The Effect of Quality Control Standard Implementation for Quality Improvement of The Casting Process on The Jewellery Manufacturing Industry

Erwin[1]*, Yefri Chan[1], Yovi Leonardo[1], Ade Supriatna[2], and Danny Faturachman[3]
Mechanical Engineering Department, Darma Persada University, Jakarta, Indonesia[1]
Industrial Engineering Department, Darma Persada University, Jakarta, Indonesia[2]
Naval Engineering Department, Darma Persada University, Jakarta, Indonesia[3]
***erwin.dosen@gmail.com**

OPEN ACCESS

***Citation*:** Erwin, Yefri Chan, Yovi Leonardo, Ade Supriatna, and Danny Faturachman. 2024. The Effect of Quality Control Standard Implementation For Quality Improvement of The Casting Process on The Jewellery Manufacturing Industry. *Journal of Research and Technology* Vol. 10 No. 1 Juni 2024: Page 103–111.

Abstract
The high demand for jewellery products increases significantly every year, but the export requirements of the products demand high quality. So, efforts are needed to improve quality, support cost savings, reduce energy needs, and improve work safety, especially in the casting process of jewellery products. This study aims to analyse the implementation of practical quality control standards to improve the quality of jewellery product casting. This research method uses a Plan-Do-Check-Action process approach that refers to ISO 9001, 14001 and 45001 standards. Implementing the PDCA (Plan-Do-Check-Action) process approach adopted in developing quality control methods in the jewellery casting process proved effective, resulting in casting shrinkage of 0.2 kg below the established standard of 0.7-1 kg. Controlling temperature casting below the melting point can also provide energy savings and heat control of the casting process to reduce occupational safety and health hazards. PDCA quality control methods can improve the quality of casting jewellery products by reducing porosity defects and shrinkage, saving energy, and reducing occupational safety hazards. This research provides an effective quality control method for the jewellery casting production process regarding quality improvement, environmental management, and safety to achieve the Company's sustainability.

***Keywords*:** *Casting, Defects, Jewellery, Manufacturing, Quality Control.*

Abstrak
Permintaan yang tinggi untuk produk perhiasan meningkat terus secara signifikan setiap tahunnya, namun persyaratan ekspor produk menuntut kualitas yang tinggi. Sehingga diperlukan upaya untuk meningkatkan kualitas dalam

mendukung penghematan biaya, mengurangi kebutuhan energi dan keselamatan kerja khususnya pada proses pengecoran produk perhiasan. Penelitian ini bertujuan untuk menganalisis implementasi standar pengendalian kualitas yang efektif untuk meningkatkan kualitas hasil pengecoran produk perhiasan. Metode penelitian ini menggunakan pendekatan proses Plan-Do-Check-Action yang merujuk pada standar ISO 9001, 14001 dan 45001. Hasil implementasi metode pendekatan proses PDCA (Plan-Do-Check-Action) yang diadopsi dalam pengembangan metode pengendalian kualitas pada proses casting perhiasan terbukti efektif dengan hasil penyusutan casting sebesar 0,2 kg dibawah standar yang ditetapkan yaitu 0,7-1 kg. Serta pengendalian temperature casting yang dibawah titik lebur mampu memberikan penghematan energi dan pengendalian panas proses casting untuk mengurangi bahaya keselamatan dan Kesehatan kerja. Metode pengendalian kualitas PDCA mampu meningkatkan kualitas hasil pengecoran produk perhiasan dengan mengurangi cacat porositas dan penyusutan, penghematan energi dan mengurangi bahaya keselamatan kerja. Kontribusi dari penelitian ini untuk memberikan metode pengendalian kualitas proses produksi casting perhiasan yang efektif untuk peningkatan kualitas, pengelolaan lingkungan dan keselamatan untuk mencapai keberlajutan Perusahaan.

Keywords: *Pengecoran, Cacat, Perhiasan, Manufaktur, Pengendalian Kualitas.*

1. Introduction

In recent years, there has been an increase in demand for quality jewellery exports to several countries in America and the Middle East. This is what engineers need to develop to improve the quality of the jewellery manufacturing process consisting of product quality, environment safety, and health. Quality control standards are a tool to improve the results of jewellery casting. High-quality standards can be achieved through continuous development and improvement so that the Company can compete and customers are loyal to the Company (Czősdörová & Gnap, 2023). By implementing quality, environmental, occupational health, and safety control standards, organizations can improve performance and increase the application level periodically (Erwin & Irawanto, 2022). Meeting customer demands that demand quality product casting results with the minimum number of defects is essential for the foundry industry to continue to improve in analyzing defects caused by many causative factors (Guan et al., 2024). The cooling rate level needs to be considered in jewellery casting, which uses investment casting, so the jewellery pattern must be designed and well-controlled (Ziat et al., 2020). Implementation of appropriate and consistent quality standards to meet customer needs continues to be carried out to improve the quality of foundry products.

Identification of production process risks can reduce casting defects. ISO standards stipulate identifying and managing risks from an industry, especially risks that impact or are essential to the organization, and there are nonconformities in the organization due to a lack of proper risk management and control (Sarkheil, 2021). A solid commitment to the development and innovation of quality management of production processes, environment, and safety needs to be facilitated by management, especially in assessing critical risks (Erwin & Asbanu, 2021). Defects from casting products, such as porosity and shrinkage, occur, causing poor product surfaces (Wenschot, 2014). Some typical defects of the casting process need to be identified so that predictions of the possibility of smallpox can be anticipated in the production process (Guan et al., 2024). Critical risks in potentially defective processes can be analyzed in depth to minimize them.

The process of making mould patterns and wax filling on the mould affects the occurrence of casting defects such as gas porosity. Metal in liquid conditions is poured into the mould for further cooling so that heat transfer and the formation of the liquid phase to solid become an essential part of the mould design to create quality processes and products (Hidayat et al., 2024). The wax temperature is below the melting point of other materials (Abdulrazzak Jasim et al., 2024). Wax solids will disappear consistently, and some cavities in the casting will require special handling (Basso et al., 2020). Proper pouring system control is needed to prevent porosity so that no gas content is trapped (Wenschot, 2014). Preparation before the casting process requires precise control related to wax filling, vacuum, mould, and cooling.

Application of the ISO standard with the PDCA approach can prevent the problem from recurring. The benefits of implementing ISO standards have both financial and non-financial impacts on organizations. Contributing to improved internal process efficiency, production process improvement provides a positive perspective for internal and external parties (Cződörová & Gnap, 2023). The PDCA (Plan-Do-Check-Act) process is a continuous improvement made by the organization starting from the "plan" stage by clearly identifying problems. The next stage is "implementation", carrying out activities following planning, followed by the "check" stage, which is an examination of the results of the implementation applied. The last stage is the "action" of following up on the results of examinations that have not met the requirements (Rodrigues et al., 2020). Corrective and preventive actions are systems that help organizations prevent recurring problems, and rapid improvement processes become the main focus on essential problems (Haleem et al., 2015). Adopting an ISO-based process approach provides improvement opportunities for organizations to prevent recurring problems with a consistently implemented PDCA staging mechanism.

Monitoring and evaluating critical processes such as audits and inspections are methods to improve the quality of foundry results. Process flow charts are necessary to observe and analyze critical production processes and make it easier to identify opportunities for corrective action (Santos et al., 2023). Contribution to achieving sustainable performance can be supported by implementing an internal audit focusing on energy efficiency management and environmental control (Erwin, 2021). Pressure and melt temperatures are controlled to control defects during the casting process, and the casting process results can be inspected and analyzed visually through a microscope (Martinez-Hernandez et al., 2013). The quality of the casting results is greatly influenced by the quality of the material (Kozana et al., 2019). Smooth surfaces are of particular concern to the quality of casting results, so special knowledge related to metal casting technology is needed (Ruzbarsky, 2022). The relationship between the inspection stage and the follow-up of the inspection and audit process is very significant, potentially to improve product quality.

Some things that are not yet known from the discussion above include appropriate quality control standard methods for the jewellery casting process, preventive measures to reduce casting defects, unknown impact of casting defects on hazards, environmental impacts and occupational safety health, the effect of quality control method effectiveness and cost, and the effect of continuous improvement on quality control standards. This research is essential because efforts are being made to improve the quality of gold jewellery casting results by implementing effective quality control methods. Practical quality control standards can affect the quality of gold jewellery casting products. This study aims to analyze the implementation of practical quality control standards to improve the quality of jewellery product casting.

2. Method

This research was conducted in one of the jewellery manufacturing industries. They are implementing ISO 9001, 14001, and 45001 quality control standards with the Plan Do Check Action (PDCA) method. The planning stage involves identifying problems and risks, preparing procedures, providing work instructions for the jewellery casting process, and maintaining quality control records. The implementation stage (Do) is done by applying the document's requirements. The check stage is carried out to check for defects in the casting process, and the action stage is an improvement made to improve the quality of jewellery products. The stages of the process approach are adopted from ISO 9001, 14001, and 45001 standards.

Based on information from interested parties, interest in this type of jewellery is dominated by rings, bracelets, necklaces and earrings. The most anticipated gold content is 70% - 75% gold content, the second is 99% gold content, followed by 80%-87.5% gold content, and the last thing is 37.5% - 42% gold content. The dominating gold content is a type or category of gold with a carat level of 17, with a gold content between 70.83%-74.99% following SNI 8880:2020. Table 1 describes the gold material and its alloys in meeting the carat content and melting point of the 17-carat jewellery alloy.

Table 1. Material and melting point of jewellery alloy material

Material	Range Composition of 17 carats	Melting Point (°C)
Gold (Au)	70,83 – 74,99	1063
Nickel (Ni)	Balance	1453
Silver (Ag)	Balance	960,8
Copper (Cu)	Balance	1083
Palladium (Pd)	Balance	1552
Platinum (Pi)	Balance	1769

3. Result and Discussion

At the planning stage, the process flow is prepared. The jewellery manufacturing process starts with the 2D design, then the 3D design, then resin printing, resin finishing and rubber printing. The wax injection is carried out and continued to the casting process. The jewellery casting process is critical because of smallpox product problems such as porosity and shrinkage. After the casting process, the frame assembly is carried out, polishing and adjusting the frame, shaving the stone, and setting the stone. After that, polishing and chrome are required. Figure 1 describes the flow of the jewellery manufacturing process.

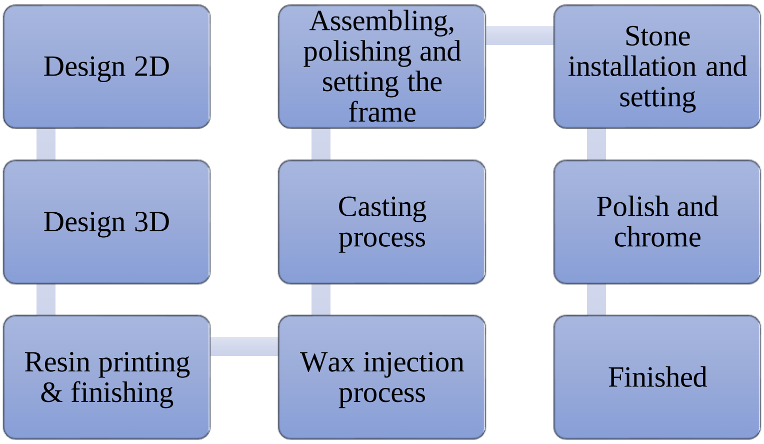

Figure 1. Stages of The Jewellery Manufacturing Process

The jewellery casting process is the core process in jewellery production, so at the preparation stage, a mechanism or work instruction is also carried out, which starts from the initial stage of operating the machine and supporting devices such as a compressor machine with proper temperature indicator adjustment, followed by starting the operation of the casting machine by determining the type of rust setting to be produced. Some things in the operation of casting machines require special attention in determining the initial temperature of preheating, mixing process time, mixing temperature, and casting temperature according to the type or type of gold content. To produce the required product quality, things that need to be considered in the casting process include setting the machine program for temperature, time, and type of gold content.

At the implementation stage (Do) related to the environmental impact of the casting process, namely the use of significant energy for the melting process so that engineering for the casting process is carried out by setting the temperature below the melting point so that the process can reduce environmental impact and energy use efficiency. Table 2 details the casting process' temperature drop below the alloy's melting point.

Table 2. Decrease in Melting Temperature in The Casting Process

Material	**Melting Point (°C)**	**Range of Casting Temperature (°C)**
Gold (Au)	1063	1030 - 1070
Nickel (Ni)	1453	

Silver (Ag)	960,8
Copper (Cu)	1083
Palladium (Pd)	1552
Platinum (Pi)	1769

Quality control is carried out at the implementation stage in the casting process by monitoring the suitability of gold material weight, alloy type, alloy colour, alloy material weight and paint residue weight. After the casting process, a cleaning process is carried out, which has an impact on the emergence of liquid waste from production, so a refining process is carried out to separate the gold content from wastewater using DC direct current electric power obtained from the rectifier, refining is carried out into 99.99% pure gold. In the safety aspect of heat exposure, direct exposure is minimized by foundry operators by regulating pouring techniques and using personal protective equipment that can protect from heat exposure.

At the inspection stage (Check), an inspection and audit of quality control is carried out, which consists of decreased porosity defects as evidenced by the depreciation value below tolerance. In quantity, the depreciation value decreases and reaches the set target. From the financial side, optimizing the production process, saving energy consumption in the foundry and recycling liquid waste positively impact the Company's sustainability. The requirements of the interested parties related to quality, environmental, and safety standards have been met, which can be proven by the achievement of international standard certificates such as ISO 9001, 14001, and 45001 and SNI national standards.

At the follow-up stage (Action), efforts are needed to improve quality through sampling techniques for gold jewellery content tests, which are only carried out on raw materials before the casting process, for finish good products have not been carried out because there needs to be a destructive process on the finished product, cost policies constrain this. The equilibrium of elements of the melting process between raw materials and finished products cannot yet be tested as efficiently as possible to obtain the most appropriate composition. Employee awareness still needs to be increased by implementing 5R and safety, so it must continue to be monitored for patrols or inspections. Environmental control requires high costs, especially for infrastructure, resources, water and air pollution testing, and disposal of B3 waste that cannot be processed for recycling; this requires consideration from management to innovate environmental management.

Improvements to advanced material technology can provide the most effective and efficient alloy composition. Engineering trials must be conducted to obtain formulas and specifications for materials and manufacturing. The results of these experiments need to be tested by testing chemical elements that produce the amount of all ingredients tested with a measured composition value of 100%. So that further analysis can be carried out on mechanical properties such as the hardness of jewellery products. Development is needed to optimize the metal casting process to reduce the energy requirements and improve the metal casting process. Conservation of smelting energy is necessary to reduce heat input and heat loss. Reducing the remaining molten metal and lowering the smelting temperature impacts the economic aspects of engineering. In terms of quality control of processes and quality testing products on the porosity of the casting products, from shrinkage of solidification and high gas content. The ability of metals to fill a minimal area leads to volume shrinkage and porosity. This needs to continue to be developed so that the foundry defects caused by trapped air can harm the jewellery industry such as product weight reduction and defective texture. So, a repair process is needed to add alloy metal elements to the product. This impacts the production process activities' processing time, cost, and productivity.

The PDCA (Plan-Do-Check-Action) process approach adopted in developing quality control methods in jewellery casting has proven effective, with casting depreciation results of 0.2 kg below the established standard of 0.7-1 kg. Prevention is carried out to reduce casting defects by identifying critical processes in the early stages of casting preparation, casting machine setup and cleaning stage after the casting process made in work standards, and monitoring the quality control of the production process. The impact on casting results' porosity defects has an impact on material shrinkage and control of liquid waste management from the casting process cleaning process and the hazard aspects of the hot steam casting process. The effect of the impact of the implementation of quality control on the casting process on production costs is obtained from the total casting value of 900 kg, the remaining casting of 607 kg, the remaining casting in the koras process of 2 kg, and the remaining casting of the polishing process of 2 kg, with a total shrinkage of 2 kg. The cost of goods produced per gram is Rp. 637,000, operational costs per unit is Rp. 500,000. The application of quality control methods based on ISO integration can reduce porosity defects and shrinkage value below tolerance, which has an impact on optimizing production processes, energy consumption, and environmental impacts to improve the Company's sustainability.

4. Conclusion

The conclusion of this research is:

1. This research proves that the quality control method with the PDCA approach is effective in reducing defects, porosity, and depreciation rates in the jewellery manufacturing industry
2. Optimization of the use of metal casting energy by lowering the melting temperature and heat utilization of the casting process has an impact on environmental, health, safety and engineering economic aspects.
3. Developing technology to reduce casting defects caused by trapped air can harm the jewellery industry through product weight reduction and defective textures. This requires a repair process to add alloy elements to the product. This impacts the production process activities' processing time, cost, and productivity.

Suggestions for further research is:

1. This research provides an effective method of quality control of the jewellery casting production process in quality improvement, environmental management and safety to achieve the Company's sustainability.
2. Further research can be done by managing air pollution from the casting process in the jewellery manufacturing industry

REFERENCES

Abdulrazzak Jasim, R., Qasim Hussen, W., Faris Abdulla, M., Ibrahim, I. J., & Zulkifli, R. (2024). Simulation of Heat Transfer during Paraffin And Gallium Melting and Solidification Processes Utilizing Star CCm+. *CFD Letters*, *16*(3), 37–54. https://doi.org/10.37934/cfdl.16.3.3754

Basso, E., Pozzi, F., Day, J., & Borsch, L. (2020). Unmasking a wild man: scientific analysis of Bertoldo di Giovanni's Shield Bearer in The Frick Collection. *Heritage Science*, *8*(1), 1–14. https://doi.org/10.1186/s40494-020-00453-5

Cződörová, R., & Gnap, J. (2023). Investigation of the Effectiveness of the Introduction of the Quality Management System According to the ISO 9001 Standard in Transport Companies: Slovakia Case Study. *Sustainability (Switzerland)*, *15*(3). https://doi.org/10.3390/su15032401

Erwin. (2021). Implementasi Sistem ISO 14001 dalam Mendukung Pencapaian Kinerja Keberlanjutan Perusahaan di Industri Manufaktur Pulp dan Kertas di Indonesia. *Research Paper*, *3*(2), 17–24.

Erwin, E., & Asbanu, H. (2021). Corporate Sustainability Improvement Strategy in Manufacturing Industry with The Use of Controls in Environmental Pollution, Quality, and Occupational Health and Safety. *Indonesian Journal of Environmental Management and Sustainability*.

Erwin, & Irawanto, D. W. (2022). Integrated Management System as a Tool to Improve Corporate Sustainability Performance in the Pharmaceutical Manufacturing Industry in Indonesia. *Proceedings of the International Conference on Innovation and Technology (ICIT 2021)*, *212*(Icit), 107–115. https://doi.org/10.2991/aer.k.211221.014

Guan, B., Wang, D. H., Shu, D., Zhu, S. Q., Ji, X. Y., & Sun, B. De. (2024). Data-driven casting defect prediction model for sand casting based on random forest classification algorithm. *China Foundry*, *21*(2), 137–146. https://doi.org/10.1007/s41230-024-3090-1

Haleem, R. M., Salem, M. Y., Fatahallah, F. A., & Abdelfattah, L. E. (2015). Quality in the pharmaceutical industry - A literature review. *Saudi Pharmaceutical Journal*, *23*(5), 463–469. https://doi.org/10.1016/j.jsps.2013.11.004

Hidayat, A., Rahmalina, D., & Rahman, R. A. (2024). Impact of Top Mold Slope on Defect Formation in Gravity Casting of Aluminum Alloy. *Annales de Chimie: Science Des Materiaux*, *48*(1), 37–42. https://doi.org/10.18280/acsm.480105

Kozana, J., Garbacz-Klempka, A., & Piękoś, M. (2019). Lead-free casting brasses. Investigations of the corrosion resistance and shaping of microstructure and properties. In *Archives of Foundry Engineering* (Vol. 19, Issue 2, pp. 113–118). https://doi.org/10.24425/afe.2019.127126

Martinez-Hernandez, M., Juarez-Hernandez, A., González-Rivera, C., & Hernandez-Rodriguez, M. A. L. (2013). Bismuth segregation and crack formation on a free lead yellow brass tap. *Engineering Failure Analysis*, *28*, 63–68. https://doi.org/10.1016/j.engfailanal.2012.10.002

Rodrigues, J., Sá, J. C., Silva, F. J. G., Ferreira, L. P., Jimenez, G., & Santos, G. (2020). A rapid improvement process through "quick-win" lean tools: A case study. *Systems*, *8*(4), 1–19. https://doi.org/10.3390/systems8040055

Ruzbarsky, J. (2022). Influence of Die Casting Speed on Properties of Casting Based on Al-Si Alloys. *MM Science Journal*, *2022-Novem*, 6114–6122. https://doi.org/10.17973/MMSJ.2022_11_2022012

Santos, E., Lima, T. M., & Gaspar, P. D. (2023). Optimization of the Production Management of an Upholstery Manufacturing Process Using Lean Tools: A Case Study. *Applied Sciences (Switzerland)*, *13*(17). https://doi.org/10.3390/app13179974

Sarkheil, H. (2021). Risk and incident analysis on key safety performance indicators and anomalies feedback in south pars gas complex. *Results in Engineering*, *9*(February), 100210. https://doi.org/10.1016/j.rineng.2021.100210

Wenschot, P. (2014). Defects caused by precipitation of in liquid copper-nickel-aluminium-bronze alloys dissolved carbon and removal by treatment of melt. *International Journal of Cast Metals Research*, *27*(2), 65–72. https://doi.org/10.1179/1743133613Y.0000000080

Ziat, Y., Hammi, M., Laghlimi, C., & Moutcine, A. (2020). Investment casting of leaded brass: Microstructure micro-hardness and corrosion protection by epoxy coating. *Materialia*, *12*(April). https://doi.org/10.1016/j.mtla.2020.100794.