ENVIRONMENTAL IMPACT AND CORROSION BEHAVIOUR ASSESSMENT OF MAGNESIUM CASTINGS

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KEY WORDS: Magnesium, LCA, Eco-design, CES

ABSTRACT

The use of magnesium and its alloys is limited by their high susceptibility to corrosion, that may be attributed to the presence of critical impurities and to the high chemical reactivity of the magnesium itself. Such characteristic justifies the great interest of performing coating technologies for the protection of magnesium parts by using environmentally friendly and cheap processes, with particular relevance in the framework of the European context.

While magnesium technologies are rapidly taking advantages of the research results obtained during the last years, some more efforts are necessary to evaluate the impacts of its production on the environment and on the use of existing energy resources. Following this main lines, the paper presents some results obtained in NANOMAG ("Development of Innovative Nanocomposite Coatings for Magnesium Casting Protection" – Growth Programme n. 40548), a research project sponsored by the European Commission in which magnesium and its coating processes are evaluated taking into account also their environmental performances with a life-cycle approach.

OBJECTIVE

The purpose of the study is to quantify energy, resources consumption and emission of pollutants to the environment resulting from cradle-to-gate analysis (eco-profile) of a magnesium ingot, according to the system boundary definition, and to propose a preliminary comparison with aluminium and titanium taking into account corrosion resistance and environmental performances.
The functional unit[1] of the cradle-to-gate analysis for magnesium is 1 kg of ingots obtained by electrolysis process.
The boundary of the considered industrial system (Figure 1) includes all the phases from raw material extraction to the production of a magnesium ingot. In this study the alloying elements are not considered. Most of the data used during model implementation are primary, that means data collected on site by using ad hoc questionnaires compiled by NANOMAG partners. Secondary data have been used with regard to the production and the delivery of energy carriers and of raw materials entering the plant. The Boustead software was used as calculation model and as main source of secondary data; the here reported results refer to an average EU energy mix.

[1] According to ISO 14040, the functional unit is the quantified performance of a product system for use as a reference unit in a LCA study.

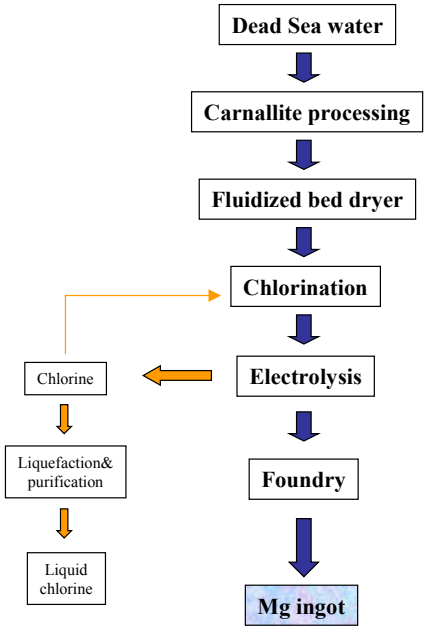

Figure 1 – System boundary of the study

ENVIRONMENTAL BURDEN OF MAGNESIUM PRODUCTION

The results of the eco-profile analysis are here split into the following categories:

1. *Energy results*: in Figure 2 the energy figures for functional unit are reported;
2. *Environmental results*: for this analysis the following impact categories are considered (Table 2): global warming potential (GWP), acidification potential (AP), eutrophication potential (EP), ozone depletion (ODP) and photochemical ozone creation (POCP).

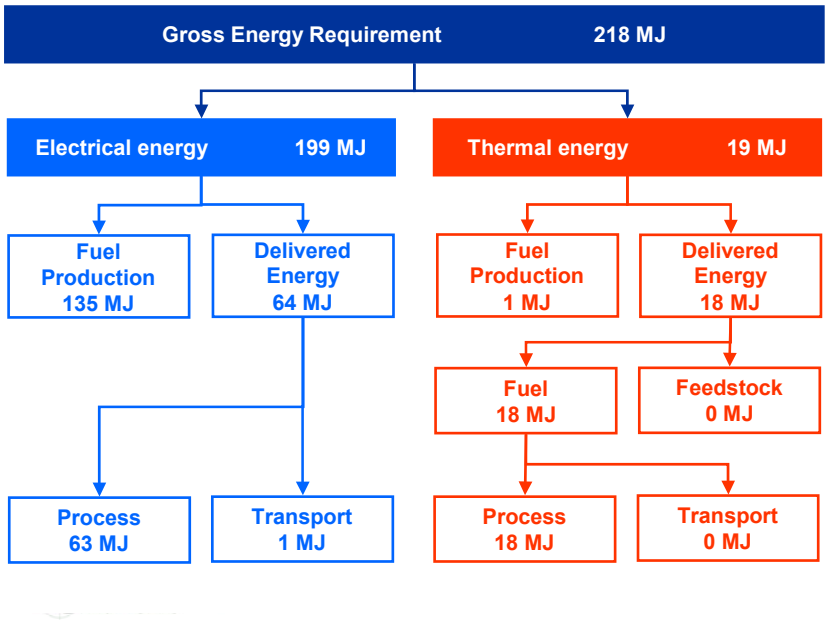

Figure 2 – Gross energy results for magnesium production (data in MJ/f.u.)

Table 2 – Environmental impact indicators with reference to the production of 1 kg of Mg

Indicator	Units	
GWP_{100}	g CO_2	11.590
AP	mol H^+	4,8
EP	g O_2	293
ODP	g CFC-11	< 0,001
POCP	g C_2H_4	4,7

In order to start with a preliminary comparison of the environmental and corrosion resistance performances with other main light structural metals, the cradle-to-gate data for the production of aluminium and titanium ingots have been reported in Figure 3.

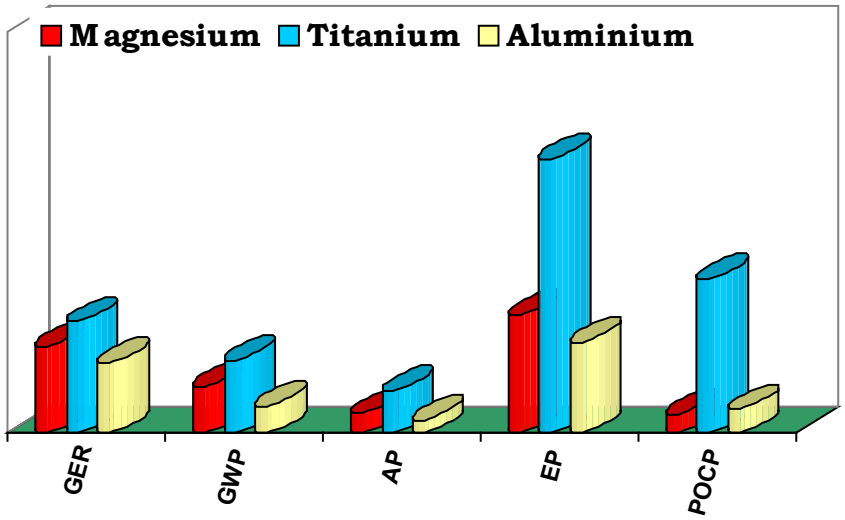

Figure 2 - Main environmental results for Mg, Ti and Al

MATERIALS SELECTION AND LCA

The CES – Cambridge Engineering Selector[2] is a windows based PC toolkit for the evaluation and selection of materials and processes for engineering design. The CES uses an extensive suite of databases containing the mechanical, thermal and electrical properties of a wide range of materials including metals, ceramics, polymers and composites. Properties data are presented in a graphical format to provide a series of "material selection charts" which, whenever combined with the use of performance indexes, enable the rapid identification of the optimum materials for a specific design.
In the last two years, the research activities have been focused on the development of an Eco-design software in which it was possible to select automatically materials and processes on the basis of both technical and environmental properties. In order to reach this objective, LCA methodology has been used to provide a detailed tool to support CES database. In particular, a specific format (LCA card) was developed to display the LCA results within CES.

To explain this Eco-design approach, in Figure 4 the output of this software is shown using a selection of light structural metals on the basis of their technical and environmental properties

[2] www.grantadesign.com

(strong alkalis corrosion resistance and global warming potential respectively). Furthermore, CES offers the possibility of comparison between the behaviour of the same alloys in weak alkaline environment as well as strong and weak acid environment. It has to be stressed the beneficial influence of PE-CVD surface treatment (data refer to 1 m^2 of coated surface), even if the environmental impact increases.

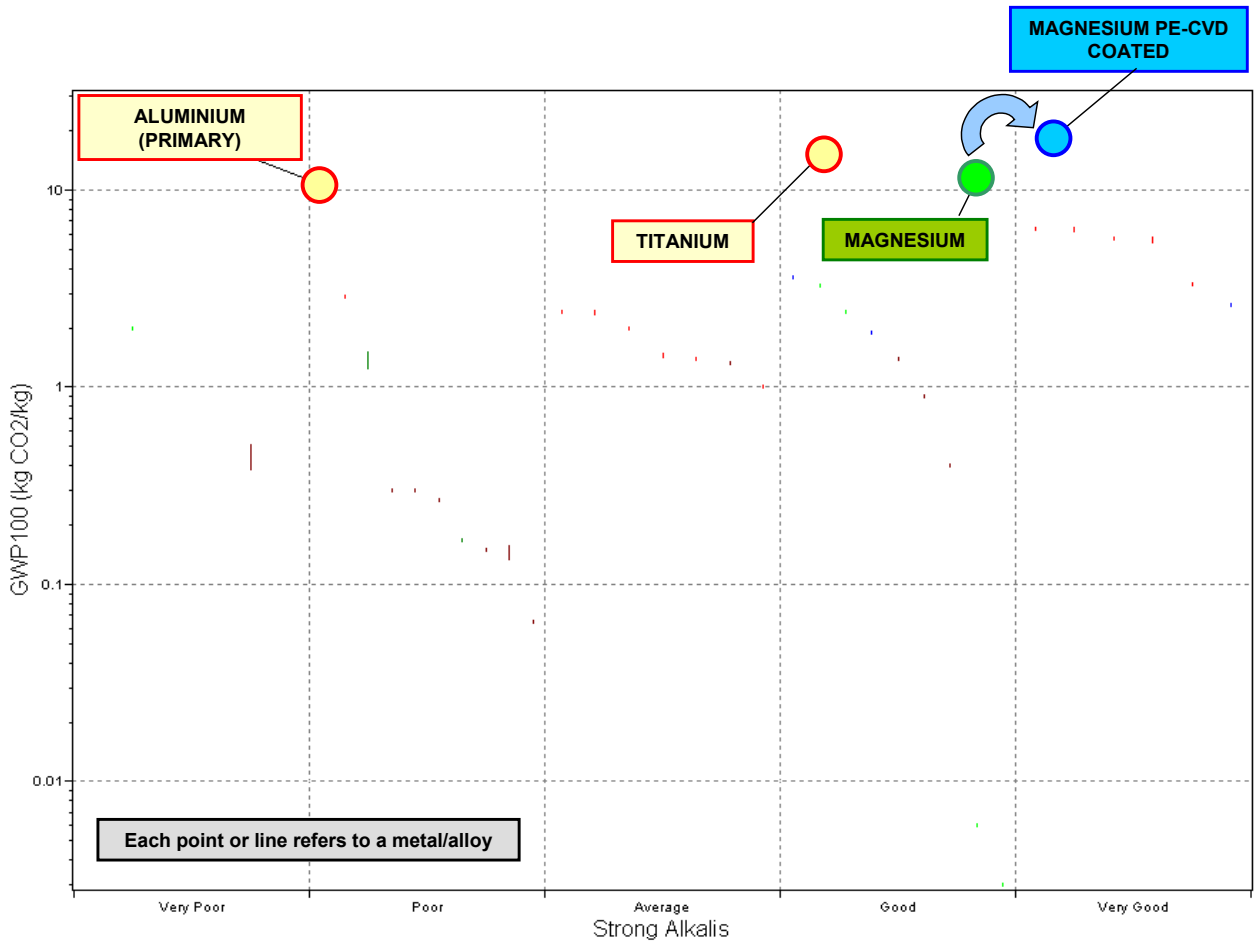

Figure 4 – Eco-design applications: strong alkalis corrosion resistance vs GWP_{100}

FURTHER DEVELOPMENT

Selecting materials by a technical and environmental point of view is the challenge to optimize materials selection by means of an eco-design tool. NANOMAG activities will continue in MATECO project, financed by the European Commission as well. The purpose is to perform a Life Cycle Analysis of new coatings for different materials based on PE-CVD technology, in order to compare their environmental impact in relation to the actual one. The Eco-design approach has proved to be a good way to manage with efficiency the involved parameters using a powerful software tool as described in the present work.

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