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ABSTRACT

The paper describes a new in-line technology for complex treatment of secondary aluminium and aluminium alloys which combines metal filtering, alkali removal and degassing operations into a single unit.

Process hydrogen removal efficiencies are expressed as a percentage of original hydrogen content.

The relationship between melt velocity and filtration efficiency, and height of filter and filtration efficiency were examined. The CTT system showed superior chlorine utilization efficiency compared to other comercialized in-line technologies.

The CTT process offers superior secondary metal treatment performance in terms of inclusion removal and comparable hydrogen and alkali removal efficiencies.

INTRODUCTION

Molten secondary aluminium contains various kinds of indigenous (Al_2O_3, $MgAl_2O_4$, TiB_2, nitrides) or exogenous (refractory particles such as AL_2O_3, SiO_2, SiC) inclusions, dissolved hydrogen and light metal impurities (such as sodium, calcium and lithium).

The requirement for higher quality and lower impurity level aluminium alloys has governed the development of a large number of molten metal treatment processes. As a result of this require-

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ment, more and more work has been conducted over recent years with the aim of developing improved in-line degassing and filtration systems[1 - 3]. Most of todays systems, ensuring the transfer of impurities out of the melt are based on one or more of the principles: sedimentation,flotation or electromagnetic forces.

This paper describes a new in-line complex treatment technology (CTT), which combines two processes : degassing and filtration in a single system to provide improved quality of aluminium melt.

EXPERIMENTAL

As illustrated in Figure 1, the CTT process consists of a heated, in-line treatment vessel with separate chambers for degassing and filtration of aluminium melt[4].

The degassing chamber is equipped with two porous plugs, through which gas mixture (Ar + 1...3 % Cl_2) is piped. The gas small bubbles ascend upward, in a counter current sense with respect to the molten metal flow.

The filtration chamber contains two layers bed: (a) titanium sponge and (b) flux covered alumina ball and tabular alumina granules.

The titanium sponge layer retains the inclusions and minimize the hydrogen content of the liquid aluminium.

The filtration bed contains flux (52% $MgCl_2$+20 % KCl+16 % MgF_2+ 12 % CaF_2) covered alumina balls and tabular alumina granules.

The melt was prepared by heating a secondary aluminium to 1023°K in an gas-fired furnace.

The inlet melt and filtered melt were sampled at regular intervals for subsequent analysis of inclusion, hydrogen and sodium contents.

RESULTS AND DISCUSSION

Hydrogen removal is effected by counter-current flow of molten aluminium and a blend of inert (Ar) and reactive gase (1...3 % Cl_2). Degassing is a mass transfer operation where dissolved monoatomic H in aluminium diffuses into an ascending sparging gas bubble with virtualy zero hydrogen partial pressure and forms H_2. The hydrogen is removed with the ascending bubbles.

The driving force to remove hydrogen from melt is controlled by Sieverts law. As hydrogen solubility in the aluminium is affected by both temperature and concentration of alloying elements, the measured hydrogen concentration was corrected as[5]:

$$[H] = S_0 \cdot \sqrt{p_{H_2}} \cdot CF(A) \cdot CF(T).$$

where S_0 is the solubility of hydrogen in pure aluminium at 973°K and equals 0.92 ml H_2/100 g.

CF (A) is the correction factor for alloy composition (= 1 for pure metal) and are based on work published by Doutre and Dewing ;

$$\log CF(A) = 0.017\ \%\ Mg - 0.0269\ \%\ Cu - 0.0119\ \%\ Si;$$

CF (T) is the correction factor for metal temperature which is derived from solubility - temperature curves for pure aluminium ;

$$\log S(T) = -\frac{2760}{T(K)} + 2.796$$

$$CF(T) = \frac{\log S(T)}{\log S(973)} = 10^{(-2760/T + 2{,}837)}$$

Process hydrogen removal efficiencies are expressed as a percentage of original hydrogen content

$$\eta_H = (H_I - H_F) / H_I \cdot 100\ (\%),$$

where H_I - initial hydrogen content and

H_F - final hydrogen content (ml/100 g) .

Typical degassing efficiencies obtained whith the CTT system are shown in Figure 2. Process degassing efficiency may be considered to be a function of alloy type, purging gas type, purging gas flow rate, purging gase / aluminium contact time,mass transfer coefficient of hydrogen (1.10^{-4} to 7.10^{-4} m/s) .

The inclusions deposit onto the grains of the filter medium due to surface forces, diffusion, gravity and direct interception.

The filtration efficiency defined as

$$\eta_F = (S_U - S_F) / S_U \cdot 100\ \%\ ,$$

was calculated by microscopic measurement of the per cent area occupied by the inclusions in unfiltered (S_U) and filtered (S_F) aluminium samples.

Figure 3 shows the filtration efficiency as a function of melt velocity.

Figure 4 shows the effect of filter height (L) on the filtration efficiency.

Thus, it is certain the CTT system has excellent efficiency in inclusion removal.

The alkali / alkaline earth impurities (Na, Li, Ca) dissolved in the molten aluminium are transferred by diffusion through the bulk metal to the treatment gas bubble where they are removed by reaction :

$$x\ M + \frac{y}{2}\ Cl_2 \longrightarrow M_xCl_y\ .$$

Alkali removal efficiency depend on the amount of chlorine injected into the melt during treatment and on the height of the liquid metal in the degassing chamber. The CTT system showed superior chlorine utilization efficiency compared to other comercialized in-line technologies. The final concentration of sodium in aluminium complex treated melt was 5 to 10 p.p.m.

CONCLUSIONS

The CTT system is a new in-line metal treatment technology combining both degassing and filtration in a single comparatively lower capital cost unit.

When compared to conventional degassing technology, the CTT process offers superior secondary metal treatment performance in terms of inclusion removal and comparable hydrogen and alkali removal efficiencies.

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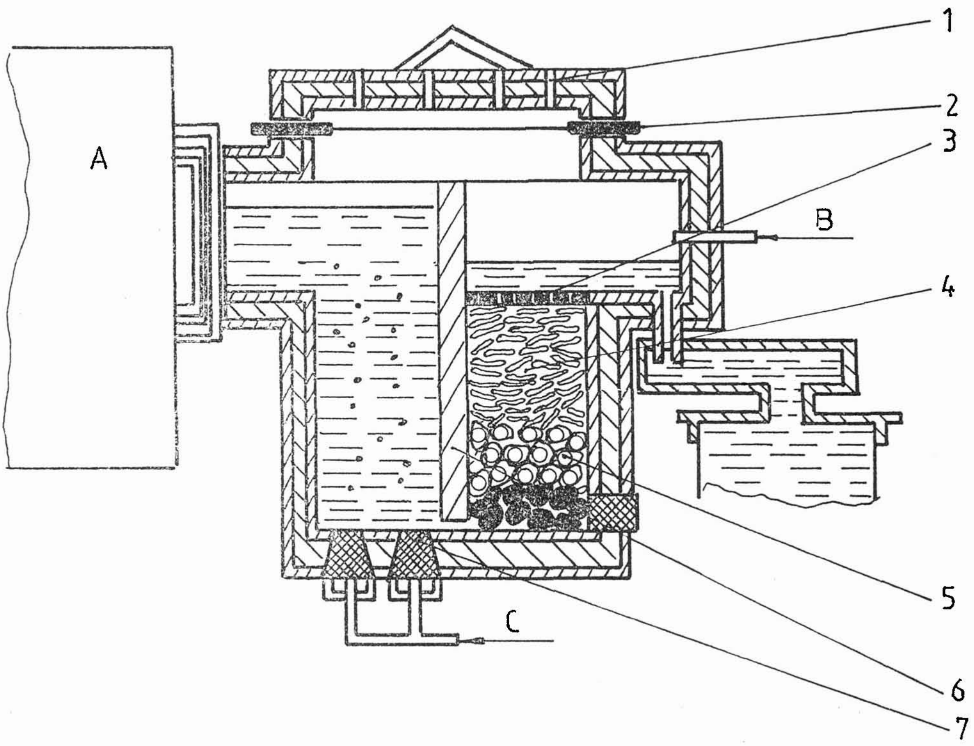

Fig.1.- Schematic of the C T T in-line Metal Treatment Process:

1. - orifice ;
2. - SIC resistors ;
3. - perforated support plate ;
4. - tabular alumina bed ;
5. - flux - covered alumina balls ;
6. - refractory wall ;
7. - porrous plug ;

A. - melting and holding furnace ;
B. - inert gase ;
C. - Ar + Cl_2 mixture ;

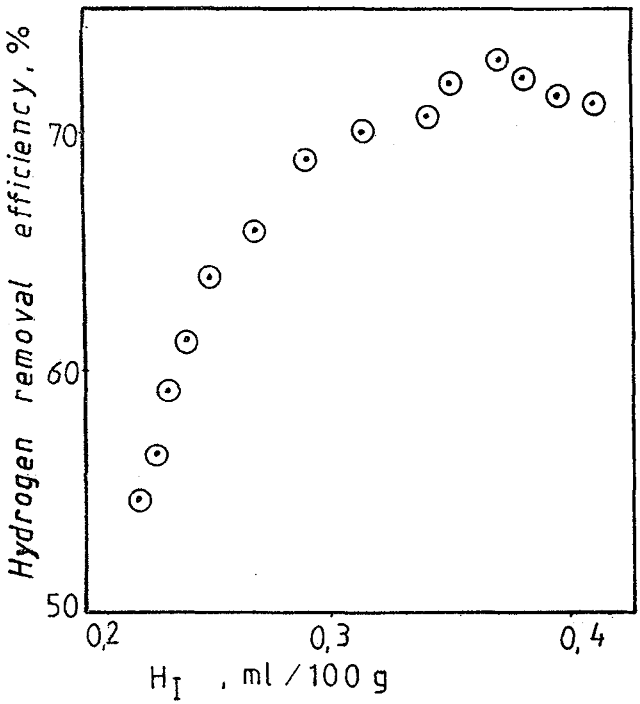

Fig.2.- Hydrogen removal efficiency

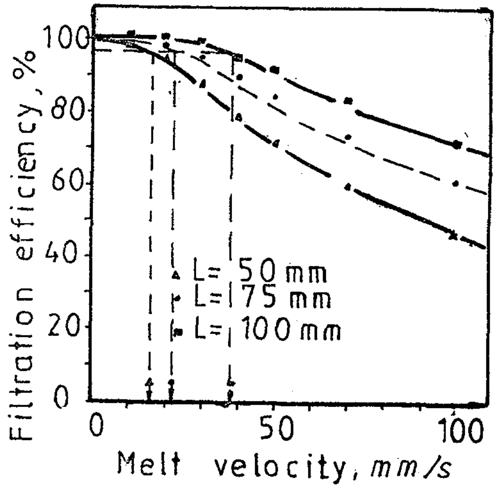

Fig.3.- The filtration efficency as a function of melt velocity.

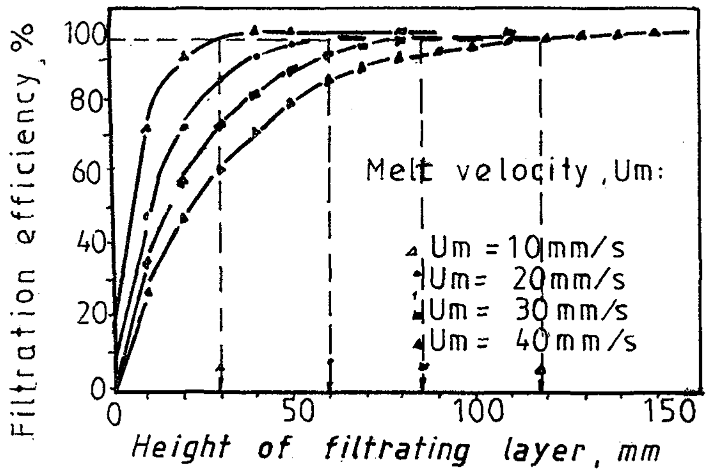

Fig.4.- Effect of filter height on the filtration efficiency .