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Benchmarking aluminium die casting operations

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ABSTRACT

Increasing demand in world automotive markets for aluminium die cast components is creating significant opportunities and challenges for the Australian industry, which is positioning itself as a global player. To meet these challenges, the industry is continuously seeking to improve its overall resource efficiency that can result in the reduction of cost and impact on green house gas (GHG) emissions. In order to understand and evaluate the current position, this study benchmarks the use of aluminium and high-use operating resources of a large representative aluminium high-pressure die casting (HPDC) facility. By modelling the complex web of product, recycling and waste flows, resource efficiencies, costs and GHG impacts of the considered resources are computed. The central focus of this study is the in-house recycling flows of aluminium, normally considered good practice, though it can have negative implications on resource efficiency, costs and GHG impact. In fact, as revealed by this study, the recycling losses contribute as much as around 49% of the total aluminium melted adding about 44% to the cost of manufacture and 50% of the GHG added in production. Using the insights obtained, the technological and other systemic factors that contribute to the losses are identified and areas of improvements are suggested.

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1. Introduction

The attractiveness of die casting is its ability to make near net-shape parts with tight tolerances and requiring little or no machining. The more applied of the different die casting processes is high-pressure die casting (HPDC) with high rates of production. The automotive industry uses an extensive range of aluminium HPDC parts including transmission housings, cylinder heads, inlet manifolds, engine sumps as well as decorative trim. This trend is increasing as replacement of steel parts with lighter aluminium HPDC parts grows (Young and Eisen, 2000).

To meet the challenges of competition, the industry is continuously seeking to improve its overall performance. While costs, delivery and quality have been the traditional determinants of this, growing concerns about environmental burdens (green house gas (GHG) emissions) created by manufacturing has the industry seeking to reduce the GHG emissions as well. Notably, HPDC processes can be energy and water intensive with high percentage of losses of high cost aluminium as trim wastes.

In order to benchmark the flows and wastes, this study considers the metabolism of physical flows in a representative die casting industry that has an estimated 10% of the Australian market. The study focuses on top five of the resources used, namely aluminium and associated operating resources, viz. water, electricity, gas and die-lubricant (die-lube). Using input–output mapping, the product, waste and circulating (recycling) flows are mapped and the amounts are estimated using material flow analysis (MFA, Brunner and Rechberger, 2004). The estimation is accompanied by calculation of direct and added costs, and the GHG impacts. The central focus being the in-house recycling flows of aluminium. Normally, such recycling is considered good practice, though it can have negative implications on resource efficiency, costs and GHG impact.

This estimation reveals the extent of the resource efficiencies that are further examined to investigate the influencing factors. These factors, normally restricted to the die casting process, are expanded to include social factors such as training, maintenance, quality assurance, and shop-floor information and management systems.

In Section 2, analysis of the physical flows and their estimation is given. This is followed by the analysis of material efficiencies, costs and environmental impacts from these flows. Section 4 discusses the results of benchmarking and examines technological and other factors that influence the losses and suggests avenues for improvement. Finally, conclusions are drawn with some pointers to future work.

2. Resource flows in HPDC

Investigating usage and cost efficiencies (or intensities) of aluminium (alloy ADC12) and associated operating inputs requires a

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study of the flows of these through the various operations in the die casting plant. Operating resources, in particular, can be the numerous lubricants (such as die-lubes, tip lubes), chemicals (anti-rust, detergents, silver grease), water, fuels (for maintenance), natural gas, electricity and so on.

In this study, the flow of resources is limited to aluminium and operating inputs of electricity, natural gas, die-lube and water used in the production. Usage of these operating resources is largely dictated by the parts produced. To understand the flows, Fig. 1 provides a schematic of the flow of aluminium through the plant and the dependent flow of the operating resources.

The flow of aluminium through the plant can be described by the following distinct stages:

- Aluminium for production comes from three sources: as hot metal deliveries (HMD), recycled process scrap (in-house, from rejects and process losses) and ADC12 ingots that are input to recycled aluminium.
- Melting and holding furnaces store the molten HMD and recycled aluminium.
- Parts are cast at the HPDC machines of different tonnages ($800\,T \times 5$, $1250\,T \times 4$, $2250\,T \times 2$ and $2500\,T \times 2$) depending on their design with some capability overlap between the machines.
- Excess aluminium in parts is trimmed and the part is finished (some parts undergo machining) and the parts, after testing and inspection, are shipped to the customers.

The in- and out-flows of aluminium and investigated operating inputs, shown in Fig. 1 can be complex. In particular, a number of waste streams (i.e. non-productive or not saleable product outputs) of aluminium and operating inputs occur right throughout the process. Significant of these (for aluminium) include:

- Oxidation losses at melting and holding furnaces (sold to aluminium recyclers).
- Process losses (such as warm-ups, mis-runs and others) at the casting process (mostly recycled).
- Yield losses (such as runners, biscuits and flashings, mainly due to die design) that is trimmed (recycled).
- Turnings from machining (sold to aluminium recyclers).

Table 1
HPDC Al flows by weight for the data period

Category	Weight (tonnes)
Aluminium processed	15,611
Aluminium waste sold	507
Aluminium waste recycled in-house	7,663
Aluminium parts shipped	7,441

Wastes from operating inputs include waste water (mixed with die-lube waste) that is treated and disposed as trade waste. Energy losses from electricity and gas use are not captured.

Using material flow analysis the inputs and outputs at the various production stages and at supporting processes are mapped. However, the depth of detailed mapping differs due to data availability and the purpose for which analysis is undertaken. For instance, flows of aluminium is tracked at the part level (due to part-dependent differences in shot weight, yield and process losses, and general availability of data), whereas, electricity is categorised by consumption by one or the other processes or equipment.

3. Usage and cost efficiencies

3.1. Aluminium (HPDC)

3.1.1. Usage efficiency

The flow (by weight) of aluminium used in HPDC is computed from design data for the individual parts and daily production data from April 2006 through March 2007 for the machine groups. This data is used in computing the material efficiency.

Normal efficiencies consider the material in a product and associated waste (that leaves the plant). This efficiency, called here as 1st pass material efficiency, is calculated from the flow data (see

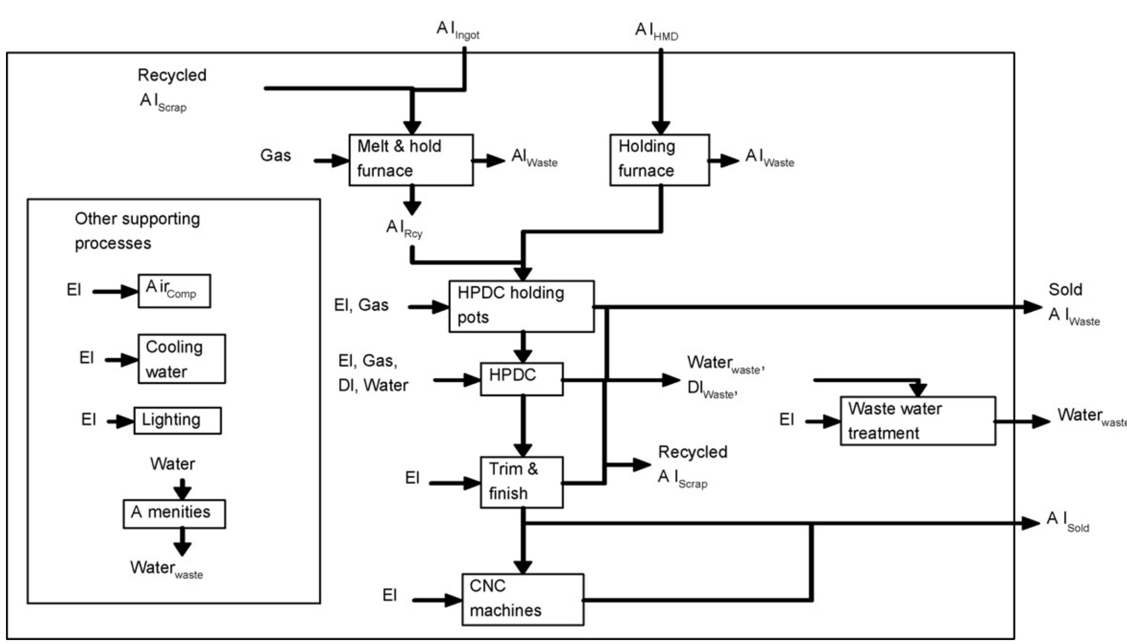

Fig. 1. Flow of aluminium and others through HPDC process.

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