E - [illegible] : GHG - [illegible] A[illegible]91D-1.5C[illegible]O [illegible]

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Employing no[illegible]able AZ91D-1.5CaO Eco-Magnesium® (Eco-Mg) alloy in the European project CRAL provides the lowest ca[illegible]tprint for the magnesium cast process. Non-flammable magnesium AZ91D alloyed with Ca (in the form of C[illegible]ccessfully processed by experimenting specific casting process window to melt the non-flammable magn[illegible] in a stationary furnace with no SF6 cover gas and then poured in the air into a vertical short-injection disp[illegible]ress machinery specifically developed in EU CRAL project.
Brake leverag[illegible]Z91-1.5CaO Eco-Mg series alloy was successfully manufactured at Brembo Spa premise, as a real example[illegible]omponent alternative to the current component made of forged aluminium alloy. As discussed in the exp[illegible]t, a preliminary computer-aided simulation test campaign reduced uncertainty in cast trials. The CRAL EU[illegible]e realization of Mg-SF6 free cast part for brake systems has promoted the drastic reduction of Global War[illegible](GWP) of the Mg cast process route. The Eco-Mg series is a feasible and affordable casting solution for int[illegible]flammable Mg alloys in the automobile sector; today struggled for researching cost-driven lightweight[illegible]ue to forthcoming CO2 emissions restrictions.

KE[illegible]ORDS: MAGNESIUM, CALCIUM OXIDE, SUSTAINABLE METALLURGY;

IN[illegible]OD[illegible]C[illegible]ION

Led in the last century by the [illegible]e industry, the development of magnesium alloys h[illegible]torically occurred to meet the needs of the transport ind[illegible]stry, 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_2 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_6 and CO_2, based on freon gas R-134a and SO_2. Both SF_6 and freon gas R-134a are greenhouse gases with very high global warming potential (GWP).
In contrast, SO_2 gas, despite being a valid alternative to greenhouse gases SF_6 and R-134a from an environmental point of view, requires stringent application protocols due to its high toxicity for operators. The SO_2 gas would be a green solution against SF_6, but it is highly corrosive to the equipment made of steel; it reacts readily with water to form H_2SO_3, thus provoking health risks for workers, especially for the skin and lungs. Compared with SO_2, SF_6 is non-toxic, non-corrosive, but
due to the negative impact on the greenhouse effect, by 1 January 2018 in the European Union, SF_6 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 partTw 0vheasu0.5 (f0.6qns)30 (es

aring ores (like dolomite) with silicon (usually supplied in from of ferrosilicon) conducted in coal-fired retorts [2]. Furthermore, due to its high reactivity, magnesium needs to be cast fo[illegible] product shaping using protective gases. In the past, SF[illegible] the preferred cover gas, was replaced by mixtures of [illegible]2 and SO2 by HFC-134a. Recently the Novec 612 flui[illegible]istered by the 3M Company promises a very low GW[illegible]1, equivalent to CO_2. Several studies have shown t[illegible]gnesium auto part produced by raw material fabric[illegible] Pidgeon process and secondly shaped by casting using pollutant cover gases could not save CO_2 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).

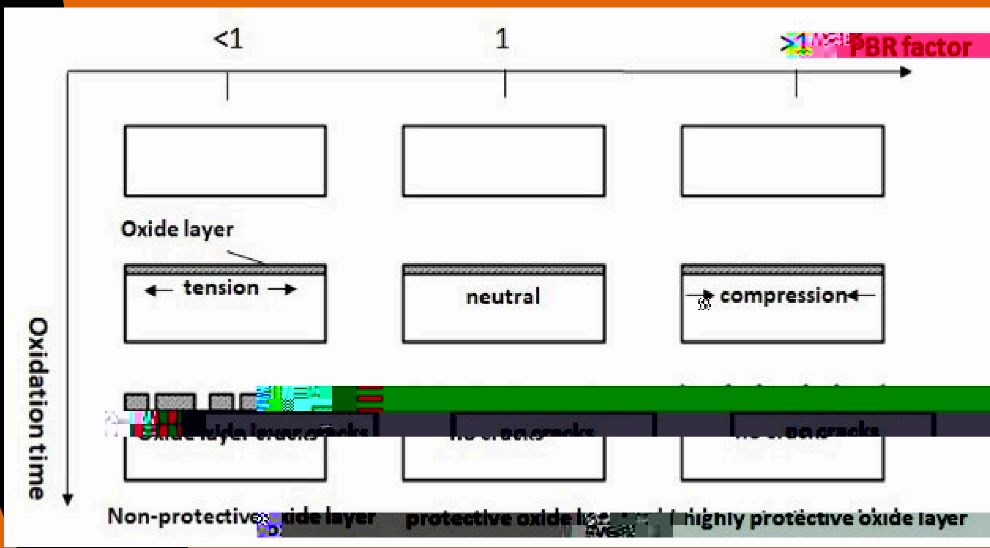

Fig.2 - The PBR [illegible]f the high temperature oxidation behavior of different metals and their oxides in c[illegible]h porous or non-porous oxide film developed by air oxidation.

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

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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 magne-sium alloy with coarse structure of α-Mg and the network of eutectic β-$Mg_{17}Al_{12}$ compound discon-tinuously distributed at the grain boundaries (fig. 3).

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An AZ91D commercial alloy with the addition of 1.5%CaO compound was tested, avoiding uses of SF6 since it has been banned for die-casting process in Brembo foundry. To that scope, the commercial Eco-Mg AZ91D-1.5CaO has been employed to retard oxidation of magnesium in a

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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 environ-mentally impacting protective gases usually employed in casting conventional magnesium. A net re-duction of 32% weight has been obtained compared to the current aluminum-made part. The pro-cess 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 consid-er in industrial manufacturing processes.

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