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## AZ91D-1.5Ca O

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Employing non-flammable AZ91D-1.5CaO Eco-Magnesium® (Eco-Mg) alloy in the European project CRAL provides the lowest carbon footprint for magnesium cast process. Non-flammable magnesium AZ91D alloyed with Ca (in the form of CaO) is processed by experimenting specific casting process window to melt the non-flammable magnesium in a furnace with no SF6 cover gas and then poured in the air into a vertical short-injection die.

Brake leverages AZ91D-1.5CaO Eco-Mg series alloy was successfully manufactured at Brembo Spa premise, as a real example of sustainable manufacturing relative to the current component made of forged aluminium alloy. As discussed in the experimental and computer-aided simulation test campaign reduced uncertainty in cast trials. The CRAL EU project AZ91D-1.5CaO Eco-Mg-SF6 free cast part for brake systems has promoted the drastic reduction of Global Warming Potential (GWP) of the cast process route. The Eco-Mg series is a feasible and affordable casting solution for introducing magnesium alloys in the automobile sector; today struggled for researching cost-driven lightweight components under increasing CO2 emissions restrictions.

**KEYWORDS:** MAGNESIUM, CALCIUM OXIDE, SUSTAINABLE METALLURGY;

### INTRODUCTION

Led in the last century by the aerospace industry, the development of magnesium alloys has historically occurred to meet the needs of the transport industry, which sought to find advantages on additional strategies related to weight reduction. Compared to aluminum alloys, magnesium has a high castability and reduced chemical compatibility with the steel used in constructing the molds. This property makes it possible to realize part geometry at very high complexity (similar to those realized with plastics), extending steel molds' lifespan.

Although these are great promising features, safety is still a concern due to high flammability when magnesium is treated in the air. Once ignited, magnesium proceeds with its self-combustion sustained by an exothermic reaction forming magnesium oxide, releasing heat. As a result, the combustion flame rapidly reaches temperatures between 2,000 ° K and 4,000 ° K. For this problem, magnesium

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alloys require unique melting plants and expert personnel, increasing the production cost of cast parts. To safely control Mg alloys in the molten state, it is necessary to eliminate the presence of O<sub>2</sub> in contact with the metal bath; that is to say, it is necessary to eliminate the primary trigger source of the Mg combustion reaction. Removing oxygen is possible by creating inert atmospheres towards the molten Mg. Various techniques are used in Mg foundries divided into a) vacuum melting plants, b) melting plants equipped with inert and protective atmospheres of the Mg bath. The inert atmospheres usually used are mixed SF<sub>6</sub> and CO<sub>2</sub>, based on freon gas R-134a and SO<sub>2</sub>. Both SF<sub>6</sub> and freon gas R-134a are greenhouse gases with very high global warming potential (GWP).

In contrast, SO<sub>2</sub> gas, despite being a valid alternative to greenhouse gases SF<sub>6</sub> and R-134a from an environmental point of view, requires stringent application protocols due to its high toxicity for operators. The SO<sub>2</sub> gas would be a green solution against SF<sub>6</sub>, but it is highly corrosive to the equipment made of steel; it reacts readily with water to form H<sub>2</sub>SO<sub>3</sub>, thus provoking health risks for workers,

especially for the skin and lungs. Compared with SO<sub>2</sub>, SF<sub>6</sub> is non-toxic, non-corrosive, but due to the negative impact on the greenhouse effect, by 1 January 2018 in the European Union, SF<sub>6</sub> has been prohibited in magnesium die-casting in the recycling of magnesium die-casting alloys [1].

Today it is common knowledge that the choice of lighter materials for manufacturing combustion engine-powered vehicles plays a crucial role in reducing emissions. For automakers, the weight saving is not only a key strategy to be compliant with a green-consciousness market pushed by demand more and more aware of the environmental and social impact that comes with eco-responsible purchases. The new stringent targets set in the EU for the fleet-wide average emissions of new cars and vans include, together with penalty payments for excess emissions, a mechanism to incentivize the uptake of zero- and low-emission vehicles. However, cleaning up vehicle emissions at the tailpipe is an effective but part

aring ores (like dolomite) with silicon (usually supplied in form of ferrosilicon) is conducted in coal-fired retorts [2]. Furthermore, due to its reactivity, magnesium needs to be cast from the melt using protective gases. In the past, SF<sub>6</sub> as a cover gas, was replaced by mixtures of nitrogen and FC-134a. Recently the Novec 612 fluid from 3M Company promises a very low GWEP and low CO<sub>2</sub>. Several studies have shown that the largest part produced by raw material fabrication is the first and secondly sha-

ped by casting using pollutant cover gases could not save CO<sub>2</sub> within the car's lifespan [3].

The high Mg reactivity with oxygen is the low density of the magnesium oxide layer formed during melting in the presence of oxygen. Although various metals form a thick, dense, and non-porous oxide layer, this does not apply to magnesium [5-9]. The volume change between molten metal and the oxide layer formed on the top surface is responsible for surface stresses (Fig.2).

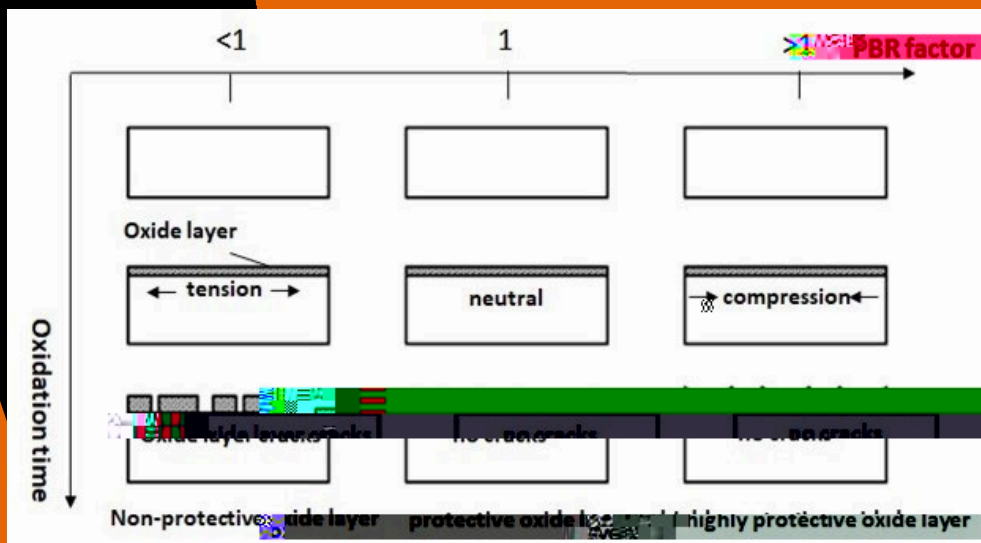


Fig.2 - The PBR explains the temperature oxidation behavior of different metals and their oxides in correlation with the porous oxide film developed by air oxidation.

elimination of protective gases during the cast part manufacturing (protective gases is still used for master alloy production).

#### **E E IMEN AL OCED E**

A commercial Eco-Mg series alloy AZ91D with a nominal composition of 8.5% Al, 0.75% Zn, 0.3% Mn, Fe and Ni below 0.001%, and Mg as a balance modified with

1.5%CaO provided by Korea Institute of Industrial Technology was employed as experimental material. The as-cast microstructure when supplied in ingot and it shows usual microstructure of high aluminum content casting magnesium alloy with coarse structure of  $\beta$ -Mg and the network of eutectic  $\beta$ -Mg<sub>17</sub>Al<sub>12</sub> compound discontinuously distributed at the grain boundaries (fig. 3).

## E L AND D ION

An AZ91D component with the addition of 1.5%CaO compound was found to be a good uses of SF6 since it has been banned for its use in industry in Brembo foundry. To that scope, the Eco-Mg AZ91D-1.5CaO has been employed for the production of magnesium in a

## CONCLUSION

A vertical high-pressure die-casting process was performed with an AZ91D-CaO added magnesium alloy to manufacture the first prototype of magnesium brake leverage without using highly environmentally impacting protective gases usually employed in casting conventional magnesium. A net reduction of 32% weight has been obtained compared to the current aluminum-made part. The process route employed has been successfully conducted safely in the air, thanks to very compact cycle time. This preliminary test campaign puts some promising premise to the affordable cover gas-free die-casting process by such results. Furthermore, the possibility of processing commercial Eco-Mg system alloys in the air in a compact and low-cost press machine that can work for Mg and Al alloys is an interesting perspective for increasing machine occupancy, one key economic aspect to consider in industrial manufacturing processes.

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