IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

QUALITY ASSURANCE IN REFRIGERATOR MANUFACTURING: THE IMPACT OF DEDICATED LOCKRING STAGE

[1]Shrikant D. Gade, [2] Prof. Sachin Lomte,

[1]M. Tech Student, Department of Mechanical Engineering
[2]Professor, Department of Mechanical Engineering
Maharashtra Institute of Technology, Aurangabad, MH, India.

Abstract: This project article explores a landmark initiative aimed at augmenting manufacturing line efficiency by introducing a dedicated lockring operation stage. Focused on the refrigerator manufacturing industry, the study aims to address vulnerabilities in the existing assembly process, specifically related to lockring combination. The project employs a multi-layered approach, incorporating process analysis, design modification, and performance evaluation. The results showcase a significant reduction in defects, enhanced product quality, and improved overall manufacturing efficiency. This research article delves into the application of Six Sigma methodology to address operational challenges and improve efficiency in a refrigerator manufacturing line. The study focuses on the identification and elimination of bottlenecks, reduction of defects, and enhancement of overall process performance. The research contributes to the broader field of manufacturing optimization and provides valuable insights for practitioners seeking to implement Six Sigma principles in similar contexts.

I. Introduction

In the modern age contemporary manufacturing, where product quality, operational efficiency, and customer satisfaction are the focus of industries, the refrigerator manufacturing industry is not exempt from the imperatives of continual improvement.

This report embarks on the complexities of a refrigerator manufacturing line, seeking to unravel challenges and fortify the production process through the Six Sigma methodology. Six Sigma, renowned for its data-driven and systematic approach, emerges as a beacon guiding the quest for heightened efficiency and excellence.

1.1 Background

The manufacturing of refrigerators, a cornerstone in households globally, demands not only precision engineering but an unwavering commitment to the highest standards of quality. As manufacturers navigate an ever-evolving market and heightened consumer expectations, the need for robust processes that minimize defects and maximize efficiency becomes increasingly paramount.

Within this context, the application of Six Sigma emerges as a strategic initiative to optimize manufacturing processes systematically. Six Sigma, with its roots in statistical analysis and process improvement, provides a structured framework to identify, analyze, and eliminate defects or variations within manufacturing processes. It offers a methodical approach Define, Measure, Analyze, Improve, and Control (DMAIC) that aligns seamlessly with the objective of enhancing the manufacturing line's efficacy. By adhering to the principles of Six Sigma, organizations can mitigate defects, reduce waste, and ultimately elevate the quality of end products.

This research delves into the application of Six Sigma methodology within a refrigerator manufacturing line, aiming to not only diagnose existing challenges but also prescribe targeted interventions for tangible improvements. By exploring the intricacies of the manufacturing process, identifying pain points, and leveraging the power of statistical analysis, this study endeavors to contribute to the growing body of knowledge in manufacturing process optimization.

As we navigate the complexities of the refrigerator manufacturing industry, this research anticipates unravelling insights that extend beyond the specific context.

The principles and practices gathered from applying Six Sigma are poised to offer valuable lessons and methodologies that can be transposed onto diverse manufacturing settings.

The excellence through systematic process improvement becomes a shared aspiration, one that resonates across industries and contributes to the advancing manufacturing practices.

1.2 Problem Statement

Refrigerators are complex appliances where the secure placement of the lockring is vital for ensuring a proper seal, preventing refrigerant leakage, and maintaining optimal cooling performance. Without a dedicated lockring stage, the current process introduces unnecessary complexities and compromises, adversely affecting product quality and, consequently, customer satisfaction.

Therefore, the pressing need for process improvement in the refrigerator manufacturing industry is evident. The implementation of a specialized lockring stage within the manufacturing line is essential to streamline the assembly process, reduce production time, minimize errors, and enhance the overall quality of refrigerators.

Addressing this issue is paramount to meeting market demands for efficient, reliable, and cost-effective refrigeration solutions.

This project aims to investigate, design, and implement a dedicated lockring operation stage in the manufacturing line, aiming to rectify the identified deficiencies and contribute to a more streamlined, efficient, and high-quality production process for refrigerators.

1.3 Objective of Project

Optimize Workflow Efficiency: Streamline the assembly process by introducing the lockring stage to reduce production cycle time and enhance overall workflow efficiency.

Reduce Production Time: Achieve a measurable reduction in production time by implementing the lockring operation stage, contributing to increased productivity and throughput.

Minimize Error Rates: Decrease the occurrence of errors related to lockring installation, ensuring a more reliable and consistent assembly process.

Enhance Product Quality: Improve the structural integrity and reliability of refrigerators by ensuring precise and accurate lockring placement, reducing the likelihood of defects and enhancing overall product quality.

Evaluate Cost-Benefit Analysis: Conduct a thorough cost-benefit analysis to assess the financial impact of implementing the lockring operation stage and justify the investment in terms of improved efficiency and product quality.

II. LITERATURE SURVEY

2.1 Early Manufacturing Process

In the early stages of manufacturing, especially before the advent of advanced joining technologies, sealing joints in various industrial processes posed challenges. Traditional methods like welding and brazing were employed, but they had limitations in terms of efficiency, flexibility, and the potential for defects.

2.2 Introduction of New Joining Technologies

The need for alternative, efficient, and leak-free joining methods led to the development and introduction of new technologies. Lockring joints, as a modern joining technology, were introduced to address some of the challenges associated with traditional methods.

2.3 Adoption of Lockring Joints

As industries adopted lockring joints for various applications, including in refrigeration and manufacturing processes, the technology brought advantages such as ease of assembly, no need for hot work, and potential cost savings. However, as with any technology, challenges and issues may arise during implementation.

2.4 Challenges with Lockring Leakages

Lockring leakage in the manufacturing process may be attributed to various factors, including design considerations, material compatibility, installation procedures, and environmental conditions. If not properly addressed, these factors can contribute to joint failures and leakage issues.

2.5 Evolution of Lockring Technology

Over time, manufacturers and engineers have worked to address and mitigate challenges associated with the lockring joints. The technology may have undergone refinements, improvements in materials, and advancements in design to enhance its reliability and performance.

2.6 Industry Standards And Best Practices

The establishment of industry standards and best practices has played a crucial role in addressing and preventing issues like lockring leakage. Guidelines for proper installation, material selection, and quality control have been developed to ensure the effectiveness of lockring joints in manufacturing processes.

2.7 Ongoing Innovation And research

The manufacturing landscape is dynamic, with ongoing innovation and research to improve existing technologies. Manufacturers and researchers continue to explore ways to enhance the performance of joints, reduce the risk of leaks, and optimize manufacturing processes.

III. METHODOLOGY

Six Sigma Methodology

Involving the principles of Six Sigma, Liebherr Appliances initiated a project to enhance the manufacturing process by introducing a lockring operation stage. The DMAIC (Define, Measure, Analyze, Improve, and Control) approach was employed to guide the implementation:

3.1 Define

Refrigerant leakage from lockring joint has become the major concern in terms of customer dissatisfaction. Product replacement due to leakage issue not only has cost impact to the company but also damage to the brand value of the company. A cross-functional team with representatives from manufacturing, quality control, and engineering was established to find a solution to overcome the problem.

3.2 Measure

Quantified the current state of joint leaks and their impact on product quality. Conducted a thorough analysis of warranty claims and customer feedback related to joint leaks.

3.3 Analyze

Various factors were analyzed during the study and worked on during the trials. After analyzing all the factors handling of lockring joint online during process found to be the key contributing factor.

3.4 Improve

Designed and implemented a dedicated lockring operation stage in the manufacturing line. Modified workflow to seamlessly integrate the new stage. Conducted employee training sessions to ensure the proper execution of the new process.

3.4 Control

Developed a comprehensive control plan to monitor and sustain the improvements. Established key performance indicators (KPIs) for joint leak rates and overall manufacturing efficiency.

3.5 Result

- Reduction in Joint Leaks: Post-implementation analysis demonstrated a significant reduction in joint leaks, leading to improved product reliability.
- Enhanced Product Quality: The lockring operation stage contributed to a more robust and consistent assembly, positively impacting overall product quality.

- Cost Savings: With fewer warranty claims and service requests related to joint leaks, there was a substantial reduction in post-sale costs.

IV. ANALYSIS OF CURRENT PROCESS

4.1 Helium Leak Detector

A Helium Leak Detector is a sensitive instrument designed to identify and quantify helium leaks. Helium is commonly used as a tracer gas because it is inert, non-toxic, and has small molecular size, making it effective for pinpointing even tiny leaks. These detectors are particularly useful in various industries, including manufacturing, refrigeration, aerospace, and vacuum technology.

4.2 How Helium Leak Detector Works

Introduction of Helium: Helium is introduced into the system being tested, either through pressurization or by using a dedicated pumping system.

- Physical Data which can be detected by the machine

a) Minimum detectable leak rate R600a - 0.3 g/a
b) Measuring Scale - 0.05-999.99 g/a
c) Response time including sniffer line - 0.8 s
d) Sensor response time - 0.3 s
e) Mass spectrometer – Quadrupole mass spectrometer
g) Maximum no. of gases detectable simultaneously - 4

- Electrical Data

a) Power consumption - ≤ 300 VA
b) Noise level - ≤ 54 dBA
OTHER DATA
a) Startup Time ≤ 2 min
b) Gas Flow 160 sccm Ambient Temperature range 10 – 45 °

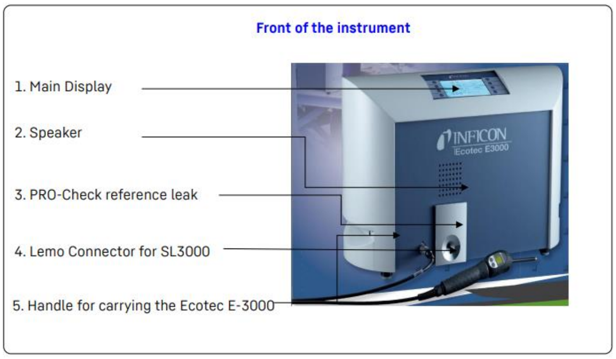

Fig. 1 Helium Leak Detector Machine

4.3 Detection Of Helium

If there are any leaks in the system, helium will escape through these openings.

4.4 Sensitivity Of Measurement

The leak detector's sensor, typically a mass spectrometer or a helium ionization detector, is highly sensitive to helium. It can measure the concentration of helium in the surrounding air.

4.5 Audible/Visual Indication

When the instrument detects helium, it provides an audible or visual indication, allowing the operator to identify the location and magnitude of the leak.

4.6 Quantification

The leak rate can be quantified based on the concentration of helium detected, helping to assess the severity of the leak.

4.7 Application of Helium Detectors

- Vacuum Systems
- Used in the testing and maintenance of vacuum systems, such as those in research laboratories or semiconductor manufacturing.
- Refrigeration and Air Conditioning:
- Applied to check for leaks in refrigeration and air conditioning systems, ensuring their efficiency and preventing the release of refrigerants.
- Aerospace Industry: Employed to locate leaks in components of aerospace systems, ensuring the integrity of critical parts.
- Automotive Industry: Used in the automotive industry to identify leaks in air conditioning systems and other components.

4.8 Advantages of Helium Leak Detection

- High Sensitivity - Helium is a small molecule, making it an excellent tracer gas for detecting even tiny leaks.
- Non-Destructive Testing - Helium leak detection is a non-destructive testing method that allows for the identification of leaks without damaging the tested system.
- Versatility - Suitable for a wide range of applications across various industries.
- Quantitative Measurement - Provides a quantitative measurement of leak rates, aiding in the assessment of the severity of leaks.

Helium Leak Detectors are valuable tools in industries where the containment of gases or fluids is critical, ensuring the safety, efficiency, and reliability of various systems and components.

V. ROOT CAUSE ANALYSIS

Logic Tree is an effective tool for finding the root cause for the lockring leakage. Issues related to Man, Method, Machine and Material related to lockring process can be identified easily. Addressing to this root cause analysis can give an solution which can be implemented to improve the issue.

5.1 Insufficient Hydraulic Pressure

- Issue: Inadequate pressure applied during the lockring operation may lead to insufficient tightening, resulting in leaks.
- Root Cause: Lack of frequency of monitoring and control mechanisms in the existing process.

5.2 Misalignment of Components

- Issue: Misalignment during the lockring operation can create gaps, allowing refrigerant to escape.
- Root Cause: Lack of alignment verification and correction mechanisms in the current manufacturing process.

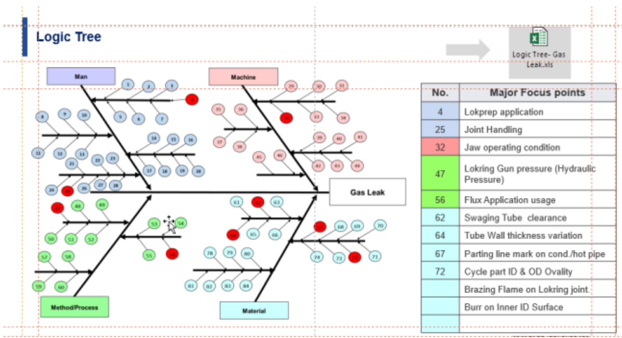

Fig. 2 Logic Tree

5.3 Variability In Material Properties

- Issue: Variations in the material properties of lockring components can impact their sealing capabilities.
- Root Cause: Inconsistent material specifications or sourcing practices leading to variations in the properties of lockring components.

5.4 Manual Assembly Process

- Issue: Manual assembly of lockring components may result in human error, leading to leaks.
- Root Cause: Overreliance on manual labor without adequate automation or error-proofing mechanisms.

5.5 Inadequate Operator Training

- Issue: Operators may lack sufficient training on the intricacies of the lockring operation, leading to errors.
- Root Cause: Insufficient training programs or a lack of emphasis on the critical aspects of the lockring process.

VI. ADDRESSING THE ROOT CAUSES

6.1 Hydraulic Pressure Monitoring

- Implement monitoring and control check sheet to ensure precise hydraulic pressure during the lockring operation. Every week the inspection of lockring joint gun hydraulic pressure is monitored by maintenance team.

6.2 Misalignment of Components

- Lockring gun jaws which are wear out may cause misalignment of lockring. Due to this the joint may cause leakage during line process. Lockring gun jaw inspection frequency also decided and followed by maintenance once in a week.

6.3 Standardize Material Specification

- Standardize material specifications and sourcing practices to minimize variations in the properties of lockring components.
- Additional check points added to inspection stage for incoming quality to ensure the specifications.

6.4 Manual Assembly Process

- Reduce the manual handling of lockring joint online after the joint operation to avoid twist on the joint which can reduce the strength of the joint causing leakage.

6.5 Enhance Operator Training Program

- Strengthen operator training programs to ensure a comprehensive understanding of the lockring operation. Only trained operators are deputed on the stage for the lockring operation. Once a year refresher training is conducted to all the operators.

By systematically addressing these root causes, the research aims to implement a solution through the addition of a separate lockring stage, ultimately eliminating leakage issues in the refrigerator manufacturing process.

VII. PROPOSED SOLUTION : INTEGERATION OF DEDICATED LOCKRING STAGE

7.1 Introduction of Dedicated Lockring Stage

- Objective: To eliminate leakage issues in the refrigerator manufacturing process, the proposed solution involves the integration of a dedicated lockring stage into the existing manufacturing line.

7.2 Key Features of the Dedicated Lockring Stage

- Real Time Hydraulic Pressure Control - Dedicated lockring stage ensures immediate monitor and control on the lockring stage to ensure precise and consistent tightening of lockring components.
- Alignment Verification - Lockring jaws are verified before the start of process to monitor the process closely. Alignment verification mechanisms helps to identify and correct any misalignments during the lockring operation, ensuring a secure and leak-free seal.
- Immediate Leak Detection - Incorporate immediate post-lockring operation leak detection methods to enhance quality control measures. This allows for the rapid identification and correction of any potential leaks.

7.3 Benefits of the proposed solution

- Reduced Leakage Rates - By addressing root causes through real-time hydraulic control, alignment verification, and immediate leak detection, the dedicated lockring stage is expected to significantly reduce leakage rates, improving product quality.
- Enhanced Efficiency - The integration of automation and real-time monitoring technologies enhances the overall efficiency of the lockring operation, reducing the reliance on manual labor and minimizing the chances of human error.
- Cost Saving - While there may be initial costs associated with implementing the dedicated lockring stage, the long-term benefits include savings in warranty claims, post-assembly quality control measures, and potential improvements in production speed.
- Improved Customer Satisfaction - The reduction of leakage issues ensures that the final refrigerators meet high-quality standards, leading to increased customer satisfaction and loyalty.

7.4 Implementation Plan

- Phase 1: Feasibility Assessment and Design: Conduct a comprehensive feasibility study to assess the technical, operational, and economic viability of the proposed solution. Collaborate with engineering teams to design the dedicated lockring stage.
- Phase 2: Continuous Improvement and Optimization: Continuously monitor and optimize the performance of the dedicated lockring stage based on real-time data and feedback. Implement improvements as needed to further enhance the efficiency and effectiveness of the lockring operation.

7.5 Expected Outcomes

- Substantial Reduction in Leakage Rate - The implementation of the dedicated lockring stage is expected to result in a significant reduction in leakage rates, leading to improved product reliability.
- Streamed Manufacturing Process - Automation and real-time monitoring contribute to a more streamlined and efficient manufacturing process, reducing manual intervention and associated errors.
- Positive Impact on Cost - While initial implementation costs may be incurred, the reduction in warranty claims and post-assembly quality control measures is anticipated to result in long-term cost savings.
- Positive Feedback From Customer - Improved product quality and reliability are likely to lead to positive feedback from customers, contributing to enhanced brand reputation and customer loyalty.

VIII. CONCLUSION

The proposed solution of integrating a dedicated lockring stage represents a proactive and comprehensive approach to addressing leakage issues in the refrigerator manufacturing process. Through careful implementation and continuous optimization, the dedicated lockring stage is poised to contribute to the industry's commitment to excellence and customer satisfaction.

The addition of a lockring operation stage proved to be a transformative measure. By employing the principles of Six Sigma and addressing a critical vulnerability in the manufacturing process, the company not only eliminated joint leaks but also experienced a improved product quality and cost savings. This case study underscores the value of strategic process improvements in enhancing overall operational efficiency and customer satisfaction.

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