Journal Industrial Engineering 9[21]1-5: e50921105
Article

Aluminum casting furnace filling: A case study on operational efficiency improvement

Llenado de hornos de fundición de Aluminio: Estudio de caso sobre la mejora de la eficiencia operacional

Pérez-García, Alejandro*[a], Muñoz-Hernández, Raquel*[b] and Rangel-Lara, Saúl*[c]

[a] ROR Universidad Politécnica del Valle de México • 0009-0007-5090-4584 • 2196060
[b] ROR Universidad Politécnica del Valle de México • I-6661-2018 • 0000-0002-4461-8027 • 103670
[c] ROR Universidad Politécnica del Valle de México • 0000-0002-4461-8027

SECIHTI classification:

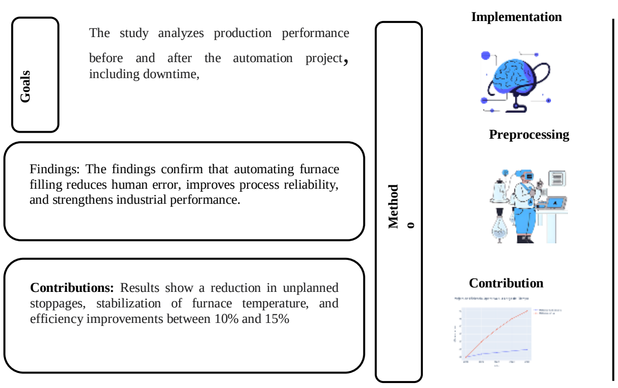
Area: Engineering
Field: Engineering
Discipline: Industrial Engineer
Sub-discipline: Manufacturing

https://doi.org/10.35429/JIE.2025.9.21.5.1.5
Article History:
Received: September 25, 2025
Accepted: December 10, 2025

* ✉ [alejandro.perez@upvm.edu.mx]

Abstract

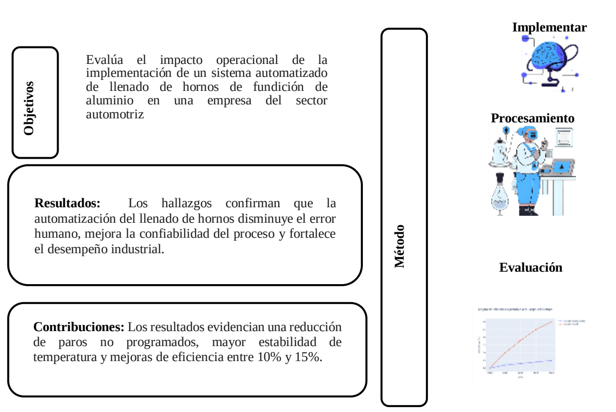
This case study evaluates the operational impact of implementing an automated filling system for aluminum casting furnaces in an automotive manufacturing company. Prior to automation, the production lines experienced frequent failures, machine stoppages, and temperature instability due to manual handling of aluminum ingots. The study analyzes production performance before and after the automation project, including downtime, defect rates, and productivity indicators. Results show a reduction in unplanned stoppages, stabilization of furnace temperature, and efficiency improvements between 10% and 15%. The findings demonstrate that automated furnace filling systems significantly reduce human error, improve operational reliability, and enhance manufacturing performance in aluminum casting processes.



Automation, Metal Casting, Operational Efficiency

Resumen

Este estudio de caso evalúa el impacto operacional de la implementación de un sistema automatizado de llenado de hornos de fundición de aluminio en una empresa del sector automotriz. Antes de la automatización, las líneas de producción presentaban fallas frecuentes, paros de máquina e inestabilidad térmica debido al manejo manual de los lingotes. El estudio analiza el desempeño productivo antes y después del proyecto, considerando tiempo muerto, defectos y productividad. Los resultados evidencian una reducción de paros no programados, mayor estabilidad de temperatura y mejoras de eficiencia entre 10% y 15%. Los hallazgos confirman que la automatización del llenado de hornos disminuye el error humano, mejora la confiabilidad del proceso y fortalece el desempeño industrial.



Automatización, Fundición de aluminio, Eficiencia

Area: Development of strategic leading-edge technologies and open innovation for social transformation

Citation: Pérez-García, Alejandro, Muñoz-Hernández, Raquel and Rangel-Lara, Saúl. [2025]. Aluminum casting furnace filling: A case study on operational efficiency improvement. Journal Industrial Engineering. 9[21] 1-5: e50921105.

1. Introduction

The automotive industry faces a highly competitive environment, characterised by constant pressure to reduce costs, improve quality, increase productivity and comply with demanding international standards.

Within this context, manufacturing processes related to aluminium casting play a strategic role, as a large part of the critical components of modern vehicles depend on castings with high levels of dimensional accuracy and metallurgical quality. Any variation in these processes can have a significant impact not only at the operational level, but also on customer satisfaction and financial sustainability.

The company under study identified structural problems in its aluminium casting production lines, which manifested themselves in decreased productivity, increased operating costs and reduced sales volume. Given this situation, the need for a comprehensive improvement project incorporating industrial automation technologies was recognised.

One of the critical issues identified was the manual process of filling the smelting furnaces. This manual procedure required the direct intervention of operators to transfer and preheat aluminium ingots for subsequent manual introduction into the furnace. This scheme generated a high physical workload, hazardous working conditions and a high probability of human error due to fatigue, distractions and informal practices.

Deviations in the manual filling process manifested themselves in the introduction of ingots without adequate preheating, overfilling of the furnaces, and a lack of synchronisation in the supply of material. These failures caused drastic variations in internal temperature, reaching reductions of between 10 °C and 45 °C.

The result was the activation of safety alarms, automatic interruption of the process, and serious technical failures, such as piston jams, injection syringe obstructions, mould failures, moisture explosions, and a high number of defective parts.

In this context, Industrial Engineering, especially in the field of *control and measurement of production processes* —as defined within *Area VII: Engineering* of MARVID— provides specific knowledge and techniques to implement, monitor, and regulate critical variables in production systems with the aim of stabilising manual processes, reducing variability, and optimising manufacturing systems.

This includes the design, implementation, and evaluation of automatic control systems that allow manual interventions to be replaced by activities with constant feedback of relevant variables (temperature, cycle times, material mass, among others), reducing dependence on subjective judgements and promoting decisions based on objective measurement of real-time data. Marvid

Based on this overview, the central hypothesis of the research emerges: the automation of the aluminium smelting furnace filling system significantly reduces unscheduled downtime, stabilises critical process variables and improves production efficiency levels. This study falls within the SECIHTI area of *Attention and Solution of National Problems*, as it proposes a technological solution applied to a real problem in the automotive industry that affects the competitiveness of the national manufacturing sector through process modernisation, knowledge management, and standardisation of technical practices.

2. Methodology

This study was developed using a methodological approach of a case study with a quasi-experimental design, aimed at evaluating the real impact of automation in an active industrial environment[21]. This design allowed for a structured comparison of the performance of the process before and after the technological intervention.

The methodological design was based on the classical principles of industrial engineering and the guidelines for work measurement described by Zandin (2001), prioritising process standardisation, variability reduction and the elimination of unnecessary manual operations.

ISSN: 2523-0344
RENIECYT-SECIHTI: 1702902

Pérez-García, Alejandro, Muñoz-Hernández, Raquel and Rangel-Lara, Saúl. [2025]. Aluminum casting furnace filling: A case study on operational efficiency improvement. Journal Industrial Engineering. 9[21] 1-5: e50921105
https://doi.org/10.35429/JIE.2025.9.21.5.1.5

2.1. Stages and Variables

a) Diagnosis and Definition of Variables

The initial diagnosis was based on direct observation, semi-structured interviews, and analysis of historical records of failures, maintenance, and production. The frequency and duration of unscheduled downtime and temperature variations during manual filling were documented.

– **Independent Variable:** Implementation of the automated furnace filling system.
– **Dependent Variables:** Total downtime due to failures, frequency of emergency shutdowns, internal temperature variation, number of defective parts, production volume per shift, and number of corrective maintenance interventions.

b) Design and Implementation

The automated system included automatic loading devices, level and thermal sensors, and programmable control systems (PLC). It was integrated with production databases to synchronise material supply with production orders and the requirements of each line. Implementation was carried out gradually to minimise risks.

c) Data Collection and Analysis

A six-month observation period was established following automation. The data was analysed using descriptive statistical tools to calculate averages, standard deviations, and percentages of change. This was supplemented with interviews with key personnel to incorporate a qualitative component on occupational safety and ease of operation.

3. Results

The results confirmed the principles established by Zandin (2001), which maintain that the automation and standardisation of processes generate substantial improvements in productivity, quality and operational stability.

3.1. Operational Stability and Efficiency

Unplanned Shutdowns: An approximate 25% decrease in the frequency of emergency shutdowns was observed after automation.

Thermal Stability: During manual operation, temperature variations reached 45 °C. With automation, variations stabilised in ranges of 10 °C.

Production Efficiency: Measurements showed increases in production volume per shift ranging from 10% to 15% per production line. This increase was explained by the reduction in downtime and greater synchronisation in the supply of material.

As mentioned by Rojas Tinoco, A. F., & Sánchez Becerra, J. F., during aluminium smelting, the temperature must be kept under control and, if necessary, slag that could alter and/or compromise quality must be removed. The data was stored in digital systems and subsequently analysed using descriptive statistical tools, as can be seen in Figure 1 before implementation:

Box 1

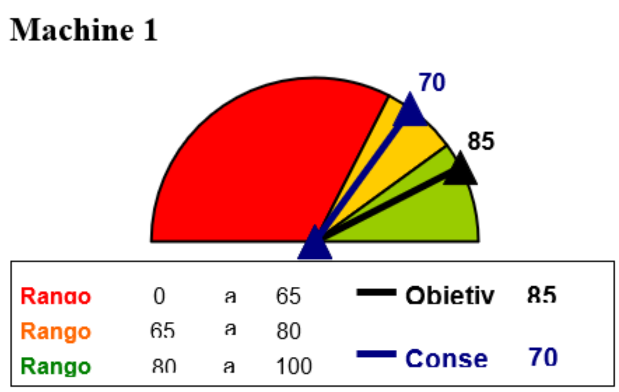


Figure 1
Before automation

Figure 2 below shows the changes following automation

Box 2

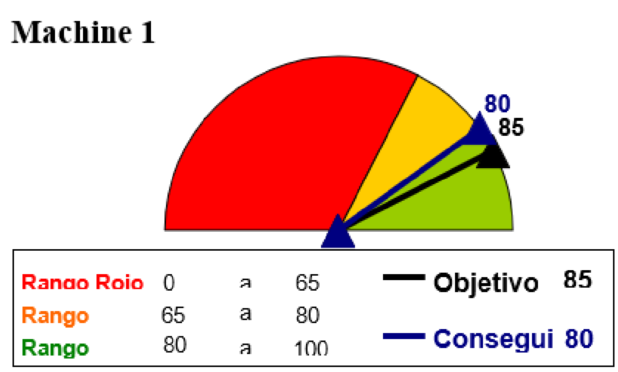


Figure 2
After automation

ISSN: 2523-0344
RENIECYT-SECIHTI: 1702902

Pérez-García, Alejandro, Muñoz-Hernández, Raquel and Rangel-Lara, Saúl. [2025]. Aluminum casting furnace filling: A case study on operational efficiency improvement. Journal Industrial Engineering. 9[21] 1-5: e50921105
https://doi.org/10.35429/JIE.2025.9.21.5.1.5

Table 1 presents the results obtained in detail, comparing them with the data collected during the manual operation stage.

Box 3

Table 1
Comparative Performance of Operational Efficiency (Machine 1)

Automation	Antes	Afterwards
Objective	85	85
Achieved	70	80
Risk	0 a 65	0 a 65
Alert	65 a 80	65 a 80
Acceptable	80 a 100	80 a 100

3.2. Quality and Maintenance

Product Quality: A decrease of more than 10% was observed in the percentage of defective parts. The uniformity of the filling process resulted in parts with greater structural homogeneity.

Maintenance: There was a significant reduction in corrective maintenance interventions, which allowed efforts to be redirected towards preventive activities.

3.3. Organisational Impact

Automation facilitated better interdepartmental coordination, allowing the planning department to adjust production schedules more accurately. It also had a positive impact on workplace safety, reducing operators' exposure to the manual handling of hot ingots[49]. Operators reported a decrease in physical fatigue and greater clarity in work instructions.

4. Conclusions

The evidence gathered shows that automating the aluminium smelter furnace filling process transforms organisational dynamics, work culture and production management schemes. Eliminating the human variability factor in critical processes significantly reduces the incidence of operational failures. The stabilisation of the thermal process and the improvement in quality demonstrate that automation is a strategic tool for long-term sustainability.

Another relevant finding is the impact on the value chain and supply chain. The improvement in the reliability of the smelting process allowed for greater synchronisation with subsequent processes (machining, assembly, and logistics), strengthening the company's ability to meet delivery times, a key requirement in the automotive industry's just-in-time schemes.

Limitations and Recommendations

The study has limitations such as its dependence on available historical records and the variability inherent in shift production. Extending the observation period is recommended to assess the long-term impact on aspects such as equipment wear and tear and the evolution of maintenance costs.

Companies are encouraged to adopt a comprehensive approach that includes strengthening staff skills, standardising procedures, and consolidating a culture of continuous improvement. In addition, the integration of complementary technologies, such as remote monitoring systems and real-time data analysis, is recommended to maximise the potential of automated systems.

Abbreviations

°C	Grados Celsius Unidad de medida para la temperatura
PLC	*Programmable Logic Controller* (Controlador Lógico Programable)
PMBOK® Guide	*Project Management Body of Knowledge* Guide (Guía del Cuerpo de Conocimiento de la Gestión de Proyectos)
PMI	*Project Management Institute*

Statements

Data availability

The data used are available upon request.

Funding:

The research did not receive external funding.

Conflict of interest:

The authors declare that they have no conflict of interest.

They have no financial interests or personal relationships that could have influenced this book.

Contributions of the authors

Pérez-García, Alejandro: Contributed to the idea for the project.

Muñoz-Hernández, Raquel: Project methodology.

Rangel-Lara Saúl: Research technique.

Acknowledgements

To the companies that responded to the surveys and the individuals who voluntarily participated.

Classification and References

Background

Ballou, R. H. (2004). *Business logistics/supply chain management: Planning, organizing, and controlling the supply chain* (5th ed.). Pearson Education.

Groover, M. P. (2010). *Automation, production systems, and computer-integrated manufacturing* (3rd ed.). Pearson.

Heizer, J., Render, B., & Munson, C. (2017). *Operations management: Sustainability and supply chain management* (12th ed.). Pearson Education.

Kalpakjian, S., & Schmid, S. (2014). *Manufacturing engineering and technology* (7th ed.). Pearson.

Fundamentals

Kerzner, H. (2017). *Project management: A systems approach to planning, scheduling, and controlling* (12th ed.). Wiley.

PMI. (2017). *A guide to the project management body of knowledge* (PMBOK® Guide) (6th ed.). Project Management Institute

Support

Slack, N., *Brandon-Jones, A., & Johnston, R.* (2016). Operations management (8th ed.). Pearson.

Wignarajah, J. (2004). *Metal casting: Computer-aided design and analysis*. Butterworth-Heinemann.

Rojas Tinoco, A. F., & Sánchez Becerra, J. F. (2025). *Formulación y evaluación de un proyecto para la producción de marcos de bicicleta mediante el proceso de moldeo por inyección de aluminio en la ciudad de Bogotá*.

Discussion

Zandin, K. B. (Ed.). (2001). *Maynard's industrial engineering handbook* (5th ed.). McGraw-Hill.

ISSN: 2523-0344
RENIECYT-SECIHTI: 1702902