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Risk Management Analysis of the Planet Gear Product at PT XYZ Batam

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ABSTRACT

This study aims to identify and analyze the root causes of product defects in the injection molding process at PT XYZ Batam, particularly in bearing and pulley components. Defects such as oversized diameter (gate high), cracks (dented), burrs, and black spots from foreign particles were frequently found during production. The Fishbone Diagram method was used to systematically categorize the potential causes into four factors: Man, Machine, Method, and Material. Further analysis was conducted using the Failure Mode and Effect Analysis (FMEA) to assess each risk based on severity, occurrence, and detection scores. The gate high defect had the highest initial Risk Priority Number (RPN) of 36, indicating a high-risk level, followed by burrs with an RPN of 35. Risk mitigation strategies included machine recalibration, regular sharpening or replacement of cutting tools, implementation of standard operating procedures (SOPs), and daily cleaning and lubrication to prevent equipment breakdown. The results highlight the importance of consistent maintenance, structured documentation of production activities, and supervisory guidance to minimize the risk of recurring defects. Through the application of quality control tools such as Fishbone Diagram and FMEA, PT XYZ Batam can improve product reliability, reduce losses, and enhance operational efficiency in the competitive field of precision manufacturing.

Keywords:

risk, management

Introduction

PT XYZ Batam is a manufacturing company specializing in precision components, one of which is the production of planet gears used in mechanical transmission systems. In producing these components, the effectiveness and efficiency of operations heavily depend on the defect rate that arises during the secondary processing stage (2nd process). Product quality is greatly influenced by how well risks are managed at each stage of production, particularly in identifying potential defect types such as G. High, Danted, Burr, and B. Spot. According to Heizer and Render (2020), consistent quality control and risk mitigation in manufacturing processes are crucial to achieving operational excellence and customer satisfaction. Based on the IN & OUT Product Record data from March to April 2024, a total of 1,055,560 units underwent additional processing, with 5,070 units recorded as defective, averaging 169 defective units per day. The most frequent defect was G. High (with an average of 53.67 units per day), followed by Danted, B. Spot, and Burr. This defect variation reflects potential instability in production quality, which poses risks not only to product performance but also to cost efficiency and lead time reliability.

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The variation in NG Qty across different production days reveals a fluctuation in process capability and quality assurance measures. On certain dates, such as March 15 and April 14, 2024, the number of non-conforming products reached 300 and 400 units, respectively. This inconsistency indicates that risk sources may not be adequately controlled or systematically addressed, leading to a higher possibility of defects affecting customer satisfaction and delivery schedules. Therefore, this study aims to conduct a risk management analysis of the planet gear production process at PT XYZ Batam using real production data as the basis for identifying, evaluating, and proposing mitigation strategies. By applying a structured risk assessment model, the research seeks to provide recommendations for reducing defects and improving the overall production reliability, in line with ISO 9001 principles of continual improvement and risk-based thinking.

Implementing effective risk management in the manufacturing process is not only about reducing defect rates but also about strengthening preventive controls and building a culture of quality awareness among operators and supervisors. According to ISO 31000, risk management should be embedded in organizational processes and tailored to the specific environment and context of the company. In the context of PT XYZ Batam, this means integrating risk identification and response mechanisms directly into production workflows, especially in stages where manual handling or equipment precision significantly affects output quality.

Additionally, the consistent presence of certain defect types—such as G. High and Danted—suggests the need for a root cause analysis (RCA) to identify systemic issues, whether they stem from human error, machine misalignment, or material inconsistencies. Utilizing tools such as Failure Mode and Effect Analysis (FMEA) or Fishbone Diagrams will assist in mapping the sources of risks and prioritizing corrective actions based on severity and frequency. By doing so, the company can not only enhance its product quality but also reduce waste, lower operational costs, and sustain its competitiveness in the precision manufacturing industry.

Methods

This study employs a qualitative-descriptive approach supported by quantitative analysis to identify and evaluate risks in the production process of planet gear products at PT XYZ Batam. The research is structured into three main stages: data collection, root cause identification, and risk evaluation. The primary data source for this study is the *IN & OUT Product Record* for the month of March to April 2024. This dataset includes daily production quantities before and after the second process, along with the number and type of defects recorded. To enrich the data, interviews with production supervisors and quality control personnel were also conducted to understand operational procedures, defect detection practices, and current corrective actions.

The root causes of the most common defects—such as *G. High*, *Danted*, *Burr*, and *B. Spot*—were analyzed using a Fishbone Diagram (Ishikawa Diagram). This tool helps categorize possible sources of defects into six key factors: Man, Machine, Material, Method, Measurement, and Environment. Through discussions with relevant stakeholders and direct observation of the production line, each branch of the fishbone diagram was populated with potential contributors to the occurrence of defects. This qualitative step forms the foundation for further risk scoring.

To quantify and prioritize the identified risks, a Failure Mode and Effects Analysis (FMEA) was applied. For each defect type, the study identifies potential failure modes and evaluates them based on three criteria:

- Severity (S): the impact of the defect on product quality or customer satisfaction,

- Occurrence (O): the likelihood of the defect happening,
- Detection (D): the probability that the defect will be detected before reaching the customer.

Each criterion is scored on a scale of 1 to 10. The Risk Priority Number (RPN) is then calculated using the formula: RPN = Severity × Occurrence × Detection.

Risks with higher RPN values are prioritized for corrective action and mitigation planning. Based on the analysis, recommendations are proposed to reduce the frequency or impact of the defects through improvements in machinery calibration, operator training, process standardization, and quality control mechanisms.

Results and Discussion

To understand the underlying causes of recurring product defects in the planet gear production process at PT XYZ Batam, a Fishbone Diagram was developed. This tool systematically categorized the root causes of defects into several key areas, namely Man, Machine, Material, Method, Measurement, and Environment. According to Kang and Kva (2011), the Fishbone Diagram serves as an illustration used to identify the various factors that may influence the emergence of a problem. In this case, it allowed the research team to visually map out potential causes contributing to defects such as G. High, Danted, B. Spot, and Burr.

The analysis revealed that under the Man category, operator inexperience and inconsistent adherence to work instructions played a significant role in generating non-conformities. In the Machine category, misalignment of tools and worn-out machinery components led to dimensional inaccuracies, particularly linked to G. High defects. The Material branch highlighted occasional inconsistencies in raw material quality, which were found to contribute to burr formation during the cutting process. Meanwhile, the Method and Measurement categories pointed to the absence of standardized operating procedures and inadequate inspection checkpoints, which allowed defective units to pass through unnoticed. Lastly, environmental factors such as poor lighting and fluctuating ambient temperatures were observed to influence operator performance and equipment stability.

The Fishbone Diagram served its purpose by helping the team systematically identify these diverse causes, allowing focused attention on the actual sources of defects rather than just the symptoms. This structured approach is in line with the diagram’s main objective—to guide teams toward effective solutions through root cause analysis. By breaking the problem down into manageable categories, it became possible to prioritize which contributing factors needed urgent intervention.

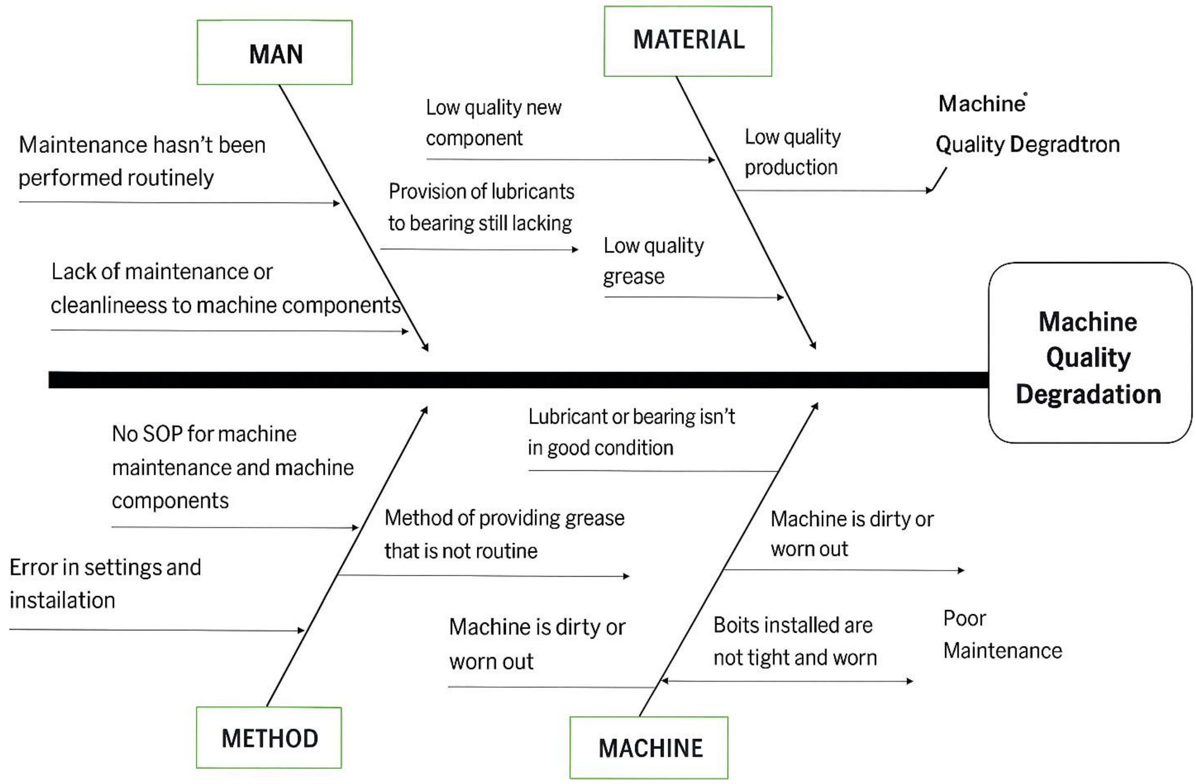

Fig 1. Fishbone Diagram

Based on the analysis of the fishbone diagram focusing on the bearing and pulley components, several factors contributing to machine component damage were identified. These contributing factors fall into four primary categories: Man, Method, Material, and Machine. Each factor plays a significant role in the root causes of machine malfunction and is explained in detail below:

1. Man (Human Factor):
Human-related factors contributing to machine component damage include insufficient maintenance and cleaning of machinery and its components. This issue stems from the lack of routine maintenance schedules, which leads to premature component wear or failure. Additionally, errors in machine setting or improper installation of components by maintenance personnel can further exacerbate the problem. Such human errors highlight the need for enhanced training and stricter adherence to maintenance protocols.

2. Method:
Method-related factors involve the absence of standardized operating procedures (SOPs) for machine maintenance. Without clear SOPs, maintenance activities may be inconsistent or performed incorrectly, increasing the risk of component failure. The lack of structured guidelines also leads to variability in how and when machines are serviced, contributing to unanticipated downtimes and reduced machine reliability.

3. Material:
The use of poor-quality replacement components is a material-related factor that contributes to damage. Substandard materials—especially in critical parts like bearings or pulleys—can accelerate wear and tear, affecting the overall performance of the machine. The selection of low-grade grease or

components that do not meet required specifications is also a risk factor, potentially resulting in secondary failures.

4. Machine:
Machine-related issues include malfunctioning or poorly maintained bearing lubrication systems. Inadequate lubrication—either due to mechanical failure or insufficient application—can cause increased friction, leading to overheating and damage to the bearing and surrounding components. Additionally, wear and contamination of the machines themselves can hinder optimal performance, signaling a need for regular inspection and replacement of aging parts.

Following the root cause identification using the Fishbone Diagram, the next stage of the research involved applying Failure Mode and Effects Analysis (FMEA) to assess and prioritize the identified risks related to damage in the bearing and pulley components. FMEA is a structured and systematic approach used to evaluate potential failure modes, analyze their causes and effects, and determine which failures pose the greatest risk to operations. In this study, each failure mode identified from the Fishbone Diagram—such as lack of routine maintenance, poor lubrication practices, substandard component replacement, and absence of SOPs—was evaluated using three key criteria: Severity (S), which measures the impact of the failure; Occurrence (O), which estimates the likelihood of the failure happening; and Detection (D), which assesses the probability of detecting the failure before it causes damage. Each criterion was rated on a scale from 1 (least critical) to 10 (most critical), and the scores were multiplied to calculate the Risk Priority Number (RPN) for each failure mode.

The FMEA analysis revealed that the highest RPN values were associated with failure modes such as lack of lubrication due to damaged bearing lubricators and absence of SOPs for component installation and maintenance. These issues not only occur frequently but also have severe consequences on machine performance and are difficult to detect without a robust monitoring system. As such, these risks require immediate corrective actions. Based on the FMEA results, the study proposed several mitigation strategies. These include the development and implementation of clear SOPs, the introduction of preventive maintenance schedules, the use of higher-quality spare parts, and routine inspections of lubrication systems. Addressing the risks with the highest RPN values ensures that the most critical sources of failure are managed effectively, leading to improved reliability, reduced downtime, and better overall product quality in the planet gear production process.

Table 1. Risk Identified and RPN

Process Activity	Failure Mode	Effect of Failure	Severity Rating (S)	Cause / Failure Mechanism	Occurrence Rating (O)	Current Control	Detection Rating (D)	Risk Priority Number (RPN)
1. Dimensional Control	Excess size on product diameter (Gate High)	Inaccuracy in cutting or forming process	9	During manufacturing or assembly process	4	QC line rechecks running product	6	216
2. Product Quality Inspection	Cracks or dimensional issues (Dented)	Out of tolerance dimension and size	5	Small cracks or inaccurate dimension reduce strength	3	Check latest sample before machine runs	5	75
3. Product Cleaning and Inspection	Burrs on product walls	Burrs may reduce product quality and appearance	10	Burrs affect assembly and may block parts	5	Molding maintenance ensures tool sharpness	7	350
4. Foreign Particle Quality Inspection	Presence of foreign particles or dirt (Black Spot)	Product considered defective, causes	7	Product appears dirty and doesn't meet visual	3	Scheduled raw material cleaning to reduce dust	5	105

The discussion on the treatment threshold and risk tolerance for defects in the product highlights how companies like PT. XYZ Batam manage product quality to meet industrial standards and ensure customer satisfaction. Risk tolerance refers to the acceptable level of defects in a product before it is deemed unfit or in need of corrective measures. This concept is particularly important in manufacturing precision components, where slight deviations can impact overall performance, safety, and customer expectations.

For instance, in the case of excessive product diameter (gate high), a strict dimensional control system is essential. The company handles this risk by implementing tight quality controls, precision measurement equipment, and process adjustments to ensure that dimensional deviations remain within the allowable limit. Any significant deviation can result in product rejection due to improper fit or function. When dents occur in areas of the product that do not affect its performance or safety, they may sometimes be tolerated. However, if the dent compromises structural integrity or performance, it must be corrected immediately. This shows that the risk tolerance for surface defects is highly dependent on the location and potential impact of the defect. Burrs—sharp or raised edges typically found on product surfaces after machining—are often addressed through secondary processes like deburring. The company establishes safe and acceptable limits for the presence and sharpness of burrs to minimize the risk they pose to product assembly, functionality, and user safety.

Lastly, foreign particles or contaminants (black spots) are generally unacceptable, especially in precision components. These defects are treated as critical due to their impact on aesthetic quality and functionality. For sensitive applications, even minor black spots are not tolerated, and the affected products are usually rejected or subjected to rework. Overall, the company sets clear tolerances and control strategies for each type of defect. These thresholds are based on product requirements, customer expectations, and industry regulations. Effective handling of these defects involves thorough quality inspections, preventive measures during production, and stringent standards in final testing to ensure consistent product quality.

Based on the risk treatment/control analysis conducted for defects found in the product components, the following summary provides a detailed risk assessment before and after mitigation for each identified failure mode:

1. Excess Product Diameter (Gate High)
- Initial Risk Assessment:
  - *Occurrence:* 4
  - *Severity:* 9
  - *Risk Score:* 36
  - *Risk Level:* High
- Risk Description:
  Inaccuracy in the cutting or forming process leads to oversized product dimensions, which can affect functionality and assembly fit.
- Mitigation/Control Action:
  Regular *machine recalibration* is essential to ensure dimensional precision. Machines must be calibrated correctly and consistently to avoid dimensional drift.
- Post-Mitigation Risk:
  If calibration is properly and consistently implemented, the risk can be significantly reduced to a moderate level, assuming no external factors disrupt machine performance.

2. Surface Cracks or Dents (Dented)
- Initial Risk Assessment:
  - *Occurrence:* 3
  - *Severity:* 5
  - *Risk Score:* 15
  - *Risk Level:* Moderate
- Risk Description:
  Cracks or dents may cause the product to exceed dimensional tolerances, potentially impacting function or aesthetics.

- Mitigation/Control Action:
  Ensure all manufacturing equipment is operating under optimal conditions. Routine maintenance and proper handling of components are key.
- Post-Mitigation Risk:
  If the mitigation strategy is not effective or inconsistently applied, the risk score may remain the same—or even increase—highlighting the need for deeper process control or inspection enhancements.

3. Burrs on Product Walls
- Initial Risk Assessment:
  - *Occurrence:* 5
  - *Severity:* 7
  - *Risk Score:* 35
  - *Risk Level:* High
- Risk Description:
  Burrs degrade the appearance and potentially the functionality of the product, lowering its perceived quality.
- Mitigation/Control Action:
  Burrs are often caused by dull or worn-out cutting tools. Regular *sharpening or replacement* of cutting tools is necessary to maintain edge quality.
- Post-Mitigation Risk:
  With proper tool maintenance, the risk can be reduced to a moderate level. However, early detection remains crucial to avoid recurrence.

4. Presence of Foreign Particles (Black Spot)
- Initial Risk Assessment:
  - *Occurrence:* 3
  - *Severity:* 5
  - *Risk Score:* 15
  - *Risk Level:* Moderate
- Risk Description:
  Foreign particles lead to product rejection or customer dissatisfaction and may result in returns or complaints.
- Mitigation/Control Action:
  Implement *routine inspection and product testing* to ensure contaminants are not present before packaging and shipping.
- Post-Mitigation Risk:
  The risk remains moderate if inspections are ineffective or if contaminants enter during post-processing. Continuous quality monitoring is needed.

Conclusion

Based on the findings of this research, the analysis using the fishbone diagram reveals that the development of Standard Operating Procedures (SOPs) is essential for carrying out proper maintenance and repairs on machines. Additionally, daily maintenance routines, such as lubrication and cleaning, must be performed regularly to prevent recurring machine damage or breakdowns.

Therefore, the following recommendations are proposed:

i) Consistently document all activities in each production process, so that every action can be evaluated and corrective measures can be implemented for future production improvements;

ii) Provide clear guidance and supervision to workers in each production area to ensure high-quality output is consistently achieved.

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