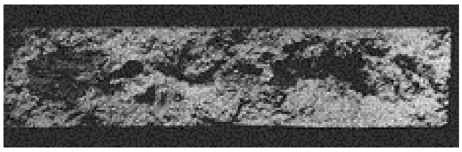


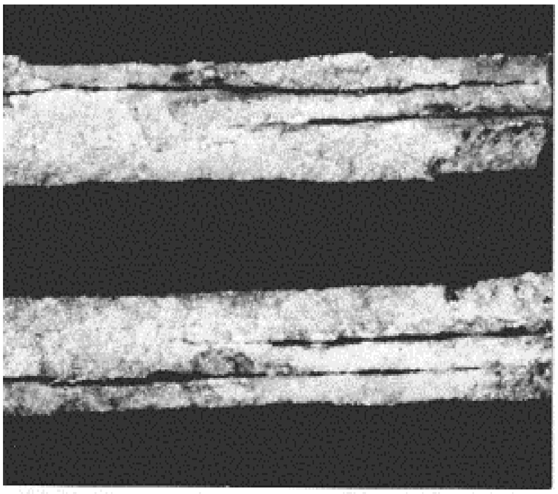
Figure 1. Mechanical properties of castings

The principal cause of these differences was the presence of numerous oxide film inclusions in the statically cast material (Figure 2 a, b). Such extremely harmful inclusions does not exist in the continuously cast material.



(a)

Figure 2a. Oxide film inclusions, fracture surface



(b)

Figure 2b. Oxide film inclusions, transverse direction

The entrapment of oxide films in the statically cast ingots may have been associated in part with the more turbulent pouring in the early stages of mould filling. The unidirectional mode of freezing in continuous casting was probably the most important factor contributing to the non-existance harmful oxide film inclusions in the continuously cast material .

Oxide film inclusions lower the mechanical properties in the short transverse direction to low and undesirable values (Table 1).

Table 1. Effect of Directionality on Mechanical Properties of Static Casting (U: Unfiltered, F : Filtered)

		UTS	Elong.	Red.in
		Kg/mm²	%	Area %
Short	U	20.4	2.6	4.1
Transverse	F	24.8	4.5	8
Transverse	U	28	7.5	10.8
	F	29.1	12.2	21.6
Longitudinal	U	29.3	17.1	33.2
	F	29.6	18.1	35.6

Filtration using unsintered kalbrite was effective in greatly reducing the amount of oxide film inclusions in the statically cast material. However, it did not give any significant improvement in the mechanical properties of the continuously cast material. This was as expected since the filter material was much less effective in trapping small compact inclusions. Results with the continuously cast material show that although unsintered filter is effective in removing oxide films and large particles it can add smaller nonmetallic inclusions (Figure 3). Thus it can cause deterioration of an initially clean melt.

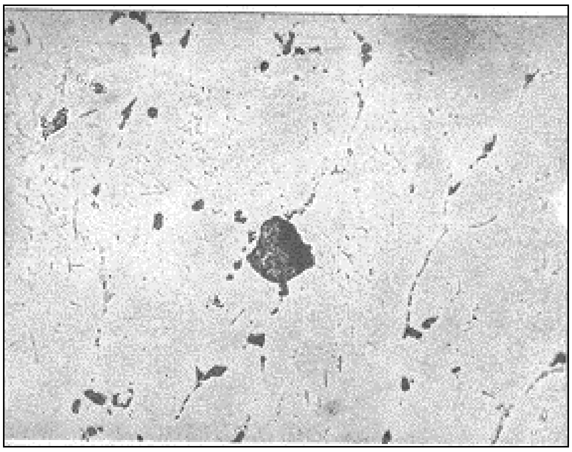


Figure 3. Nonmetallic particle inclusions in the matrix

Results with the sintered kalbrite filter have shown distinct evidence of improvement in ductility properties both for the statically and semi-continuously cast material (Figure 4).

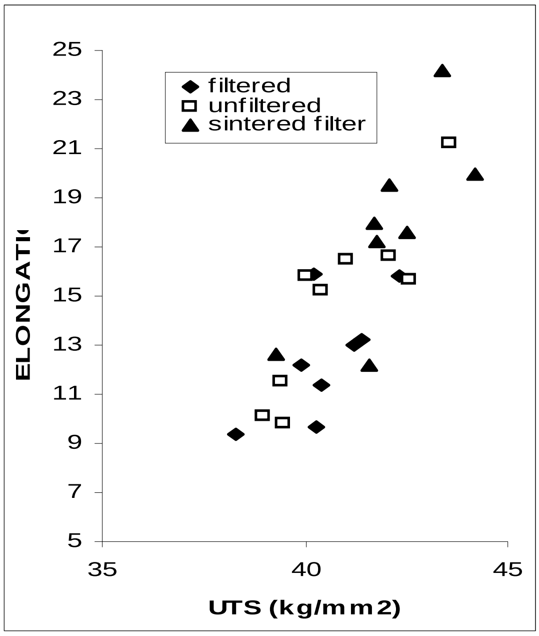


Figure 4. Effects of filter materials on mechanical properties of semi continuous casting

4. CONCLUSION

Filtration can be helpful under conditions of casting where oxide film inclusions present a problem, but much more reduction in the solid particle inclusion content of the melt can be achieved by using sintered filter material. By this means quite high values of short transverse ductility can be achieved in rolled plates of commercial high strength aluminum alloys.

5. REFERENCES

Dündar, S. 1976. “The Effects of Inclusions on Mechanical Properties of Wrought Aluminum Alloys”, M.Sc.Thesis , University of Birmingham.

Dündar, S. and Yılmaz, F. 1984. “Inklüzyonların Aluminyum Alaşımlarının Mekanik Özelliklerine Etkisi” 2nd National Aluminum Congress, 311- 322.

Gayle, F. W. 1997. Philosophical Society of Washington , Minutes of the 2078 th Meeting.

Sanders, R. E. Jr. 2001. “Technology Innovation in Aluminum Products” **JOM**, 53 (2), 21-25.