

Impact of Casting Defects on Productivity in Sand Casting Foundries

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Abstract

This study evaluates the impact of casting defects on productivity within a South African sand casting foundry by analyzing operational data collected between January and August 2025. Common defects such as porosity, gas holes, and cross-jointing were identified as significant contributors to production inefficiencies. Using key performance metrics, including job quantity, job losses, rejected weight, and associated financial costs, monthly productivity was calculated and analyzed. The results show that productivity fluctuated within a narrow range of 90.84% to 91.89%, with defect-related rejections accounting for an average monthly loss of 22 jobs, approximately 128 kg of material, and over R5,400 in financial losses. Although the productivity levels appear stable, the persistent nature of defects highlights systemic inefficiencies with cumulative economic consequences. The findings underscore the need for targeted quality improvement strategies, such as real-time process monitoring, enhanced mold design, and workforce training, to reduce defect rates and improve operational performance. This research contributes to the broader discourse on manufacturing optimization by quantifying the tangible effects of quality issues on foundry productivity and profitability.

Keywords

Casting defects, Sand casting, Quality control, Productivity, Foundry management.

1. Introduction

Productivity in manufacturing systems is a key determinant of operational efficiency, cost-effectiveness, and long-term competitiveness. In metal casting industries, particularly sand casting foundries, productivity is often compromised by inherent process variability and a high incidence of casting defects. Sand casting, one of the oldest and most widely adopted manufacturing techniques, is valued for its flexibility, low tooling costs, and suitability for complex geometries. However, it is also highly susceptible to a range of defects including porosity, blowholes, shrinkage cavities, inclusions, and cold shuts. These defects significantly reduce usable output, increase scrap rates, prolong production cycles, and contribute to elevated rework and material handling costs.

The occurrence of casting defects can be attributed to multiple factors, such as inadequate mold design, improper gating and riser systems, suboptimal process parameters (e.g., pouring temperature and metal flow rate), and poor-

quality raw materials. From a production systems perspective, these defects represent forms of non-value-adding waste and are symptomatic of deeper issues in process control, material management, and workforce training. Consequently, casting defect reduction is not merely a quality assurance concern but a strategic imperative for enhancing manufacturing performance.

In the context of emerging and developing economies, such as South Africa, the foundry industry faces additional structural and systemic challenges. These include volatile energy prices, aging equipment, limited investment in technological upgrades, and shortages of skilled labor. Under such conditions, even marginal productivity losses due to casting defects can have disproportionately large economic impacts. Furthermore, foundries operating in competitive global supply chains must contend with increasingly stringent quality standards and delivery expectations, making defect control essential for maintaining market viability.

This study aims to quantitatively assess the impact of casting defects on productivity in a South African sand casting foundry, using empirical data collected over an eight-month period (January to August 2025). By analyzing job losses, rejected material weight, and the associated financial costs, the research provides insights into the operational consequences of casting defects and highlights the importance of systematic quality management. The study contributes to the broader literature on manufacturing productivity by offering an applied case analysis grounded in real-world production data, with implications for both industry practitioners and academic researchers interested in manufacturing optimization, quality engineering, and operations management.

2. Literature Review

The relationship between casting defects and productivity has been widely explored across manufacturing engineering, quality control, and operations management disciplines. Defects in casting processes are not merely symptomatic of technical inefficiencies but represent a significant aspect of the Cost of Poor Quality (COPQ), a metric encompassing material wastage, lost labor hours, energy inefficiencies, equipment wear, rework, and reputational damage due to product failures (Juran & Godfrey, 1999; Feigenbaum, 2001).

2.1 Technical Causes and Defect Mitigation

In sand casting, the susceptibility to defects such as gas porosity, shrinkage, cold shuts, and inclusions has prompted considerable research into prevention strategies. Singh and Kumar (2018) demonstrated that precise control over mold moisture, gating system optimization, and pouring temperature regulation are critical to defect reduction. Even small parameter adjustments yielded measurable gains in both product quality and plant throughput.

Similarly, Choudhary et al. (2019) conducted a detailed classification of sand casting defects and linked them to root causes such as poor sand quality, inadequate venting, and operator error. Their findings reinforced the importance of non-destructive testing (NDT) methods and in-line process monitoring to detect defects before solidification, thus enabling early corrective action and minimizing scrap rates. Lanz et al. (2020) emphasized the significance of real-time diagnostics and digitalization in metal casting. By integrating Industry 4.0 tools such as thermal imaging and sensor-based feedback, foundries can enhance their ability to detect mold defects and irregularities during production.

2.2 Process Control and Continuous Improvement

Statistical process control (SPC) remains a widely recommended approach to stabilize and optimize casting operations. Black and Wiliam (1998) introduced the role of formative assessment and feedback mechanisms in continuous process improvement, which can be translated into manufacturing through defect tracking dashboards, control charts, and corrective action loops. These tools align well with Total Quality Management (TQM) and Six Sigma practices (Montgomery, 2020), both of which promote defect minimization through disciplined process refinement.

Abhishek et al. (2020) applied the Six Sigma DMAIC framework in a foundry and observed a 37% reduction in defect rate over four months. Their research highlights the necessity of data-driven interventions, multidisciplinary teamwork, and standardization in achieving sustainable quality improvements.

2.3 Productivity Losses and Economic Impact

Defects significantly impact overall equipment effectiveness (OEE) and productivity, especially when rework, downtime, and raw material loss are considered. Khan and Verma (2020) estimate that casting defects can inflate total

production costs by up to 20%, while Jadhav and Bhosale (2017) found that foundries often underestimate the financial burden of quality failures due to poor internal cost visibility.

Moodley (2015) and Ramphaul et al. (2021) explored these issues in the South African context, reporting that inefficient quality control not only increases unit costs but also disrupts supply chains, particularly in export-driven foundries. Their work stresses that integrating lean principles with quality management enhances resilience and responsiveness to defect-related disruptions.

2.4 Challenges in the South African Foundry Sector

Context-specific studies underline that South African foundries operate under unique constraints. Molefe et al. (2020) cite high energy prices, outdated infrastructure, limited digitization, and a shortage of skilled artisans as compounding factors that hinder quality assurance and productivity. These challenges make defect prevention more difficult and costly, increasing the strategic importance of preventive quality systems.

Botha and Pretorius (2017) advocate for a lean-defect reduction hybrid model, emphasizing low-cost process improvements such as daily defect audits, kaizen events, and skills development programs. Their framework is especially relevant for small to medium-sized enterprises (SMEs) with constrained capital and limited automation capabilities. In addition, Njowa and Chikumba (2018) emphasize the importance of skills transfer and operator training in improving foundry output. Their research found that human error remains a leading contributor to quality variation in local foundries.

2.5 Literature Gap

While the literature robustly establishes a link between casting defects, process efficiency, and financial losses, most studies either focus on experimental trials or macro-level reviews. Few have offered empirical, data-driven case studies that quantify the monthly productivity and monetary losses caused by specific defect types in real industrial settings. This study aims to fill that gap by using operational data from a South African sand casting foundry to examine how recurring defects contribute to job losses, material waste, and financial underperformance. In doing so, it bridges academic theory with industry practice and contributes to both scholarly understanding and actionable insight.

3. Methods

This study adopts a quantitative case study approach to examine the impact of casting defects on productivity in a sand casting foundry located in South Africa. Operational data were collected over an eight-month period, from January to August 2025, encompassing key performance indicators such as job quantity, job losses due to defects, produced and rejected casting weight, and monetary losses associated with rejected jobs.

3.1 Data Collection

Data were obtained from the foundry's internal production records, quality control reports, and financial logs. For each month, the following variables were captured:

- Job Quantity (units): Total number of casting jobs processed.
- Job Lost (units): Number of jobs rejected due to casting defects.
- Weight Produced (kg): Total weight of acceptable castings.
- Weight Rejected (kg): Total weight of defective castings.
- Job Lost (Rand): Financial loss associated with defect-related rejections.
- Productivity (%): Calculated using the equation in section 3.2.

3.2 Productivity Calculation

Productivity was measured using a standard ratio of accepted output to total input, as defined below:

$$\text{Productivity (\%)} = (\text{Job Quantity} - \text{Job Lost}) / \text{Job Quantity} \times 100$$

This formula captures the efficiency of converting raw input (total jobs attempted) into usable output (jobs accepted). Monthly productivity trends were then analyzed to identify patterns and fluctuations corresponding to defect rates.

3.3 Data Analysis

Descriptive statistical techniques were used to analyze the dataset. The monthly results were compiled into a table, and visual trends were presented graphically. The aim was to correlate productivity fluctuations with defect-related variables such as rejected weight and financial loss.

The dataset analyzed spans January to August 2025 and includes variables such as job quantity, job losses due to defects, produced weight, rejected weight, and monetary losses. Productivity was measured using the formula:

$$\text{Productivity (\%)} = (\text{Job Quantity} - \text{Job Lost}) / \text{Job Quantity} \times 100$$

Descriptive statistics, tables, and charts were generated to identify monthly productivity trends and the relative contribution of casting defects to overall efficiency.

4. Results

The analysis of production data from January to August 2025 reveals several notable trends in productivity performance and defect-related losses. Over the eight-month period, the foundry processed a total of 2,058 casting jobs, of which 178 jobs (8.65%) were rejected due to various casting defects. The monthly productivity ranged between 90.84% and 91.89%, as detailed in Table 1.

4.1 Productivity Trends

The highest productivity was recorded in July (91.89%), with the lowest in June (90.84%). This relatively narrow band of fluctuation, just over one percentage point, suggests consistent operational performance. However, as illustrated in Figure 1, minor variations in productivity correlate with fluctuations in job losses and rejected weight, implying an operational sensitivity to defect occurrence.

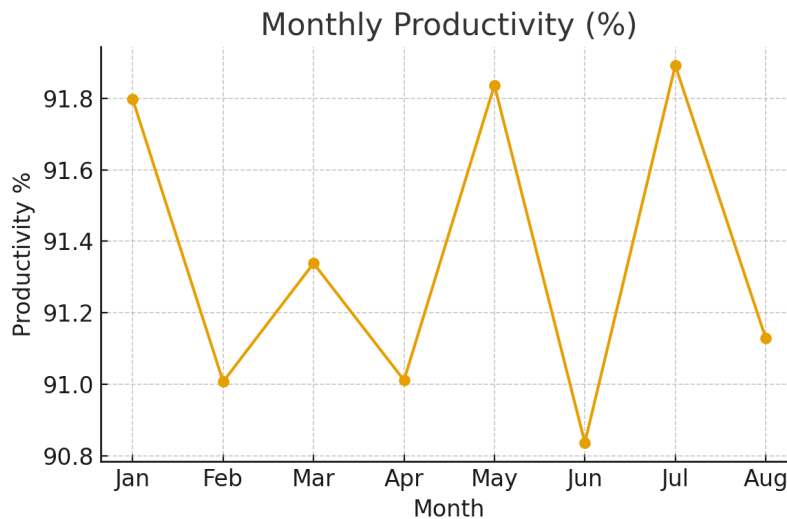


Figure 1. Monthly Productivity Trend

4.2 Defect-Related Material and Financial Losses

Monthly rejected weight due to defective castings ranged from 118 kg (May) to 141 kg (February). These losses are substantial in the context of monthly production weights, which averaged approximately 1,520 kg. The financial impact of these defects was similarly non-trivial, with monthly losses ranging from R4,920 (May) to R6,125 (February). The total cumulative financial loss over the eight-month period was R43,495.

4.3 Patterns in Job Losses

Job losses due to defects remained relatively stable, ranging from 20 to 25 jobs per month (Table 1). Notably, no clear improvement trend was observed over the study period, suggesting that corrective actions, if any were either ineffective or not systematically implemented.

Table 1. Monthly Productivity and Defect-Related Metrics

Month	Job Quantity	Job Lost	Weight Produced (kg)	Weight Rejected (kg)	Financial Loss (Rand)	Productivity (%)
Jan	256	21	1500	122	5,250	91.80
Feb	278	25	1620	141	6,125	91.01
Mar	254	22	1480	127	5,380	91.34
Apr	267	24	1590	136	5,900	91.01
May	245	20	1450	118	4,920	91.84
Jun	251	23	1520	129	5,520	90.84
Jul	259	21	1495	123	5,100	91.89
Aug	248	22	1475	126	5,300	91.13

5. Discussion

The analysis of the eight-month dataset reveals that productivity remained relatively stable, fluctuating between 90.84% and 91.89% (see Figure 1). While these values suggest a high baseline efficiency, even minor variations of 1% represent significant losses when scaled over longer production cycles and large volumes.

A closer examination of Table 1 indicates that the number of rejected jobs is consistently in the range of 20–25 per month, suggesting a systemic issue rather than random variation. Furthermore, the correlation between job losses and rejected casting weight underscores the material inefficiency resulting from defects. For instance, in February, the highest number of job losses (25) coincided with the highest rejected weight (141 kg) and the greatest financial loss (R6,125).

These trends support findings by Singh and Kumar (2018), who argued that casting defects have a cascading effect on downstream operations, affecting not only material usage but also production scheduling, rework capacity, and customer lead times. The persistent presence of defects such as porosity, gas holes, and cross-jointing may also indicate inadequacies in mold preparation or poor control over process parameters such as venting and pouring temperature.

Moreover, financial losses tied to defect rates (as shown in Table 1) point to the importance of integrating cost accounting with quality metrics. The average monthly financial loss over the study period was approximately R5,437, which, if extrapolated annually, equates to over R65,000 in direct losses, excluding indirect costs such as labor, rework, and potential customer dissatisfaction.

The consistent defect rate also implies potential gaps in workforce training, equipment maintenance, or raw material quality assurance. Given the context of South African foundries, where infrastructure limitations and skills shortages are common, such issues may be further exacerbated by external constraints.

Ultimately, the findings highlight the need for targeted quality improvement strategies, such as the implementation of real-time defect tracking, continuous process monitoring, and Six Sigma methodologies. Reducing even a fraction of these defects could significantly improve productivity and reduce financial losses, thereby enhancing the foundry's competitive position.

6. Conclusion

This study investigated the impact of casting defects on productivity in a South African sand casting foundry, using operational data from January to August 2025. The analysis demonstrated that even within a relatively stable

production environment, casting defects exert a measurable and consistent negative influence on both material efficiency and financial performance.

Across the eight-month period, productivity ranged narrowly between 90.84% and 91.89%, yet these seemingly small fluctuations corresponded to significant cumulative losses. A total of 178 defective jobs resulted in the rejection of 1,022 kilograms of cast material and a direct financial loss of R43,495. These losses do not account for secondary impacts such as downtime, rework, and reputational damage, which would likely elevate the true cost of defects even further.

The persistence of defects, despite their predictability and measurable impact, suggests that more rigorous quality control interventions are warranted. Specifically, strategies such as process standardization, statistical process control (SPC), Six Sigma defect reduction, and employee training should be considered to address root causes such as porosity, gas holes, and cross-jointing. Furthermore, integrating real-time defect monitoring with production dashboards could enable more responsive decision-making on the shop floor.

In a broader industrial context, especially within the constraints of South African foundries, where energy costs, skills shortages, and aging infrastructure prevail, defect management represents a critical and cost-effective lever for performance improvement. By reducing defect rates even marginally, foundries can achieve notable gains in productivity, resource efficiency, and profitability.

Future research could expand on this study by incorporating a broader data set over a longer time frame, conducting root cause analysis of specific defect types, and evaluating the impact of specific quality improvement initiatives post-implementation.

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