Implementation of Metallurgical Industry Management Using the DMAIC Method in TS Aluminum

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Abstract

The case study in this research comes from the TS Aluminum company in Yogyakarta. This research aims to reduce the number of defects in metal in the casting process from an industrial management point of view. This research method uses quantitative and qualitative methods through literature studies and experimental data with the DMAIC method.

From the results of production and marketing carried out with a production volume of 250 pcs per day, there were 4% failures in the products produced. Defects that often occur are rat tail defects, cold shot, and porosity. Defects are caused by factors such as human error, methodology, and materials. Recommendations for improvement include providing regular training to employees, updating work procedures, and checking materials.

Keywords: Defect, DMAIC, Metallurgical Management

Introduction

Indonesia has entered the industrial era 4.0 which makes competition in the household equipment industry increasingly fierce (Ly Duc et al., 2023). Therefore, in order to ensure the continuity of business processes in the household appliances industry, quality products and services are the main requirements to support the sustainability of an industry (Guleria, Pathania, Shukla, et al., 2021).

Product quality plays an important role in increasing the competitiveness of the household appliances industry (Guleria, Pathania, Sharma, et al., 2021). However, even though the production process has been carried out well, imperfections are often found in the product so that the resulting product does not meet expectations (Sithole et al., 2019). This can be caused by deviations from various factors, whether originating from raw materials, labor, or from the tools used (Shukla et al., 2021).

Cor Aluminium TS Putra 2 is a small and medium industry that produces household equipment located in Yogyakarta. However, in the production process there are still many imperfections in the production results, so that if they are ignored it can threaten aspects of product quality which play an important role in industrial competition (da Silva et al., 2023).

Nowadays, consumers have become more selective in choosing products by considering the price of the product and the quality obtained. It is very important to pay

attention to product quality, both in terms of durability and resilience, because the quality of this product influences consumer satisfaction with the product produced (Nallusamy, 2020). Therefore, to improve product quality, quality control is necessary (Guleria, Pathania, Bhatti, et al., 2021).

Quality control is an important activity related to the production process, where quality control carries out various stages such as checking and testing the quality characteristics of a product which aims to determine the level of efficiency of the production process which is adjusted to the standards of the product specifications (Jones et al., 2010). One method of controlling product quality is using the DMAIC method. This method is a method often used by companies to control quality by minimizing the number of defects (Dhingra et al., 2022).

Research Methods

In this research, samples were taken from one of the foundry companies in Yogyakarta, TS Aluminum. This research uses the DMAIC method (Zope et al., 2023). DMAIC is Define, Measure, Analyze, Improve, and Control which is a structured framework based on data to solve a problem (*Six Sigma within Doosan Heavy Industries & Construction Company*, 2006).

The data used comes from company data and the results of field observations. The steps taken are (Ranade et al., 2021) :
1. Define
   This stage will define and define important issues in the process.
2. Measure
   This stage will calculate the process capability
3. Analyze
   At this stage, we will analyze and determine the root cause of a defect or failure.
4. Improve
   At this stage, an improvement plan will be made based on the results of calculations and analyses that have been done previously.
5. Control
   This stage makes a control plan for the improvement plan that has been made.

Result and Discussion

Based on observations in Cor Aluminium TS Putra 2, data on the number of production and defects in product results was obtained through observations carried out over a period of 5 days from October 2 2023 to October 6 2023. Next, analysis and discussion were carried out according to the DMAIC method to determine the research results.

1. Define

At this stage, the research object has been determined, namely cast products (Kolbusz & Antosz, 2023). Next, identify product quality or CTQ (Critical To Quality).

CTQ value can be determined based on the type of defect in the product (Sahoo et al., 2008). There are three types of defects in products at TS Aluminum, namely rat tail defects, coldshot and porosity.

2. Measure

In this second step, the data used is total production data and the number of defective products. Cast production data can be seen in Table 1.

Tabel 1. Production Data on Cor Aluminium TS Putra 2

Number	Day	Production	Number of Defects
1.	Monday	200	8
2.	Tuesday	200	10
3.	Wednesday	200	9
4.	Thursday	200	7
5.	Friday	100	4

Based on the following table, it can be seen that every day there are production defects of $\geq 4\%$. Of the 4% of defects that occur, several defects that often occur are rat tail defects, coldshot, and porosity (Glazoff et al., 2004). This rat tail defect is a defect that occurs on the surface of the cast product which can be seen with the eye. The shape of this defect is like a rat's tail which is caused by the surface of the molding sand expanding and the liquid metal used flowing into the surface. Apart from that, it can be caused because when the mold is made there is still a gap between the top of the mold and the bottom of the mold so that the liquid metal fills the gap (Zhang et al., 2022).
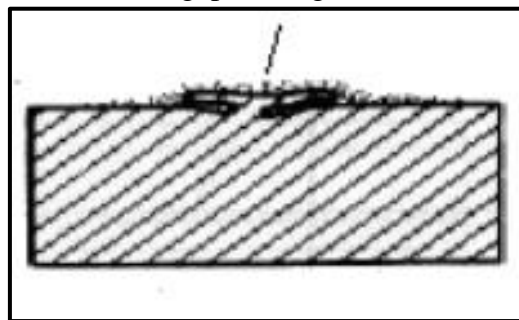
Figure 1. Rat tail defect

One of the reasons for this expanding surface is because the quality of the molding sand is not good enough to withstand high temperatures. Then there is coldshot which occurs in cast products. This cold shot can occur because foreign material such as metal splashes, slag or sand enters the liquid metal during melting, pouring or freezing. As a

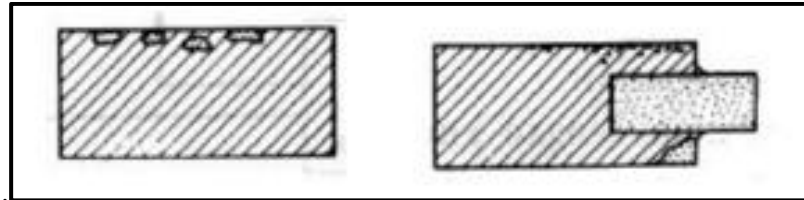result, foreign material entering the liquid metal will form solid bubbles and become trapped in the mold

Figure 2. Coldshot

Then porosity defects (cavities) occur in the cast product. This porosity is a hole defect caused by steam or gas trapped in the cast product (Fan et al., 2010). This steam comes from the water content that is still too much in the sand so it evaporates due to exposure to heat from the liquid metal flowing into the mold cavity
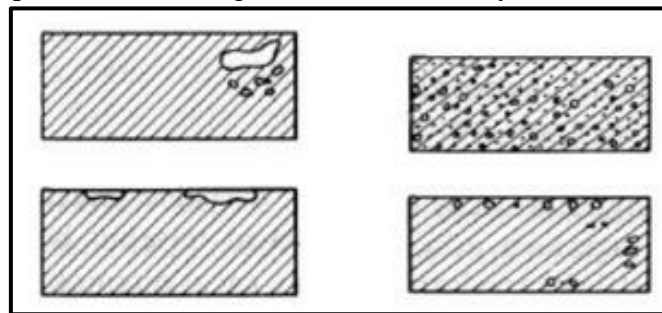

Figure 3. Porosity

3. Analyze

In the third step, researchers look for the cause of the defect, then look for the cause. Based on the data that has been obtained based on the observations that have been made, a cause and effect diagram can be used (Fishbone) to find out preventive actions or solutions that can be taken to prevent and reduce the level of product defects that occur during the production process. A cause and effect diagram or Fishbone diagram is a tool that helps identify, sort and display various possible causes of a problem or certain quality characteristics. This diagram illustrates the relationship between the problem and all the causal factors that influence the problem. This diagram aims to help identify the root cause of a problem, help generate ideas for solutions to a problem, and reduce high levels of product defects.

After it was discovered that there were many defects in the final product from the aluminum metal casting process, observations were made of the causes of defects in the final product using a cause and effect diagram. Based on observations during the research site, the causes of defects are caused by several factors, such as man, machine, method and material.

4. Improve

The fourth step is making an improvement plan. This stage is carried out after knowing the factors that cause defects. The following are several proposed improvement plans to minimize the factors that cause defects. From several defects found in the product, several suggestions were obtained to minimize the occurrence of product failure which can be seen in the table below.

Tabel 2. Proposed Improvement Plan

Factors Causing Defects	Reasons Factors Causing Defects	Proposed Improvement Plan
Man	Lack of accuracy	Establish new policies and sanctions for negligent workers
	Lack of skills	Conduct periodic training
Methods	Manufacturing process is not up to standard	Establish work procedures on mold making and liquid metal pouring techniques
Material	Poor material quality	Selectively choose materials to be used from collectors or distributors

From several defects that occur in cast products, action can be taken to prevent defects from occurring in cast products. This rat tail defect can be prevented by using high quality molding sand so that it can withstand the high temperatures of the liquid metal used. Apart from that, you can also make the mold carefully so that there are no gaps between the top mold and the bottom mold. Then cold shot can be prevented by using a close, smooth and fast pouring technique so that no foreign material enters the molten metal. Apart from that, it can also remove slag in the melting furnace optimally so that the slag that is still in the furnace does not contaminate the molten metal. Then, porosity defects can be prevented by maintaining the humidity of the molding sand that will be used. With the humidity of the molding sand not being too high, the water content in the molding sand is also not too high. Therefore, the water contained in the sand does not experience much evaporation which will cause porosity.

5. Control

The final stage of the DMAIC method is control. From the results of the analysis of product defects and defects, there are several improvement plans that can be realized with

improvement plans to minimize failures in cast products in small industries Cor Aluminium TS Putra 2. The plan can be seen in the table below.

Tabel 3. Control Plan

Improvement Plan	Control Plan
Establish new policies and sanctions for negligent workers	Policies and sanctions created for a more optimized process
Conduct periodic training	Training conducted with experts to optimize
Establish work procedures on mold making and liquid metal pouring techniques	Update work procedures to prevent product failure
Selectively choose materials to be used from collectors or distributors	Checking the materials to be purchased

Conclusion

Based on observations and observations made in small and medium industries Cor Aluminium TS Putra 2 It can be concluded that :

- 4% of 200 products produced were defective
- Frequent defects include rat tail defects, cold shot, and porosity
- Efforts that can be made to prevent defects in products are setting policies and sanctions, regular employee training, updating work procedures, and checking materials.

References

da Silva, H. G., Ferreira, J. C. E., Kelm, T., & Ivaniski, T. M. (2023). Life cycle assessment of the casting process with the addition of niobium from scrap. *SN Applied Sciences*, *5*(12). https://doi.org/10.1007/S42452-023-05569-4

Dhingra, S., Guleria, P., Khargotra, R., & Shukla, R. K. (2022). Improvement in Dents at Gear Manufacturer Company Through Lean Six Sigma. *Proceedings - 2022 International Conference on Computational Modelling, Simulation and Optimization, ICCMSO 2022*, 412–415. https://doi.org/10.1109/ICCMSO58359.2022.00085

Fan, K. C., Chen, S. H., Chen, J. Y., & Liao, W. B. (2010). Development of auto defect classification system on porosity powder metallurgy products. *NDT & E International*, *43*(6), 451–460. https://doi.org/10.1016/J.NDTEINT.2010.04.005

Glazoff, M. V., Barlat, F., & Weiland, H. (2004). Continuum physics of phase and defect microstructures: bridging the gap between physical metallurgy and plasticity of

aluminum alloys. *International Journal of Plasticity*, *20*(3), 363–402. https://doi.org/10.1016/S0749-6419(03)00093-7

Guleria, P., Pathania, A., Bhatti, H., Rojhe, K., & Mahto, D. (2021). Leveraging Lean Six Sigma: Reducing defects and rejections in filter manufacturing industry. *Materials Today: Proceedings*, *46*, 8532–8539. https://doi.org/10.1016/J.MATPR.2021.03.535

Guleria, P., Pathania, A., Sharma, S., & Sá, J. C. (2021). Lean six-sigma implementation in an automobile axle manufacturing industry: A case study. *Materials Today: Proceedings*, *50*, 1739–1746. https://doi.org/10.1016/j.matpr.2021.09.177

Guleria, P., Pathania, A., Shukla, R. K., & Sharma, S. (2021). Lean six-sigma: Panacea to reduce rejection in gear manufacturing industry. *Materials Today: Proceedings*, *46*, 4040–4046. https://doi.org/10.1016/J.MATPR.2021.02.559

Jones, E. C., Parast, M. M., & Adams, S. G. (2010). A framework for effective Six Sigma implementation. *Total Quality Management and Business Excellence*, *21*(4), 415–424. https://doi.org/10.1080/14783361003606720

Kolbusz, P., & Antosz, K. (2023). Assessment of the Effectiveness of Six Sigma Methodology Implementation - A Literature Review. *Lecture Notes in Networks and Systems*, *790 LNNS*, 200–214. https://doi.org/10.1007/978-3-031-45021-1_15

Ly Duc, M., Hlavaty, L., Bilik, P., & Martinek, R. (2023). Enhancing manufacturing excellence with Lean Six Sigma and zero defects based on Industry 4.0. *Advances in Production Engineering And Management*, *18*(1), 32–48. https://doi.org/10.14743/APEM2023.1.455

Nallusamy, S. (2020). Execution of lean and industrial techniques for productivity enhancement in a manufacturing industry. *Materials Today: Proceedings*, *37*(Part 2), 568–575. https://doi.org/10.1016/j.matpr.2020.05.590

Ranade, P. B., Reddy, G., Koppal, P., Paithankar, A., & Shevale, S. (2021). Implementation of DMAIC methodology in green sand-casting process. *Materials Today: Proceedings*, *42*, 500–507. https://doi.org/10.1016/J.MATPR.2020.10.475

Sahoo, A. K., Tiwari, M. K., & Mileham, A. R. (2008). Six Sigma based approach to optimize radial forging operation variables. *Journal of Materials Processing Technology*, *202*(1–3), 125–136. https://doi.org/10.1016/J.JMATPROTEC.2007.08.085

Shukla, V., Swarnakar, V., & Singh, A. R. (2021). Prioritization of Lean Six Sigma project selection criteria using Best Worst Method. *Materials Today: Proceedings*, *47*, 5749–5754. https://doi.org/10.1016/j.matpr.2021.04.038

Sithole, C., Nyembwe, K., & Olubambi, P. (2019). Process knowledge for improving quality in sand casting foundries: A literature review. *Procedia Manufacturing*, *35*, 356–360. https://doi.org/10.1016/J.PROMFG.2019.05.052

Six Sigma within Doosan Heavy Industries & Construction Company. (2006). 143–156. https://doi.org/10.1016/B978-0-7506-6459-2.50012-3

Zhang, J., Yuan, W., Song, B., Yin, S., Wang, X., Wei, Q., & Shi, Y. (2022). Towards understanding metallurgical defect formation of selective laser melted wrought aluminum alloys. *Advanced Powder Materials*, *1*(4), 100035. https://doi.org/10.1016/J.APMATE.2022.100035

Zope, A., Swami, R. K., & Patil, A. (2023). LEAN SIX SIGMA BARRIERS WITH POTENTIAL SOLUTIONS IN ELECTRICAL VEHICLE ASSEMBLY: A REVIEW. *Proceedings on Engineering Sciences*, 5(3), 375–382. https://doi.org/10.24874/PES05.03.002