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# MLCA for Production of Magnesium Diecastings

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**In order to comply with the growing demand for life cycle environmental effect, material life cycle assessment (MLCA) was carried out for production of AZ91D magnesium alloy diecastings, based on what has been experienced as needed for LCA study. This is important not only in environmental point of view but in commercial point of view, partially because the environmental data are sensitive to the design of the cast part and the efficiency of the diecasting operation. In the present study, the process evaluated is based on yields of finished parts relative to the metal input.**

Key words: Diecasting, *AZ91D* Mg Alloy, MLCA, Environmental Burden

## 1. INTRODUCTION

Driven largely by the never ending quest for weight reduction to decrease fuel consumption and emission, the automotive industry in Korea is predicting significant growth in the use of magnesium alloys. About a half decade ago, the price of magnesium alloys was more than twice that of aluminum alloys on a weight basis in Korea. Currently, magnesium alloys cost about one and a half times that of aluminum alloys on a weight basis. Therefore the price of magnesium alloys is the same as or is lower than that of aluminum alloys on a per volume basis [1-3].

Until now, it has been qualitatively acknowledged that lightweight materials are beneficial for reducing fuel consumption and emission. However, no quantitative analysis of the potential environmental impact of diecasting process has been done.

In order to comply with the growing demand for life cycle environmental effect, material life cycle assessment (MLCA) was done for production of AZ91D magnesium alloy diecastings, based on what has been experienced as needed for LCA study. This is important not only in environmental point of view but in commercial point of view, partially because the environmental data are sensitive to the design of the cast part and the efficiency of the diecasting operation.

In the present study, material life cycle assessment (MLCA) was carried out to evaluate the potential environmental impact of hot chamber type diecasting process for magnesium AZ91D alloy, with the emphasis to obtain life cycle inventory data, quantify environmental impacts and try to get solutions for environmental improvement.

## 2. STRUCTURE OF DIECASTING PROCESS

Diecasting is a manufacturing process for producing accurately dimensioned, sharply defined, smooth- or textured-surfaced metal parts. It is accomplished by forcing molten metal under high pressure into reusable metal dies. The term diecasting is also used to describe the finished part or casting. Diecastings are among the highest volume, mass-produced items manufactured by the metalworking industry. Fig. 1 shows a hot chamber type diecasting machine for magnesium alloys and Fig. 2 shows process steps with input and output materials flow.

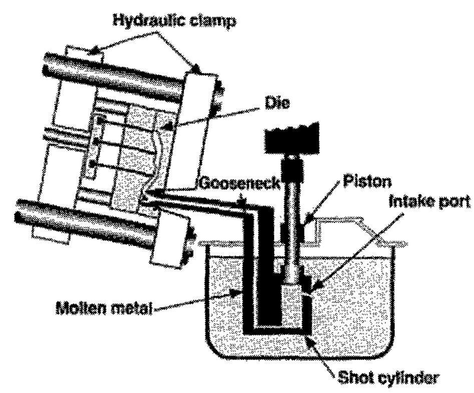

Fig. 1 Hot chamber diecasting machine.

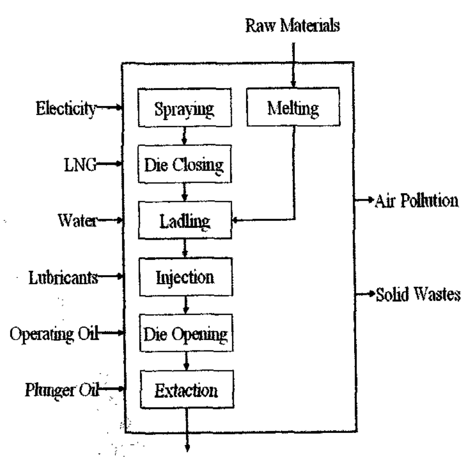

Fig. 2 Diecasting steps with materials flow.

Table 1 Gate-to-gate Database for AZ91D Magnesium Diecasting Process.

| INPUT | | | |
|---|---|---|---|
| Group | Name | Unit | Amount |
| raw material | AZ91D Magnesium Alloy | kg | 1.016E+00 |
| energy | Electricity | kWh | 1.009E+01 |
| | LNG | kg | 3.961E-01 |
| ancillary material | Lubricant | kg | 2.138E-02 |
| | Spray | kg | 4.239E-03 |
| | SF6 | kg | 3.683E-03 |
| | Process Additives | kg | 5.381E-03 |
| utility | Water | kg | 1.775E-02 |

| OUTPUT | | | |
|---|---|---|---|
| Group | Name | Unit | Amount |
| product | AZ91D Diecastings | kg | 1.000E+00 |
| waste | Liquid Wasts | kg | 9.115E-03 |
| | Sludge | kg | 1.585E-02 |
| air emission | $CO_2$ | kg | 9.009E-01 |
| | VOC | kg | 2.189E-02 |
| | SF6 | kg | 3.683E-03 |
| | SOx | kg | 7.604E-06 |
| | NOx | kg | 7.700E-07 |
| | CO | kg | 1.541E-04 |
| | Dust | kg | 1.369E-05 |

Table 2 Characterization model used for impact categories.

| Impact category | Unit | Source |
|---|---|---|
| *ARD* (Abiotic Resource Depletion) | 1/yr | World resource(1992) Crowson(1992) |
| *GW* (Global Warming) | g CO2-eq/g | IPCC (1994+1995) (100 years) |
| *OD* (Ozone Depletion) | g CFC-11-eq/g | UNEP(1997) |
| *ACID* (Acidification) | g SO2-eq/g | EDIP Stoichiometric H+ Guinee et al.,(1992) |
| *EUT* (Eutrophication) | g PO4-3-eq/g | Guinee et al.,(1992) |
| *POC* (Photo-chemical Oxidant Creation) | g ethene-eq/g | Heijung et al (1992) EDIP |
| *HT* (Human toxicity) | g body wt/g | Guinee et al.,(1992) |
| *ET* (Eco-toxicity | m3 water/g | Guinee et al.,(1992) Eco-indicator |

3. LIFE CYCLE INVENTORY ANALYSIS

Life cycle assessment is a technique for systematically analyzing a target from cradle-to-grave, that is, from resources extraction through manufacture and use to disposal. It is an important constituent of ISO14000 series. It is an important tool that can give the detail information of environmental profiles of a material, product or a process [4-7]. Material is one of the foundation industries for the development of society and economy, therefore, the research of materials life cycle assessment (MLCA) has been an important part in LCA [4, 6].

In this study, MLCA was carried out to evaluate the potential environmental impact of hot chamber type diecasting process for AZ91D magnesium alloy by the function unit of 1kg magnesium components based on 1 year LCI (Life Cycle Inventory) data collection. The system boundary is from material melting through extraction of components, as given in Fig. 2. Therefore there was no consideration about raw materials production and transportation and mold manufacturing stage.

The assumption made in this LCI stage is that there is no effect of infrastructures on the potential environmental impact of cold chamber type diecasting process. Table 1 shows gate-to-gate database of input and output after LCI analysis of magnesium diecasting process.

4. LIFE CYCLE IMPACT ASSESSMENT

LCIA (Life Cycle Impact Assessment) component is a technical, quantitative, and/or qualitative process to characterize and assess the effects of the resource requirements and environmental loadings (atmospheric and waterborne emissions ad solid waste) identified in LCI stage. In this LCI stage, there is no waterborne emission because water used for operation is circulated in the factory, which is seen in Table 1.

The characterization model used in this LCIA is given in Table 2 for each impact category [4, 5]. Fig. 3 shows the results of LCIA after weighting through characterization and normalization based on equivalency factor model (EFM), based on each impact category.

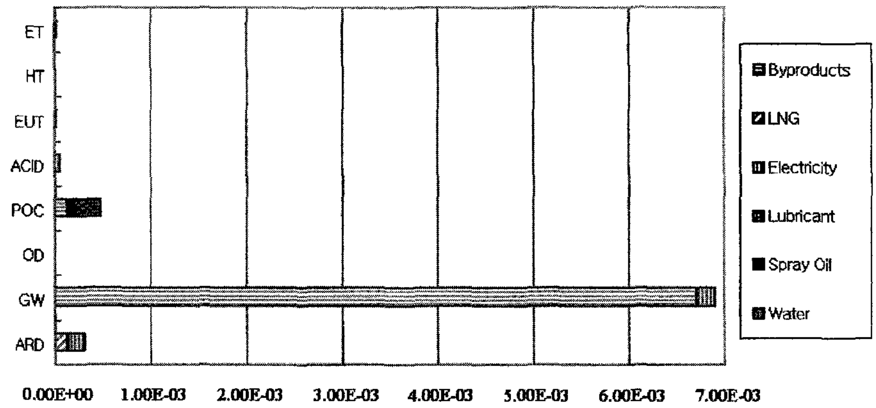


Fig. 3 Results of LCIA after weighting based on each impact category.

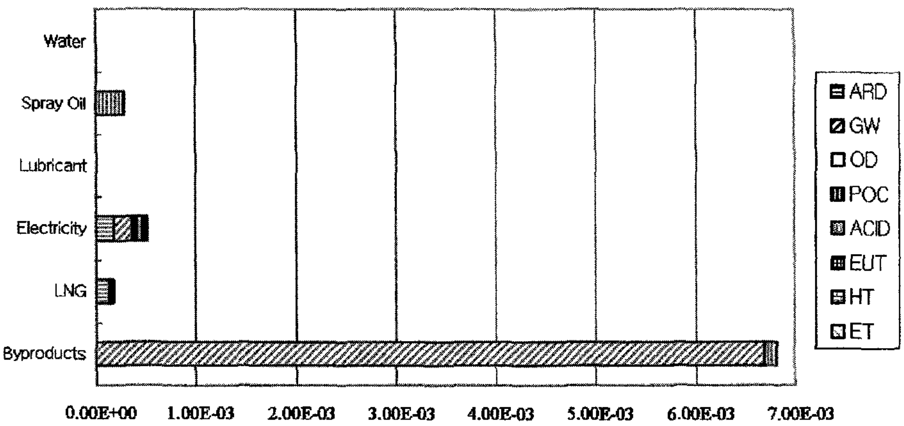


Fig. 4 Effect of input and output materials on each environmental impact category.

The abbreviations of impact categories used in Fig. 3 are corresponding to them of Table 2. From Fig. 3, it is well known that the most environmental impacts result in the order of decreasing amount in the following sequence: global warming (GW) → photo-chemical oxidant creation (POC) → abiotic resource depletion (ARD). Global warming comes from $CO_2$, which in turn comes from LNG combustion as well as from generating electricity, most of which in Korea is obtained by thermal power generation. Photo-chemical oxidant creation comes from VOCs, which in turn come from generating LNG and LNG combustion as well as from oil and lubricant used in diecasting process. Abiotic resource depletion mostly comes from LNG used for melting magnesium alloys.

5. LIFE CYCLE INTERPRETATION

Fig. 4 shows the effect of input and output materials on each environmental impact category, based on each input and output material. Fig. 4 indicates that byproducts mostly affect global warming. In this case, byproducts could be generated from oxidation-inhibiting sulfur hexafluoride gas diluted to about 1% in carbon dioxide gas to prevent the burning of molten magnesium during the process as well as from VOCs (Volatile Organic Compounds), which are in turn generated by burning gas, electricity and chemicals used in the process. The problem we have is that we cannot help but use $SF_6$-$CO_2$ mixture for magnesium diecasting process.

Interesting point is that LNG does not seriously affect global warming. LNG is one of green energy resources because the main constituent of LNG, methane, $CH_4$, has high hydrogen ratio to carbon, compared with ethane, $C_2H_6$ and profane, $C_3H_8$ of high carbon ratios.

As expected, spray oil used during the process is the main reason for photo-chemical oxidant creation. Electricity, which is used for operating diecasting machine, affects not only abiotic resource depletion and global warming but also photo-chemical oxidant creation and human toxicity.

From the results, it can be said that the main environmental issue in diecasting process for AZ91D magnesium alloy comes from 2 types of byproducts – the one is given as input source and the other is generated by burning gas, electricity and chemicals used in the process. One of good ways to reduce the potential environmental impact in magnesium diecasting process is to replace oxidation-inhibiting $SF_6$-$CO_2$ gas, for which there are many research to be initiated and some outstanding results have been obtained. The other good way is to replace gas burning melting furnace by electric resistance furnace or by induction furnace, with small improvement by adjusting spraying system to reduce the amount of necessary lubricant.

6. CONCLUSION

The potential environmental impact of diecasting process for manufacturing lightweight magnesium components was investigated by life cycle assessment as a function unit of 1kg AZ91D magnesium components, based on 1 year data collection in one Korean diecasting factory. It is not intended in this feasibility study to generalize the potential environmental impact of magnesium diecasting process, but to assess it in one factory for improving magnesium diecasting process as environment-friendly one. For generalization, more MLCA should be done in many magnesium diecasting factories in various locations and countries, with comparison with other manufacturing processes. MLCA of diecasting process in wide system boundary should also be done, containing magnesium raw material production step, alloying step and transportation to and from the system factory. More than that, consideration of mold, which does great role on diecasting process environmentally and economically, is necessary from mold material manufacturing step through mold tooling step. We hope this study would be good foundation for improving diecasting process to green process and even for Eco-manufacturing.

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