Research on Quality Improvement for Mass Production

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Abstract. An analysis of quality issue statistics reveals that, in the preliminary research, development, and mass production phases of aerospace products, while a small number of quality issues stem from defects in technical or process design, the majority are primarily attributable to human factors. Issues such as missed inspections and operational errors can be mitigated by optimizing the organization's production quality management processes and refining management requirements. Particularly for products intended for mass production, management factors are the key determinants of product quality. In today's mass production environment, products pass through multiple suppliers from raw materials to the final product. As products move between various suppliers, the question arises of how the client organization can effectively control the quality of products supplied by the supplier. Relying solely on the supplier's quality management system to control production can easily lead to quality risks accompanying the product's circulation, resulting in frequent quality issues later on. This is particularly evident in the mass production of aerospace products. Therefore, introducing an acceptance supervision phase is of paramount importance, as the client's requirements for product quality and performance are often more stringent and objective. For mass-produced aerospace products, companies can identify low-level, repetitive, and human-induced quality issues early on by refining acceptance criteria and standardizing acceptance procedures. This prevents defective products from entering the final assembly phase, significantly reducing quality-related costs and minimizing the impact of quality issues. This is particularly crucial for mass-produced aerospace products, which are subject to tight deadlines and demanding schedules; improving the quality of production acceptance is essential for ensuring that mass production tasks are completed on time and to specification.

Keywords: Mass production; Quality management; Inspection

1 Introduction

First, from the user's perspective, improving the quality of product production and acceptance can significantly reduce the occurrence of quality issues during the final assembly phase. This leads to sustained improvements in user satisfaction, helping the

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company build a strong reputation and image as a provider of high-quality, reliable products.

Second, from the company's perspective, improving the quality of product production and acceptance can minimize quality-related costs. Addressing quality issues early on is the most efficient and convenient way to resolve them. Companies should standardize product inspection and acceptance procedures at all levels and refine acceptance requirements to ensure that quality issues are identified early[1].

Finally, from the perspective of future development, improving the quality of product production, inspection, and acceptance can drive the entire industry toward higher and more refined standards. For the company, strengthening quality control and acceptance management in mass production is of paramount importance for achieving high-quality development, whether viewed from the perspective of national strategy or user needs. Therefore, researching acceptance control mechanisms under mass production models is of great significance for enhancing the company's core competitiveness.

In 1993, American scholar Pine II systematically elaborated on the concept of mass production and, in collaboration with David Anderson, discussed the challenge of developing agile products for mass production[2]. They believe that the essence of mass production lies in continuing to carry out design, production, and management processes on a large scale while meeting users' diverse customization needs. This allows for effective control of production costs and a reduction in product production cycles. Mass production is based on a "customer-centric" business philosophy. According to Crosby's principles of quality management, if you get it right the first time, quality is free. Therefore, by ensuring quality through product design and addressing quality issues at their source, we minimize the costs associated with problems and create maximum value for both the company and its users. However, based on current statistical analyses of corporate quality data, quality issues still cannot be completely eliminated once products reach the mass production stage. Defects in technical or process design are generally identified early on during the development phase. On the other hand, companies transitioning from small-scale to mass production frequently encounter a steady stream of quality issues caused by human error[3]. Therefore, focusing on process quality control, identifying shortcomings in management procedures, and refining production management processes are all manifestations of a company's efforts to enhance its management capabilities.

Unlike the mass production of standardized products such as automobiles and mobile phones, the mass production of aerospace products requires companies to be able to rapidly adjust their production capacity in response to customer needs[4]. In other words, companies must meet customers' mass production requirements by re-planning and reorganizing their resources. The goal of mass production is to continuously build the capacity to fully meet customer needs. Therefore, mass production is built on the foundation of continuous improvement, and quality control should place greater emphasis on quality control and supervision between modules, with a focus on preventive measures. Such preventive measures may take the form of documented technical or management requirements to ensure control over subordinate enterprises, or they may involve on-site participation in acceptance inspections and supervision to conduct product quality inspections. It is clear that, for companies, conducting inspections and acceptance tests on suppliers' products is the most direct and efficient approach[5].

In summarizing research on quality issues in mass production, we can see that while the emphasis on eliminating the "three categories" of quality issues is important, in addition to companies focusing on manufacturing quality during production, post-production quality inspection and supervision are actually key to identifying problems early on[6].

2 Comprehensive Analysis of Quality Issues

Taking a specific product in three mass-production phases (2021, 2023, and 2025) as an example, we perform a statistical analysis of the quality problems occurring in mass-produced aerospace products in order to explore the causes of these quality problems and analyze the effectiveness of quality improvement measures implemented via acceptance-based supervision.

2.1 Analysis by Time of Occurrence of Problems

Based on statistics by time of occurrence, in 2021 there were 3 quality problems, with a first-pass delivery pass rate of 97%. In 2023 there were 12 quality problems, with a first-pass delivery pass rate of 97%. In 2025 there was 1 quality problem, with a first-pass delivery pass rate of 99%. From the trend, the number of product quality problems in 2023 increased compared with 2021, but the first-pass delivery pass rate did not change significantly, because the 2023 production lot size also increased. By 2025, the first-pass delivery pass rate had increased slightly compared with previous years, indicating that the comprehensive quality improvement measures taken have yielded tangible results.

2.2 Analysis by Cause of Problems

An analysis of the specific causes of 16 quality problems for this product across the three mass-production periods shows that the problems are mainly concentrated in two areas: management and outsourcing. Specifically, 5 problems are attributable to management, accounting for 31%; 7 problems are attributable to outsourcing, accounting for 44%; 3 problems are due to process-related factors, accounting for 19%; and 1 problem is due to design, accounting for 6%. See Figure 1 for details. This indicates that process control during the outsourcing phase of mass production of aerospace products is still relatively weak, and that supervision and screening of outsourced product processes need to be further strengthened.

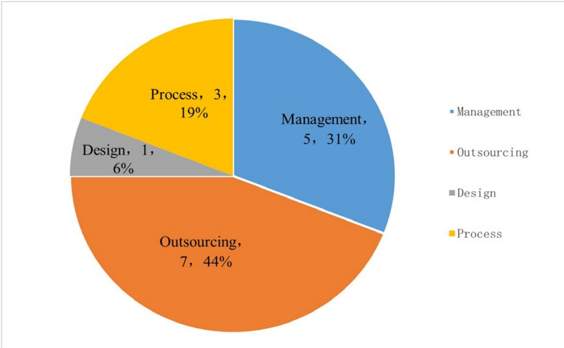

Fig. 1. Classification of Quality Problems by Cause.

2.3 Quality Data Analysis

A comprehensive analysis of the quality problems in the three periods(Figure 2), combining their causes with the different time periods, shows that after the product enters the mass-production phase, problems are mainly concentrated in management and outsourcing, with human factors playing a dominant role, such as missed or incorrect inspections and operational errors, which occasionally expose deficiencies in product design and manufacturing processes. For outsourcing-related quality problems, after implementing 100% on-site acceptance at supplier facilities in 2025, the number of outsourcing quality problems decreased significantly, and quality problems were exposed earlier in the process, indicating that adopting on-site acceptance as a supervisory approach can bring outsourcing-related quality problems in mass-produced aerospace products to light and resolve them earlier. This approach has a significant effect in improving outsourcing-related quality problems in aerospace products that are caused by human factors. The underlying reason is that, due to their system complexity and limited production volumes, aerospace products cannot be produced in a standardized and highly automated manner like automobiles, mobile phones, and other mass-market products.

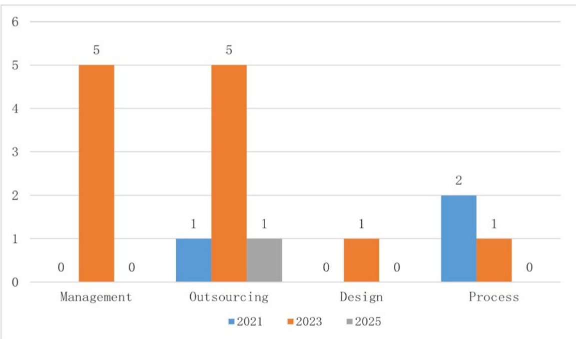

Fig. 2. Trends in Causes of Quality Problems, 2021–2025.

3 Key Aspects of Mass Production Management

3.1 Production Process

By analyzing the six key elements involved in the large-scale production process-people, machinery, materials, methods, environment, and measurement-the following production process control management workflow has been established(Figure 3).

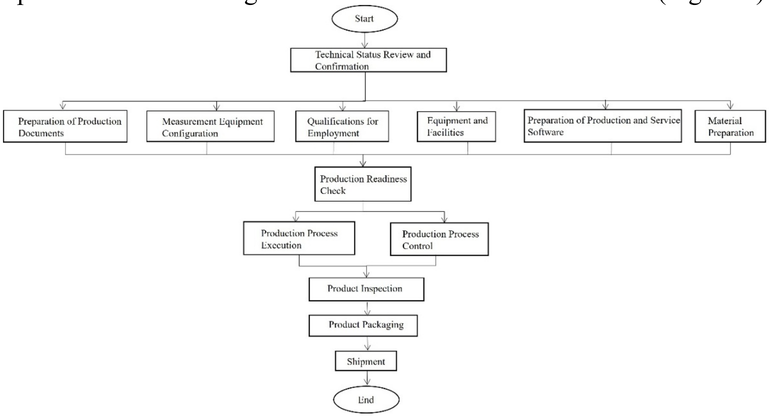

Fig. 3. Flowchart of Production Process Control Management.

3.2 Batch Management

When issuing production task notifications, clearly specify identification information such as product name, drawing (or part) number, and serial number, and ensure the uniqueness of this information. For mass-produced products, the product batch must also be specified. During the production process, distribute production materials by batch and quantity in accordance with production tasks and technical document requirements to prevent situations such as the mixing of raw materials, over-packing, incorrect packing, or omissions. Properly label areas on the production floor and arrange products by status within designated zones to prevent product mix-ups.

Batch management involves primarily establishing batch identifiers and maintaining batch ledgers. Production departments should organize material input, production, material flow, assembly, and delivery by batch, and define the characteristics of each batch and their combinations. Batch identifiers must be reflected in all source records and internal production information.

3.3 Quality Management of Outsourced and Purchased Parts

Quality management for outsourced and purchased parts in mass production primarily focuses on material preparation[7]. This includes quality management related to raw materials, outsourced processes, and the preparation of outsourced parts. Key areas of focus are as follows:

Purchased components, raw materials, and basic electromechanical products are subject to re-inspection and screening as required.

Re-inspection of metallic materials, non-metallic materials, and standard fasteners shall be conducted in accordance with the relevant industry standards.

Components that have passed re-inspection and screening should be stored in an environment that meets the specified requirements. Components that have exceeded their valid storage period should undergo re-inspection in accordance with the relevant industry standards.

Based on requirements such as production volume, service life, and service period, we will carry out material preparation, the procurement and re-inspection of outsourced components, and the initiation of outsourced processes.

3.4 Inspection and Acceptance Management

Based on an analysis of the production process, the inspection can be broadly divided into three stages.

Raw Material Inspection. Raw material inspection is the foundation of product quality assurance and must be strictly controlled. It is essential to verify that the specifications and models of raw materials meet production requirements. Through sampling, physical and chemical properties, as well as other relevant indicators, are tested to ensure consistent and reliable quality.

In-process Inspection. In-process inspections enable the timely identification and correction of issues, thereby preventing batch-wide defects. A combination of routine patrols and fixed-point inspections is employed to focus monitoring on critical processes and quality control points. Inspections verify that equipment is operating properly, that process parameters meet standards, and that operators are following established procedures.

Final Inspection. Final inspection serves as the final quality control check for finished products. Based on product standards and customer requirements, a comprehensive inspection is conducted to evaluate the appearance, dimensions, and performance of the finished products. The visual inspection includes assessing surface finish, checking for scratches, and verifying that there is no deformation. Dimensional inspection ensures that the product meets design specifications. Performance testing verifies that the product functions as intended.

Taking into account the key aspects of comprehensive, mass production management, it is proposed that the client's representatives be invited to the facility to oversee the final product inspection. This acceptance process should take place after the contractor has completed the final product inspection and may involve a joint acceptance conducted in conjunction with a third-party supervisory body.

4 Management Process

4.1 Organizational Structure

An acceptance team shall be established, comprising personnel from the project management department, quality management department, design/engineering department, inspection department, and other relevant departments.

4.2 Division of Responsibilities

4.2.1 Project Management Department.
The project management department shall, in accordance with the signed contract, determine the names and technical versions of the documents to be used for factory acceptance. It shall organize the design team to verify the completeness, validity, and technical versions of the factory acceptance documents to be used, and conduct a review during the factory acceptance process. During factory acceptance inspections, the project management department is responsible for verifying that all products are included in the delivery, including the inspection of accessories.

4.2.2 Quality Management Department.
The quality management department is responsible for compiling a record of past quality issues for use during acceptance inspections. Upon receiving a notice of on-site acceptance from the project management department, the quality management department shall promptly notify the quality management department of the subcontractor (external partner) to verify the documentation required for on-site acceptance. If the required documentation is incomplete or the conditions for on-site acceptance are not met, the quality management department shall notify the project management department accordingly. During factory acceptance inspections, the quality management department is responsible for reviewing the control of the production process. After the factory acceptance inspection is completed, the quality management department will follow up on and resolve any issues identified during the inspection, ensuring that the production unit implements corrective actions. The resolution process generally takes no longer than one week. The quality management department is responsible for collecting, organizing, and archiving the complete set of factory acceptance inspection records.

4.2.3 Design/Engineering Department.
Determine the status of design and process documents, and participate in the resolution of quality issues.

4.2.4 Inspection Department.
During factory acceptance testing, inspectors are responsible for examining the product's appearance, functionality, and performance in accordance with the design specifications.

4.3 Status of Responsibility for Mass Production

In accordance with the division of responsibilities for factory acceptance inspections, we propose to define the responsibilities of personnel in the departments involved in mass production(Table 1).

Table 1. List of Responsibilities for Mass Production.

Department	Scope of Responsibility	Output file
Project Management Department	1. Planning production volumes, production groups, risk analysis, and control measures. 2. Organizing production status inspections. 3. Issuing production documents. 4. Preparing acceptance and delivery schedules and acceptance notices.	1. Production task planning Report. 2. Production readiness inspection report. 3. Production and inspection task notification. 4. On-site acceptance notification.
Quality Management Department	1. Develop production quality control plans. 2. Organize specialized quality system audits for production departments and external contractors. 3. Organize investigations, resolution, and closure of technical and management-related quality issues.	1. Production quality planning and quality control requirements; quality control plans (specific to each product). 2. Special inspection plans, inspection records, lists of inspection issues, etc. 3. Meeting review records, meeting minutes, issue resolution records, etc. 1. List of production design documents. 2. List of production process documents. 3. Sign-off on the data in the product acceptance form.
Design/Engineering Department	1. Verify the status of design documents. 2. Understand manufacturing methods, production processes, and any changes thereto, and analyze their impact on product performance. 3. Analyze product performance data, investigate fluctuations and variations in the data, and verify product quality.Participate in the resolution of quality issues.	1. Detailed rules for in-plant re-inspection and acceptance; 2. Acceptance results form; 3. Acceptance feedback form.
Inspection Department	1. Develop outgoing (or incoming) inspection procedures based on the quality plan and in accordance with design and manufacturing documents. 2. Conduct outgoing or incoming inspections of products in accordance with the quality plan. 3. Provide feedback on risks identified during inspections.	

4.4 Product Acceptance Flowchart

Based on the division of responsibilities, the product inspection and acceptance process can be outlined as follows(Figure 4).

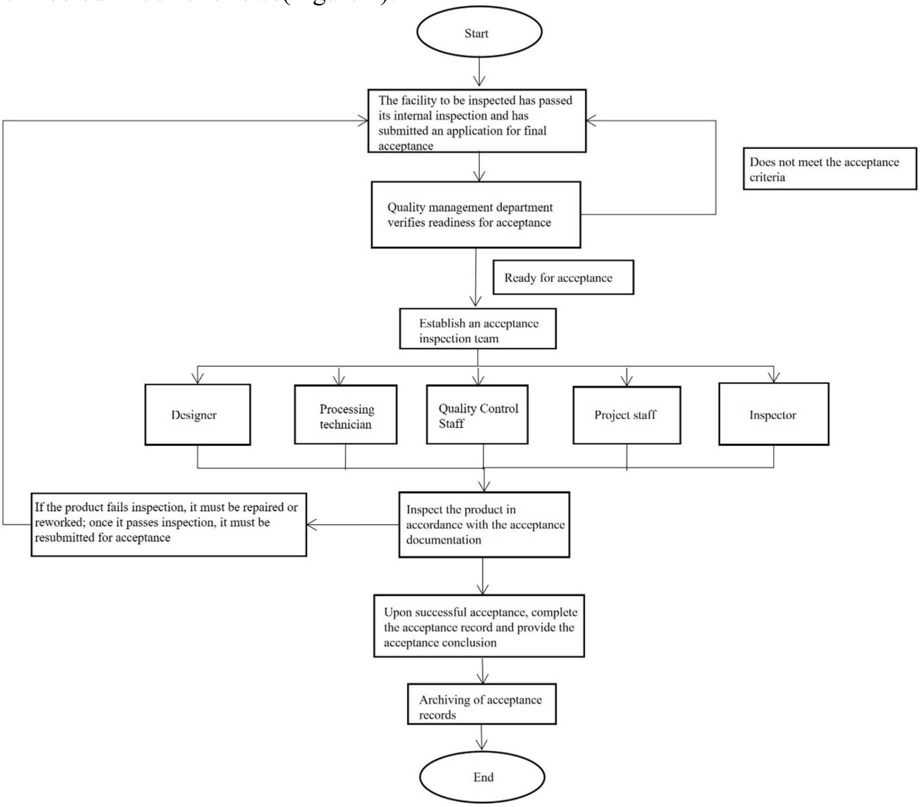

Fig. 4. Product Acceptance Flowchart.

5 Analysis of Results

Based on the above division of responsibilities and practical application considerations, the primary personnel involved in the acceptance stage are still the inspectors. During the development phase, designers also take part in product acceptance, but inspectors are still the main ones involved. Because inspectors do not have completely consistent interpretations of the technical documents during acceptance, there are still differing opinions about the product's appearance after it is delivered to the customer's organization[8]. In addition, the quality management systems of some external suppliers are relatively weak, and quality problems occur frequently, so they rely heavily on in-plant acceptance inspection personnel to act as gatekeepers. Therefore, the enforceability of the acceptance documents is crucial to the effectiveness of inspection work. The inspection requirements can be clarified by making the acceptance documents more detailed and quantifiable; for inspection requirements that cannot be fully detailed or quantified, clear, illustrative drawings should be provided to facilitate inspection judgments, and at the same time inspectors' skills training should be strengthened to achieve consistency in inspection judgments. Overall, conducting 100% in-plant acceptance inspections for aerospace products allows a large number of problems to be exposed in advance, thereby minimizing the risk of quality problems reaching the final assembly stage. Although conducting 100% in-plant acceptance inspections increases resource costs, mass production of aerospace products is different from the highly standardized, assembly-line mass production of products such as cars and mobile phones: they are produced in relatively small quantities and with a lower degree of automation. Compared with the additional resources required for acceptance, greater emphasis should be placed on quality assurance before product delivery. By investing resources early and identifying problems in advance, they can be resolved at the lowest cost, with the highest efficiency, and with minimal impact, which can significantly improve the rate of conforming product deliveries.

6 Conclusion

For aerospace products, a good design and sound manufacturing processes can prevent most quality problems. However, due to the complexity of aerospace systems and the relatively low level of automation at this stage, many manufacturing steps still involve significant manual work. Even though a series of quality measures has reduced human error and production requirements are clearly defined, nonconforming products caused by human factors may still occur. The client's evaluation of the product tends to be more objective, so it is necessary to introduce an on-site acceptance and oversight process. This process aims to ensure that the products delivered by Party B to Party A are ensured to be 100% compliant before delivery, or that any issues are identified and addressed as early as possible. Currently, the competitive bidding environment for aerospace products is becoming increasingly intense. Customers and companies alike are raising their expectations for products. They not only focus on product performance and cost, but also pay close attention to how frequently quality issues occur during production. Therefore, if a company wants to maintain a strong position in this competition, it must strengthen both product quality and service assurance. For companies, clarifying acceptance criteria and tightening acceptance controls are essential measures for improving product quality assurance, and are key to enhancing competitiveness and earning customer trust.

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