IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)
An International Open Access, Peer-reviewed, Refereed Journal

Implementation Of Six Sigma Process In Pressure Die Casting Of Oil Ring Using ADC12 Alloy For Product Quality Improvement

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Abstract

Pressure die casting is one of the most widely used manufacturing processes for producing complex aluminum components with high dimensional accuracy and surface finish. However, defects such as porosity, shrinkage, blowholes, cold shuts, and surface cracks often reduce product quality and increase rejection rates. ADC12 aluminum alloy is commonly used in die casting due to its good castability, strength, and corrosion resistance, but it is also prone to casting defects if process parameters are not optimized. The implementation of Six Sigma methodology has become an effective approach for reducing defects and improving process capability in manufacturing industries.This review paper focuses on the implementation of the Six Sigma DMAIC (Define, Measure, Analyze, Improve, Control) methodology in pressure die casting of oil rings using ADC12 material. The study reviews previous research related to quality improvement in die casting through process optimization, statistical quality control, and defect reduction techniques. Literature indicates that Six Sigma tools such as Pareto analysis, cause-and- effect diagrams, control charts, and design of experiments significantly improve product quality and reduce rejection rates.The review also discusses process parameter optimization including injection pressure, molten metal temperature, die temperature, cooling rate, and gating design which directly affect casting quality. Studies show that proper control of these parameters combined with Six Sigma methodology can reduce process variation and improve consistency.This paper concludes that Six Sigma implementation in pressure die casting can significantly improve productivity, reduce defects, and enhance customer satisfaction. Future research should focus on integrating Industry 4.0 tools such as machine learning and real-time monitoring with Six Sigma practices for further quality improvement.

Keywords: Six Sigma, Pressure Die Casting, ADC12 Alloy, Quality Improvement, DMAIC.

1. Introduction

Pressure die casting (PDC) is a manufacturing process in which molten metal is injected into a die cavity under high pressure to produce precision components. This process is widely used in the automotive, aerospace, and mechanical industries due to its high production rate and good dimensional accuracy.

ADC12 aluminum alloy is commonly used in die casting because of its excellent fluidity, low shrinkage, and good mechanical properties. However, defects such as porosity and surface defects remain major challenges affecting quality. In modern manufacturing industries, quality improvement is essential to remain competitive. Six Sigma is a data-driven methodology focused on reducing variation and defects in processes. It uses statistical tools to achieve near-perfect quality levels.

Six Sigma follows the DMAIC cycle:

- Define
- Measure
- Analyze
- Improve
- Control

Research shows that Six Sigma implementation in die casting helps reduce rejection rates and improve process efficiency. This review paper focuses on Six Sigma implementation in pressure die casting of oil rings made from ADC12 alloy to improve product quality.

2. Objectives

The main objectives of this review paper are:

1. To study pressure die casting process of ADC12 alloy
2. To analyze defects in oil ring die casting
3. To review Six Sigma implementation in casting industries
4. To identify quality improvement techniques
5. To understand DMAIC implementation

3. Methodology

The methodology used for quality improvement of oil ring produced by pressure die casting using ADC12 aluminum alloy is based on the Six Sigma DMAIC approach. This approach consists of five systematic steps: Define, Measure, Analyze, Improve and Control. These steps help in identifying defects, analyzing their causes and implementing corrective actions to improve product quality and reduce rejection rate.

Step 1: Define Phase

The first step of the methodology is to clearly define the problem and project objectives. In this study, the major problem identified is the high rejection rate of oil ring components due to casting defects such as porosity, cold shut, shrinkage, flash and misrun. Customer requirements such as good surface finish, dimensional accuracy and defect-free casting are identified. These requirements are converted into Critical to Quality (CTQ) characteristics. A SIPOC diagram is prepared to understand the process flow from raw material to finished product. A project charter is also prepared which defines the problem statement, improvement targets and expected outcomes. The main objective of this phase is to reduce rejection rate and improve product quality.

Step 2: Measure Phase

The second step involves measuring the current performance of the die casting process. Production data is collected to determine the rejection rate and major defects. Data such as number of parts produced, rejected parts, types of defects and process parameters are recorded. Quality tools such as check sheets and Pareto charts are used to identify major defects contributing to rejection. Important process parameters such as molten metal temperature, die temperature, injection pressure and cooling time are also measured. Process capability analysis is performed to determine whether the process is capable of meeting quality requirements. This phase helps establish the baseline performance of the process.

Step 3: Analyze Phase

The third step focuses on identifying the root causes of defects. Quality analysis tools such as fishbone diagram and 5 Why analysis are used to identify the reasons for defects. Possible causes are classified under categories such as machine, material, method, manpower and environment. For example, improper temperature control, low injection pressure, poor die design and improper cooling may cause casting defects. Statistical analysis is also performed to study the relationship between process parameters and defect formation. This phase helps identify the most critical factors affecting product quality.

Step 4: Improve Phase

The improve phase focuses on implementing corrective actions to eliminate the root causes identified in the analysis phase. Process parameters such as molten metal temperature, die temperature and injection pressure are optimized. Improvements in die design such as proper gating and venting are also implemented to reduce air entrapment and improve metal flow. Cooling systems are optimized to ensure uniform solidification. Standard operating procedures are developed to maintain process consistency. Operator training is also conducted to improve process control. Design of Experiments (DOE) techniques may be used to determine the optimal process parameter combination. These improvements help reduce defects and improve productivity.

Step 5: Control Phase

The final step ensures that improvements are maintained over time. Control plans are developed to monitor important process parameters. Statistical Process Control charts are used to monitor process variation. Standard operating procedures are implemented to ensure consistent process execution. Preventive maintenance schedules are followed to maintain machine and die conditions. Regular inspection and quality monitoring ensure that defect levels remain low. Continuous monitoring of key performance indicators such as rejection rate and process capability helps sustain improvements. This phase ensures long-term quality improvement and process stability.

4. Literature Review and Discussion

Paper1:
Marques and Matthé (2014) studied the implementation of Six Sigma DMAIC methodology in aluminum pressure die casting industries. Their research focused on identifying major rejection causes using statistical tools. The study showed that Six Sigma reduced defect rates and improved process capability. They concluded that structured problem solving improves manufacturing quality.

Paper2:
Marathe and Quadros (2018) researched optimization of high pressure die casting parameters using Six Sigma techniques. They analyzed injection pressure, die temperature and molten metal temperature. Their results showed that proper parameter optimization reduces porosity and improves casting strength.

Paper3:
Singh et al. (2017) performed defect analysis using quality control tools such as Pareto charts and fishbone diagrams. Their study showed that most defects were caused by process variation and improper temperature control. Their research confirmed that Six Sigma tools help reduce rejection rates.

Paper4:
Campbell (2015) explained casting defect formation and prevention methods. His research identified turbulence, improper gating and poor venting as major defect causes. The study suggested improving die

design to improve product quality.

Paper5:
Groover (2016) discussed manufacturing processes and quality control systems. His study highlighted the importance of maintaining stable process parameters to reduce defects and improve productivity.

Paper6:
Montgomery (2012) studied statistical quality control methods used in Six Sigma. His research explained the use of control charts and process capability analysis. The study showed that statistical monitoring helps maintain process stability.

Paper7:
Pyzdek and Keller (2014) studied Six Sigma implementation strategies in manufacturing industries. Their research showed that DMAIC methodology improves product quality, reduces waste and improves customer satisfaction.

Paper8:
Taguchi (1986) introduced design of experiments for quality improvement. His study showed that process parameter optimization reduces process variation and improves product consistency.

Paper9:
ASM Handbook (2017) explained casting processes and defect prevention techniques. The study showed that cooling rate, die temperature and metal flow affect casting quality.

Paper10:
Ross (1996) studied Taguchi quality engineering methods. His research showed that robust process design improves quality by reducing process variation.

Discussion

Based on the literature review, it is evident that Six Sigma methodology is an effective approach for improving quality in pressure die casting processes. The research findings show that casting defects such as porosity, shrinkage, cold shut, and flash are the major factors affecting product quality and increasing rejection rates. These defects are mainly caused by improper process control, temperature variation, poor die design, and inadequate cooling systems.The discussion of previous research indicates that process parameter optimization plays a significant role in improving die casting quality. Parameters such as molten metal temperature, die temperature, injection pressure, and cooling time directly affect the solidification process and defect formation. Maintaining these parameters within optimal limits helps achieve better casting quality. Studies also show that improper metal flow and air entrapment are major reasons for internal defects. Therefore, proper gating and venting design is essential.The literature also highlights the importance of statistical quality tools in defect reduction. Tools such as Pareto charts help identify the most critical defects. Fishbone diagrams help identify possible causes of defects. Control charts help monitor process stability. These tools help engineers make data-driven decisions rather than relying on trial and error methods. Research shows that organizations implementing Six Sigma experience significant reduction in rejection rates and improvement in process capability.Another important observation from the literature is the role of operator training and process standardization. Lack of proper training often leads to improper machine settings and inconsistent quality. Therefore, training programs and standard operating procedures are necessary to maintain process stability. Preventive maintenance is also critical because machine wear and die damage can cause process variation and defects.The discussion also shows that modern manufacturing industries are moving towards integration of advanced technologies with Six Sigma practices. Technologies such as simulation software help optimize die design before production. Real time monitoring systems help detect process variation early. Artificial intelligence and machine learning techniques are increasingly being used for defect prediction and process optimization. These developments indicate the future direction of quality improvement in die casting industries. Despite the advantages, some challenges in Six Sigma implementation are also identified. These include the need for skilled manpower, data collection difficulties, implementation cost, and resistance to change within organizations. However, most studies conclude that the long-term benefits such as reduced waste, improved productivity, and better customer satisfaction justify the investment.

Overall, the discussion confirms that Six Sigma DMAIC methodology provides a systematic framework for quality improvement in pressure die casting of ADC12 oil rings. By focusing on defect prevention rather than defect detection, organizations can achieve sustainable quality improvement. The literature strongly supports the use of Six Sigma tools combined with process optimization techniques for achieving near defect-free production.

5. Conclusion

The Pressure die casting of oil rings using ADC12 alloy requires strict process control to achieve high product quality. Defects such as porosity, shrinkage, and surface defects reduce productivity and increase rejection cost.This review shows that Six Sigma DMAIC methodology is an effective approach for improving die casting quality. By identifying critical process parameters and reducing variation, Six Sigma helps achieve defect reduction and process stability.Literature shows that process optimization, die design improvement, temperature control and statistical quality tools significantly improve casting quality.Implementation benefits include:•Reduced rejection rate

- Improved process capability
- Reduced cost

• Better customer satisfaction.The study concludes that Six Sigma implementation in pressure die casting of oil rings is an effective strategy for achieving quality improvement.Future work should focus on combining Six Sigma with digital manufacturing tools for better results.

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