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Optimization of the casting technology and sustainable manufacture of 100mm grinding balls for the mining Sector in Zimbabwe

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Abstract

Excess waste is common in foundry die-casting processes due to a number of factors. These include sizes of runners and gates, heat and pressure that may result in expanded sizes of runners and oversized products that require more time for fettling after solidifying and removal from moulds. The gating system, runners and handling of the molten metal play critical roles in the efficiency and productivity of casting processes. This research was prompted and motivated by one of Zimbabwe's largest foundries' desire to reduce product costs brought on by drops in sales caused by more affordable imports. The research focused on the company's major challenges such as excess waste and the long hours spent in manual fettling. This was done by optimizing the casting technology through the redesign of the gating systems for the sustainable manufacture of 100 mm grinding balls for the mining sector. The conventional casting approach, which is often unsystematic, was optimized using computational fluid dynamics and resizing of the gating system for the efficient and sustainable production of grinding media. Reductions in waste from 37% to 24% were anticipated based on the redesign, thus marginal reductions in the cost of grinding balls.

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Keywords: Die-casting; foundry; fettling; gating system; mould; optimization; sustainable production

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1. Introduction

Gating systems and how molten metal is poured in sand and die-casting in foundry industries contribute to the quality of cast products [1]. Substandard or inadequately designed gating systems and the pouring mechanism can result in a number of challenges such as variable sizes of the end products, gas porosity and excess waste that usually results in costly products [2]. Other factors such as temperature of the molten metal, pouring speed and opacity of the moulds also contribute to the difficulties encountered in evaluating the processes visually. This has an indirect effect on the quality and size of cast products. The research was carried out at one of Zimbabwe's largest foundries involved in the manufacture of a wide of range of cast products for the agricultural and mining sectors. Traditionally, the company supplied most of the required grinding balls for ball mills for mining companies in Zimbabwe. However, due to the general recession and financial crisis that affected Southern Africa in 2008 [3], the volume of sales plummeted, forcing the company to look at ways of reducing their product costs in order to remain operational. Global competition, especially with imports of cheaper grinding balls from Asia, also contributed to the drop in sales, requiring innovative ways to reduce their product costs. This was a growing concern for many companies in the developing world as those from the developed world continued to outgrow the global market because of strategies that they adopted to reduce costs [4]. Although the company was fully equipped with various smelting, sand and die-casting machines, these were all conventional, increasing the chances of inaccuracies. This was clearly a challenge to compete with companies equipped with modern state-of-the-art precision machines.

Apart from production costs that included preparation of charges for the smelters, transportation, smelting and laboratory tests, one of the major cost centres for the company was fettling. This section was involved in the trimming and cleaning to required sizes of the cast products emanating from the runners. Fettling is regarded as one of the most important stages in any foundry as it is the final stage for polishing and preparing the cast products for dispatch to customers [5]. According to research carried out at Mahindra and Mahindra, the manufacturers of engine blocks in India, fettling was one of the most 'ignored' processes in foundry industries and yet it was the cornerstone of determining the salability of a company's products, hence the need to ensure that it was properly carried [6]. The time spent in fettling depends on a number of factors such as the quality of cast products and equipment used. Even in the use of precision machines for casting, some form of fettling is still required to perfect the end product in preparation for dispatch [7]. Over the years, foundries in the developed world have been improved by equipping them with automated fettling machines to enhance productivity and efficiency [8]. However some of these machines are clearly out of the reach for many foundries in developing countries due to limitations in financial capacity [8].

Observations made during the work study revealed three major problems, firstly the gating systems and the runners gave rise to excessive waste in cast products that required long periods for manual fettling. Data gathered during the same period showed that during the production of grinding balls, close to 40% was lost either in pouring after smelting or fettling after casting. Although this excess waste was not thrown away but recycled, the process was costly and thus increased the cost of products. The research aimed at optimizing the casting technology by way of redesigning the gating systems and runners for the 100 mm grinding ball moulds in order to reduce excess waste and conserve energy by avoiding re-smelting. This was expected to result in less defects and an overall improvement in the quality of the grinding balls that would require less or no fettling, hence improved productivity, efficiency and sustainable manufacture of affordable grinding balls. This was also expected to restore the company's competitive market share.

2. Casting technology literature and review

Metal casting, traditionally involved the smelting of charges, usually in the form of scrap metal, using induction, cupola, arc or crucible furnaces. The molten metal was poured into moulds which contained cavities of the desired shape and on solidification, the molten-metal took the shape of the cavities [9]. It has been one of the oldest and ancient manufacturing methods that has been in use since 3200 BC in Mesopotamia and since then a number of improvements have been effected on the technology in order to improve productivity and efficiency as well as reducing product costs [10, 11]. Some of these methods and improvements are summarized in Table 1.