Proceedings of the 3rd International Conference on Financial Technology and Business Analysis
DOI: 10.54254/2754-1169/149/2024.19265

Supply Chain Management and Quality Control of Aviation Magnesium Alloy Casting

Kunyu Gao[1,a,*]

[1]*Sichuan University, Chengdu, 610065, China*
a. gaokunyuhrb@163.com
**corresponding author*

Abstract: Magnesium alloys serve as a pivotal material for lightweighting products and find extensive applications in various industries. Particularly in recent years, the burgeoning aviation sector has unveiled new prospects for magnesium alloy casting. Concurrently, effective supply chain management and stringent quality control have emerged as critical factors that facilitate the progress of the magnesium alloy casting industry while bolstering enterprise competitiveness. This study delves into the supply chain of a magnesium alloy production entity (referred to as Company D), covering aspects such as raw material administration, production quality oversight, and sustainable supply chain management. It delves into a supply chain management framework tailored to actual casting operations, ensuring feasibility and fostering long-term growth. The analysis unfolds the nuances of magnesium alloy supply chain management, delineates the hurdles encountered, and outlines pivotal quality control measures. Conclusively, it puts forth strategies for refining supply chain management and quality control, aiming to furnish insights for the advancement of magnesium alloy enterprises.

Keywords: Casting, Supply chain, Quality management, Production operation, Incentive mechanism.

1. Introduction

Magnesium alloy, often referred to as the "green engineering material of the 21st century," stands out as the only metal material more dense than lithium. Magnesium alloys possess remarkable specific strength and stiffness, making them highly versatile for various industries including aviation, aerospace, marine, automotive, and electronics. However, the integration of magnesium alloys into industrial processes requires a robust quality management system throughout the supply chain, facing challenges like varying raw material quality, complex production procedures, and evolving market demands. A stable supply and high-quality magnesium alloy products depend not only on the capabilities of manufacturers but also on the efficiency of the entire supply chain.

Despite the extensive research on the amalgamation of quality management (QM) and supply chain management (SCM) into supply chain quality management (SCQM), manufacturers encounter numerous challenges in actual production and operations[1]. This study focuses on a Chinese magnesium alloy production company (Company D), highlighting the importance of Supply Chain Quality Management (SCQM). The company faces significant pressure for swift product delivery in a highly competitive global market, especially with the stringent requirements for flight safety and

© 2025 The Authors. This is an open access article distributed under the terms of the Creative Commons Attribution License 4.0 (https://creativecommons.org/licenses/by/4.0/).

DOI: 10.54254/2754-1169/149/2024.19265

aviation product quality standards. The study addresses the challenges posed by tight research and development timelines, strict quality standards, and increasing market demands, aiming to enhance research and development, production operations, and quality assurance.

To effectively meet end-user demands, the study emphasizes the enterprise's role in the supply chain by improving upstream and downstream relationships and refining internal processes. It proposes a supply chain management system tailored to actual casting production scenarios, focusing on practical execution and long-term sustainability. The study presents a comprehensive examination of the intricacies of magnesium alloy supply chain management, elucidating the prevalent market challenges and delineating the indispensable quality control measures. A targeted strategy for optimizing supply chain management and quality control is presented to offer practical insights and adaptable models for magnesium alloy enterprises navigating dynamic market conditions. In conclusion, this strategic approach will boost the competitiveness of magnesium alloy enterprises, supporting sustainable development and strategic growth objectives in a fiercely competitive market environment.

2. Characteristics and Challenges of Magnesium Alloy Supply Chain Management

2.1. Diversity of Raw Materials

Auxiliary materials play a critical role in the occurrence of metallurgical defects in castings[2]. When preparing molding sand and core sand, resins and curing agents are essential components to ensure the required strength and permeability. It is crucial to balance cost and performance when selecting auxiliary materials. By assessing the cost-effectiveness, it is recommended to opt for resins and curing agents that offer both quality and affordability. This decision can be made through a comparison of product prices, performance metrics, and service life from different suppliers, followed by a cost-benefit analysis to determine the most economical options. Furthermore, the stability of the supply chain must be considered to prevent any disruptions in the production schedule. Establishing long-term partnerships with reputable suppliers, signing supply contracts, and seeking technical support are essential steps to ensure a consistent and reliable supply of auxiliary materials. Suppliers should be selected based on their ability to offer technical assistance promptly, especially in troubleshooting or optimizing formulas. Effective technical support can enhance the utilization of auxiliary materials, ultimately improving the quality of moulding sand and core sand preparation.

2.2. Production Links and Challenges

The production of magnesium alloys involves a series of interconnected processes including smelting, casting, and processing, with each step playing a crucial role in determining the quality of the final product. Ensuring effective coordination and adherence to scientific protocols throughout the production chain represents a significant challenge in maintaining seamless operations. Upon investigation, Company D has identified specific issues that require further attention.

2.2.1. Inadequate Refinement of Process Regulations

The complexity of interactions among casting parameters poses challenges in accurately defining production requirements and standards in actual practice[3]. Insufficient refinement of production process regulations directly contributes to inconsistencies in product quality. Presently, the control of production processes heavily relies on individual skills and experience, introducing risks and instability. Establishing a stable long-term management mechanism is imperative to mitigate quality fluctuations, enhance market competitiveness, and prevent potential economic and reputational consequences.

DOI: 10.54254/2754-1169/149/2024.19265

2.2.2. Inadequate Statistical Analysis of Basic Data

Quality data plays a critical role in guiding quality management decisions by reflecting quality status, identifying production issues, and suggesting improvement strategies. The absence of a comprehensive product quality information database at Company D results in ad hoc data analysis when problems arise, limiting the effectiveness and accuracy of decision-making. Systematic data collection is essential to prevent skewed analysis outcomes and erroneous quality management decisions. Companies should prioritize information sharing and database construction to enhance data processing capabilities. Internal cross-functional integration can facilitate seamless information sharing among departments, enabling managers to make informed decisions, identify risks proactively, and minimize adverse outcomes[4].

2.3. Varying Market Demand

Magnesium alloys are utilized across diverse industries with varying requirements for performance and quality, resulting in fluctuating market demand. Adapting production plans swiftly to meet changing market needs poses a significant challenge.

In terms of procurement, Company D encounters difficulties in ensuring procurement volume and prices due to the nature of unstable volumes and frequent, small batches. This situation hampers the company's ability to prioritize conventional and speculative procurement, leading to elevated procurement costs. Unstable procurement volumes also strain supplier relationship management, resulting in disruptions in production plans and hindering negotiation leverage, resulting in higher costs, delivery delays, and service issues. Moreover, such instability impacts the workload and expenses of the procurement department and undermines long-term supplier trust and cooperation.

Furthermore, fluctuating procurement volumes complicate inventory management, necessitating high inventory levels to ensure material availability during demand spikes, tying up capital and inflating costs while risking overstock and expiration.

In addition, ensuring timely goods delivery remains a significant challenge, as suppliers frequently fail to meet the delivery schedules outlined in formal contracts. Such delays disrupt the company’s production planning, particularly during peak sales periods, jeopardizing order fulfillment and overall operational efficiency.

3. Supply Chain Management and Control

3.1. Quality Control of Raw Materials

3.1.1. Supplier Evaluation and Selection

Establishing a stringent supplier evaluation system and choosing suppliers with consistent quality is a crucial element of effective supply chain management. Company D faces challenges in its supplier management system due to the absence of a robust mechanism in the supply chain environment. The evaluation process of suppliers lacks emphasis on critical factors like production methods, integrity, logistics capabilities, and communication. This deficiency hinders the company's ability to ensure product quality, timely delivery, and effective collaboration with suppliers. The current system operates in isolation, lacking connectivity internally and with external partners along the supply chain. To enhance supplier selection and evaluation systematically, Company D plans to implement the Carter model ("10C" model) to identify top-quality suppliers with competitive potential. The company aims to reduce information distortion, predict demand accurately, and enhance risk management in the supply chain[5]. This strategic approach, coupled with market research and

DOI: 10.54254/2754-1169/149/2024.19265

proactive interventions, will elevate the company's competitiveness and strengthen the industrial chain.

3.1.2. Inspection and Acceptance of Raw Materials

Strict quality inspection and acceptance procedures are conducted on purchased raw materials to ensure compliance with production standards. It is recognized that each step in the process impacts material properties and sets the stage for subsequent processes[6]. To achieve the desired quality of magnesium alloys, precise control measures must be implemented in accordance with product specifications. This includes monitoring processes, evaluating raw material quality, and assessing magnesium alloy performance post-annealing. Various inspection points in industrial production are identified, each serving to determine the continuation or halt of processes based on quality assessment. The initial inspection point involves scrutinizing magnesium ingots, a critical factor influencing the ultimate performance of magnesium alloys[7]. Visual and random metallographic inspections are conducted on magnesium ingots to mitigate issues like insoluble inclusions, low purity, and slag inclusions. Non-compliant deliveries are rejected and contested. Sampling inspections have been proven effective in enhancing supplier product quality, as illustrated by numerical analyses[8]. While quality inspections can enhance product quality, challenges like high inspection costs and result uncertainties persist. Aside from raw material quality, numerous factors impact process stages and final product quality, necessitating rigorous process control to promptly address any deviations and meet quality objectives. Currently, Company D has placed a growing emphasis on data gathering during the magnesium alloy production technology and process development phase, setting the groundwork for the implementation of a robust control and regulatory framework.

3.2. Key Measures and Integration Strategies for Enhancing Production Process Control

Company D is currently engaged in the development of an integration strategy and optimization process aimed at enhancing stability and strengthening control within its production and operations. Optimization entails the adjustment of parameters to ensure product performance and quality adherence, thereby maintaining consistent product quality. Collaboration with external experts enhances technology management, introducing cutting-edge practices and technologies. It is imperative to align the optimization of production process control with the quality management system to deliver high-quality products and meet industry standards. This integration combines process optimization with product design, innovative accomplishments, and external management strategies to elevate competitiveness and product excellence.

3.3. Equipment Maintenance

Regular maintenance and servicing are crucial for production equipment to maintain functionality, prevent quality issues, and uphold casting quality in magnesium alloy production. Equipment precision directly affects casting quality, with routine maintenance ensuring optimal parameters and reducing defects like pores and shrinkage cavities. Timely maintenance helps detect potential issues early, prevent failures, and enhance production efficiency. Proper upkeep not only extends equipment lifespan but also lowers replacement costs and reduces rejection rates. Company D has developed a thorough maintenance plan, conducted operator training, and implemented a supervision system based on equipment usage and manufacturer recommendations. These measures are essential in maintaining superior quality, maximizing efficiency, and achieving cost-effectiveness.

DOI: 10.54254/2754-1169/149/2024.19265

3.4. Personnel Training

Enhancing personnel training is crucial for improving production staff's skills and quality management awareness. Company D is committed to advancing the casting industry by assigning senior management to oversee the casting center, actively participating in production meetings, gaining on-site operations knowledge, and reinforcing employees' quality awareness and confidence.

Furthermore, in order to enhance quality improvement, Company D has chosen five castings for special assessment initiatives, introduced incentive policies, formed quality improvement teams for each casting type, and implemented a project responsibility system to ensure structured project evaluation, assessment, and incentivization.

The company conducts statistical analyses to evaluate casting and machining quality rates, pinpoint issues, and evaluate technical quality statuses. Subsequently, lean management projects are devised, detailing improvement strategies, responsible parties, and completion timelines in comprehensive action plans. To foster a culture of continuous improvement, rewards are given to all casting team members.

As a result of this incentive system, Company D has effectively enhanced the quality rates of the assessed castings, resulting in an annual decrease in quality loss.

3.5. Finished Product Inspection and Quality Feedback

3.5.1. Finished Product Inspection

A thorough inspection of the finalized products is conducted to ensure compliance with quality standards and customer specifications. Company D has enhanced its standard system to address new challenges and requirements in high-quality development. By refining existing standards through elimination, integration, and revision, outdated criteria are replaced with new standards focusing on emerging areas like green and low-carbon technologies. The implementation of the ISO 9001 quality management system helps in defining quality policies, establishing a robust quality management organization, and standardizing various processes to enhance product quality control. Continuous improvement is emphasized through internal audits and management reviews to identify and rectify quality management issues, fostering ongoing enhancement in enterprise quality management.

3.5.2. Quality Feedback

Company D is continuously improving its quality feedback system to efficiently handle and resolve quality issues brought up by customers, thus promoting the continuous improvement of product quality. In magnesium alloy casting, having a quality feedback mechanism is essential for manufacturers[9]. By partnering with suppliers who have dependable quality management systems, manufacturers can establish a supply chain setting that provides prompt information for pinpointing the underlying reasons for quality issues and implementing corrective measures.

Company D prioritizes collecting and addressing customer feedback promptly. Customer input is crucial for identifying and resolving quality issues, ensuring high satisfaction, trust, and loyalty. Effective handling of quality concerns enhances product quality, meets customer needs, and boosts competitiveness in the magnesium alloy casting industry. Establishing a quality feedback mechanism is vital for understanding market demands, improving products, and enhancing brand reputation to sustain growth and competitiveness.

DOI: 10.54254/2754-1169/149/2024.19265

3.6. Optimization Strategies for Supply Chain Management and Quality Control

Supply chain collaborative management involves establishing an information sharing platform through digital means to enable seamless information exchange and collaborative operations across all supply chain links. Differentiated management strategies and procurement approaches are applied to effectively manage supplier relationships[10]. Adopting the multi-supplier principle is crucial for mitigating risks of supply chain disruptions, with tailored relationship management strategies ensuring supplier competitiveness[11]. Fostering a mutually advantageous supplier partnership is focused on attaining peak levels of quantity, quality, and punctual delivery, leading to cost savings and streamlined inventory management. Recognizing the intensifying market competition, Company D has acknowledged the significance of effective supply chain management and has proactively implemented relevant strategies. This includes setting up a communication network with key suppliers, leveraging Internet technology for swift data transmission, creating specialized task forces, and organizing routine reciprocal visits. Strengthening supplier cooperation entails fostering a long-term and stable relationship through detailed long-term contracts outlining reward and penalty criteria, incentivizing suppliers to enhance product quality, supply cost, and punctuality[12]. Clear guidelines on information exchange frequency and authenticity are essential for successful collaboration.

Overall, enhancing quality control systems through advanced management systems, efficient production planning, quality data analysis, and technology adoption is vital for businesses to standardize quality practices, enhance efficiency, and remain competitive in the market. Continuous innovation and improvement in quality control systems will enable enterprises to achieve sustainable growth and greater market competitiveness by adapting to evolving customer needs and market dynamics.

4. Conclusion

Supply chain management and quality control of magnesium alloys are pivotal for enterprises to enhance competitiveness and ensure product quality. This study demonstrates that by optimizing supply chain management and quality control strategies, such as strengthening supplier cooperation, introducing advanced quality management systems, and strengthening quality data analysis, the supply chain management level and product quality of magnesium alloy enterprises can be effectively improved, thereby meeting market demands and achieving sustainable development. This also provides an answer to the research question presented in the introduction, namely how magnesium alloy enterprises can enhance their competitiveness and ensure product quality.

However, the current research also has some limitations. For example, the sample size may be insufficient and may not encompass other categories of magnesium alloy enterprises, which could potentially influence the generalizability of the research findings. Further research into the specific technical details of quality control is recommended in order to better adapt to the complex and changeable production environment.

To address these deficiencies, it would be beneficial to expand the scope of the research sample in the future to include a greater number of magnesium alloy enterprises, representing a wider range of scales and production modes, in order to ensure greater representativeness of the research results. In terms of quality control technology, there is a need to strengthen the combined research with advanced manufacturing technologies and explore more efficient and accurate quality control methods.

Future research should mainly focus on the following aspects. First, it is essential to develop strategies for effectively addressing the new challenges and opportunities presented by technological advancement. This includes utilising innovative technologies, such as artificial intelligence and big

DOI: 10.54254/2754-1169/149/2024.19265

data, to enhance supply chain management and quality control processes. Second, in order to meet the changing demands of the market, it is necessary to identify methods of rapid adaptation to diverse and personalised market demands. Third, a further in-depth study of the collaborative mechanism of each link in the supply chain is required in order to achieve more efficient resource allocation and value creation, and ultimately improve the satisfaction of intermediate customers and end users.

References

[1] *Claudia, K., Mariusz, L., & Michael, H. (2019) SUPPLY CHAIN QUALITY MANAGEMENT OF AUTOMOTIVE 2 COMPONENTS, Zeszyty Naukowe - Politechnika Śląska Organizacja i Zarządzanie, 2019.133: 69-83.*

[2] *Guo, Z., Shan, Z., Du, D., et al. (2018). Experimental investigation on the flow properties of sand granules in the process of sand mold printing. Rapid Prototyping Journal, 24(9), 1599-1608.*

[3] *Hai, B. (2011). Casting Technology and Quality Improvement of Magnesium Alloys. Special Issues on Magnesium Alloys.*

[4] *Riley, J. M., Klein, R., Miller, J. L., & Sridharan, V. (2016). How internal integration, information sharing, and training affect supply chain risk management capabilities. International Journal of Physical Distribution & Logistics Management, 46(10), 953-980.*

[5] *Schoenherr, T., & Swink, M. (2012). Revisiting the arcs of integration: Cross-validations and extensions. Journal of Operations Management, 30(1), 99-115.*

[6] *Nam, A., Kawalla, R., Zinoviev, A., Erisov, Y., Prüfert, U., & Eiermann, M. (2017). Temperature validation of 3D model for the reversing hot rolling in connection with a coil model. Key Engineering Materials, 746, 132–137.*

[7] *Kawalla, C., Höck, M., & Oswald, M. (2015). Concept of a quality assurance system for hot rolled TRC magnesium strips. In Proceedings of the 10th international conference on magnesium alloys and their applications (pp. 1-8). Korean Institute of Metals and Materials.*

[8] *Starbird, S. A. (2001). Penalties, rewards, and inspection: Provisions for quality in supply chain contracts. Journal of the Operational Research Society, 52(1), 109-115.*

[9] *Zhang, M., Hu, H., & Zhao, X. (2020). Developing product recall capability through supply chain quality management. International Journal of Production Economics, 229, 107795-107795.*

[10] *Parmigiani, A., Klassen, R. D., & Russo, M. V. (2011). Efficiency meets accountability: Performance implications of supply chain configuration, control, and capabilities. Journal of Operations Management, 29(3), 212-223.*

[11] *Awaysheh, A., & Klassen, R. D. (2010). The impact of supply chain structure on the use of supplier socially responsible practices. International Journal of Operations & Production Management, 30(12), 1246-1268.*

[12] *Zimmer, K. (2002). Supply chain coordination with uncertain just-in-time delivery. International Journal of Production Economics, 77(1), 1-15.*