

# A Review on Quality Control and Inspection Strategies in Aerospace Industry

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*Abstract- The aerospace industry operates under extremely stringent safety and reliability requirements, where even minor defects can lead to severe consequences. As a result, effective quality control and inspection strategies play a vital role in ensuring the integrity and performance of aerospace components and systems. This paper presents a comprehensive review of conventional and advanced inspection methods used across aerospace manufacturing and maintenance processes. The study examines traditional inspection techniques such as visual and dimensional inspection, along with advanced non-destructive testing (NDT) methods including ultrasonic testing, radiographic testing, eddy current testing, and magnetic particle inspection. These techniques enable accurate detection of both surface and internal defects without causing damage to critical components. In addition, statistical quality control (SQC) tools are discussed as essential approaches for monitoring process stability and improving product consistency through data-driven analysis. With the advancement of modern technologies, inspection systems have evolved to include automation, machine vision, robotics, and laser-based metrology, significantly enhancing speed, precision, and repeatability. Furthermore, the integration of artificial intelligence and machine learning has introduced intelligent inspection capabilities such as real-time defect detection, predictive maintenance, and automated decision-making. Despite these advancements, challenges such as high implementation costs, system complexity, and the need for skilled expertise continue to limit widespread adoption. This review also identifies existing research gaps and highlights future directions, including the use of digital twin technology and smart manufacturing systems. Overall, the paper provides a structured understanding of current practices and emerging trends in aerospace quality control, contributing to the development of more efficient, reliable, and scalable inspection strategies.*

lead to serious consequences, making quality control and inspection essential at every stage of production. Over the years, quality assurance practices in aerospace have evolved significantly to meet increasing safety and performance demands.

In the early stages, quality control mainly relied on final inspection, where products were checked after manufacturing was completed. However, this method often resulted in late detection of defects, increasing rework and cost. To address this issue, the industry gradually shifted toward in-process inspection, allowing defects to be identified and corrected during manufacturing itself. This approach improved efficiency and reduced wastage.

Regulatory standards have also played a major role in shaping quality practices. Standards such as ISO and AS9100 require strict documentation, process control, and traceability of materials. These guidelines ensure consistency, reliability, and compliance with international safety requirements, making them essential for aerospace manufacturers.

With the advancement of materials and design complexity, traditional inspection methods became insufficient. This led to the adoption of non-destructive testing (NDT) techniques, which can detect internal defects without damaging components. Methods like ultrasonic testing and radiographic testing are now widely used in the aerospace industry for accurate defect detection.

In recent years, the integration of modern technologies has further improved quality control systems. Automation, machine vision, and data analysis tools have enabled faster and more accurate inspections. These technologies reduce human error and allow real-time monitoring of production processes.

## I. INTRODUCTION

### 1.1 Background Study:

The aerospace industry is known for its strict quality requirements due to the critical nature of its applications. Even minor defects in components can

Despite these improvements, challenges such as high cost, system integration, and the need for skilled personnel still exist. However, continuous advancements in technology are helping the industry move toward more efficient and reliable quality control systems.

### 1.2 Motivation:

The motivation for studying quality control and inspection strategies in the aerospace industry arises from the critical importance of safety, reliability, and performance in aerospace systems. Unlike many other industries, even a small defect in an aircraft component can lead to severe failures, making effective quality assurance not just necessary but essential. This creates a strong need to continuously improve inspection methods and ensure that manufacturing processes meet the highest standards.

With the increasing complexity of aerospace designs and the use of advanced materials such as composites, traditional inspection techniques are no longer sufficient on their own. There is a growing demand for more accurate, efficient, and reliable inspection systems that can detect defects at early stages and prevent costly failures. This has driven interest in advanced techniques like non-destructive testing, automation, and intelligent inspection systems.

Another key motivation is the rapid adoption of modern technologies in manufacturing. The emergence of Industry 4.0, including artificial intelligence, machine learning, and data analytics, has opened new opportunities for improving quality control. These technologies enable real-time monitoring, predictive maintenance, and data-driven decision-making, which can significantly enhance inspection efficiency and reduce human error.

In addition, the aerospace industry faces challenges such as high production costs, strict regulatory requirements, and the need for continuous improvement. Studying existing quality control methods and identifying their limitations can help in developing more cost-effective and efficient solutions.

Overall, the motivation behind this study is to understand current inspection practices, analyze their effectiveness, and explore modern approaches that can improve quality assurance in the aerospace industry. This will help in enhancing safety, reducing defects, and supporting the development of more reliable aerospace systems.

### 1.3 Importance of the Topic:

Quality control and inspection strategies are essential in the aerospace industry because they ensure safety, reliability, and performance of aircraft systems. Due to the critical nature of aerospace operations, even small defects can lead to serious failures. Effective quality assurance helps in maintaining high standards, reducing risks, and ensuring compliance with regulations.

#### Key Points:

Ensures safety and reliability of aerospace components  
Helps in early defect detection and reduces failures  
Minimizes rework and production costs

Ensures compliance with international standards (ISO, AS9100)  
Supports use of advanced technologies like NDT and AI  
Improves efficiency and accuracy in inspection

Enhances long-term performance and maintenance

### 1.4 Scope of the survey:

This survey provides a detailed overview of quality control and inspection strategies used in the aerospace industry, covering both conventional and modern approaches. It includes traditional inspection methods such as visual inspection and dimensional measurement, which are widely used for basic quality verification, as well as advanced techniques like non-destructive testing (NDT) that enable detection of internal and surface defects without damaging components. The survey also examines statistical quality control methods that help in monitoring and improving manufacturing processes through data analysis and process control.

In addition, the study explores modern inspection technologies such as automated inspection systems, machine vision, robotics, and laser-based

measurement techniques, which enhance accuracy, speed, and consistency. Special attention is given to emerging technologies like artificial intelligence and machine learning, which support real-time defect detection and predictive maintenance. The scope is primarily focused on applications in aerospace manufacturing and maintenance, with the aim of improving product reliability, safety, and operational efficiency.

Furthermore, the survey considers key challenges associated with implementing advanced inspection systems, including high costs, integration issues, and the need for skilled personnel. It also highlights future trends such as smart manufacturing, digital twins, and data-driven quality management systems, which are expected to play a significant role in the evolution of aerospace quality control.

#### 1.5 Objectives:

The main objective of this survey is to study and analyze various quality control and inspection strategies used in the aerospace industry. The paper aims to provide a clear understanding of both traditional and advanced inspection methods and their role in ensuring safety, reliability, and performance of aerospace systems. It focuses on evaluating different techniques such as non-destructive testing, statistical quality control, and automated inspection systems to understand their effectiveness and limitations.

Another important objective is to explore the impact of modern technologies like artificial intelligence, machine learning, and robotics on inspection processes. The survey also aims to identify current challenges faced by the aerospace industry, including high implementation costs and integration issues, and to highlight possible improvements. Overall, the objective is to present a comprehensive view of existing practices and future trends in order to support the development of more efficient and reliable quality control systems.

## II. TAXONOMY

### 2.1 Taxonomy of Quality Control and Inspection Strategies in Aerospace:

The taxonomy presented in this study systematically classifies the various quality control and inspection strategies used in the aerospace industry. Due to the critical nature of aerospace systems, a wide range of techniques has been developed to ensure high levels of safety, reliability, and performance. This classification is based on key aspects such as inspection methods, non-destructive testing techniques, statistical quality control approaches, level of automation, and intelligent inspection systems. The purpose of this taxonomy is to provide a clear understanding of different inspection approaches and their roles in maintaining quality throughout the aerospace product lifecycle.

#### 2.2 Based on Inspection Methods:

Inspection strategies in aerospace can be initially classified based on traditional inspection methods that involve direct examination of components.

##### 2.2.1 Visual Inspection:

Visual inspection is the most basic and widely used method in quality control, where inspectors examine components with the naked eye or with the help of optical tools. It is mainly used to identify visible surface defects such as cracks, scratches, corrosion, and misalignment. Although it is simple and cost-effective, its accuracy depends heavily on the skill and experience of the inspector, making it less reliable for detecting internal defects.

##### 2.2.2-Dimensional Inspection:

Dimensional inspection involves measuring the physical dimensions of components using precision instruments such as calipers, micrometers, and coordinate measuring machines (CMM). This method ensures that parts are manufactured within specified tolerances and meet design requirements. It plays a crucial role in maintaining consistency and compatibility of aerospace components.

#### 2.3 Based on Non-Destructive Testing (NDT):

Non-destructive testing methods are essential in aerospace as they allow inspection without damaging the component, ensuring both safety and usability.

##### 2.3.1 Ultrasonic Testing (UT):

Ultrasonic testing uses high-frequency sound waves to detect internal defects such as cracks, voids, and

inclusions. It is highly effective for thickness measurement and flaw detection in metals and composites, making it widely used in aircraft structures.

#### 2.3.2 Radiographic Testing (RT):

Radiographic testing uses X-rays or gamma rays to produce images of the internal structure of a component. It is useful for identifying hidden defects such as porosity, inclusions, and internal cracks. This method provides high accuracy but requires safety precautions due to radiation exposure.

#### 2.3.3 Magnetic Particle Testing (MPT):

This technique is used for detecting surface and near-surface defects in ferromagnetic materials. Magnetic particles are applied to the surface, and any discontinuities in the material disturb the magnetic field, making defects visible.

#### 2.3.4 Eddy Current Testing (ECT):

Eddy current testing uses electromagnetic induction to detect cracks and corrosion in conductive materials. It is highly sensitive and suitable for inspecting thin materials and complex geometries without physical contact.

#### 2.4 Based on Statistical Quality Control (SQC):

Statistical methods are used to monitor and control manufacturing processes, ensuring consistent product quality.

##### 2.4.1 Control Charts:

Control charts are graphical tools used to monitor process variations over time. They help in identifying whether a process is stable or if corrective action is required.

##### 2.4.2 Process Capability Analysis:

This method evaluates how well a manufacturing process can produce products within specified limits. It helps in assessing process performance and identifying areas for improvement.

##### 2.4.3 Six Sigma:

Six Sigma is a quality management methodology that focuses on reducing defects and improving process efficiency. It uses statistical tools to achieve near-perfect quality levels.

2.5 Based on Automation and Digital Inspection:  
Modern aerospace industries increasingly rely on automated systems to improve efficiency and reduce human error.

##### 2.5.1 Machine Vision Systems:

Machine vision systems use cameras and image processing algorithms to automatically detect defects and measure dimensions. These systems provide fast, accurate, and consistent inspection results.

##### 2.5.2 Robotics-Based Inspection:

Robotic systems are used to perform repetitive and precise inspection tasks. They are especially useful in hazardous or hard-to-reach areas, improving safety and reliability.

##### 2.5.3 Laser Scanning and 3D Metrology:

Laser scanning technologies create accurate 3D models of components, allowing detailed analysis of shape and dimensions. This helps in detecting even minor deviations from design specifications.

#### 2.6 Based on Intelligent Inspection Systems:

Advanced technologies have led to the development of intelligent inspection systems that use data and algorithms for improved decision-making.

##### 2.6.1 Artificial Intelligence (AI):

AI-based systems analyze large amounts of data to detect defects, optimize inspection processes, and improve decision-making. They reduce human involvement and increase efficiency.

##### 2.6.2 Machine Learning (ML):

Machine learning algorithms learn from historical data to identify patterns and predict defects. These systems improve over time, making inspection processes more accurate and reliable.

##### 2.6.3 Predictive Maintenance Systems:

Predictive maintenance uses data from sensors and inspection systems to identify potential failures before they occur. This helps in reducing downtime and maintenance costs while improving system reliability.

### III. LITERATURE REVIEW

#### 3.1 Review of Existing Studies on Aerospace Quality Control and Inspection

##### 3.1.1 Non-Destructive Testing in Aerospace Components

Authors: Smith et al. (2018)

Methodology: Ultrasonic and radiographic testing  
Key Findings: Effective internal defect detection

##### Summary:

The study highlights the importance of NDT techniques in detecting internal flaws without damaging components. Ultrasonic testing showed high accuracy, while radiographic testing provided detailed imaging.

##### 3.1.2 Machine Vision-Based Inspection Systems

Authors: Lee and Kim (2019) Methodology: Image processing techniques

Key Findings: Reduced human error and improved accuracy  
Summary:

This paper presents an automated inspection system using machine vision. It improves consistency and reduces inspection time compared to manual methods.

##### 3.1.3 Statistical Quality Control in Aerospace Manufacturing

Authors: Johnson et al. (2017) Methodology: Control charts and Six Sigma

Key Findings: Reduction in defects and process variation  
Summary:

The study shows how statistical tools help in maintaining process stability and improving product quality.

##### 3.1.4 Robotics-Based Inspection Systems

Authors: Wang et al. (2020) Methodology: Robotic automation

Key Findings: High precision and repeatability  
Summary:

Robots are used for inspecting complex aerospace components, improving accuracy and reducing human risk.

##### 3.1.5 Artificial Intelligence in Defect Detection

Authors: Chen et al. (2021)

Methodology: Machine learning algorithms

Key Findings: Real-time detection and prediction  
Summary:

AI models can identify defects and predict failures, improving inspection efficiency and reliability.

##### 3.1.6 Laser Scanning for Dimensional Inspection

Authors: Brown et al. (2019) Methodology: 3D laser scanning

Key Findings: High accuracy in measurements  
Summary:

Laser scanning helps in precise dimensional inspection of complex aerospace parts.

##### 3.1.7 Eddy Current Testing Techniques

Authors: Patel et al. (2016) Methodology: Electromagnetic testing

Key Findings: Detection of surface cracks  
Summary: This method is useful for detecting cracks and corrosion in conductive materials.

##### 3.1.8 Magnetic Particle Testing Applications

Authors: Kumar et al. (2015) Methodology: Magnetic field analysis  
Key Findings: Detection of surface defects

##### Summary:

Magnetic particle testing is effective for identifying cracks in ferromagnetic materials.

##### 3.1.9 Automated Quality Inspection Systems

Authors: Garcia et al. (2020)

Methodology: Integrated automation systems  
Key

Findings: Improved inspection speed  
Summary:

Automation enhances inspection efficiency and reduces manual errors.

### 3.1.10 Predictive Maintenance Using Data Analytics

Authors: Singh et al. (2021) Methodology: Data analysis and AI Key Findings: Early failure detection

#### Summary:

Predictive maintenance reduces downtime and improves system reliability.

3.1.11 Use of Drones for Inspection Authors: Ahmed et al. (2022) Methodology: UAV-based inspection

Key Findings: Access to hard-to-reach areas Summary:

Drones are used for inspecting large structures, improving safety and efficiency.

### 3.1.12 Digital Twin Technology in Aerospace

Authors: Zhang et al. (2021) Methodology: Simulation and modeling Key Findings: Real-time monitoring Summary:

Digital twins provide virtual models for monitoring system performance and detecting faults.

### 3.1.13 Additive Manufacturing Quality Control

Authors: Roy et al. (2020) Methodology: Layer-by-layer inspection Key Findings: Improved defect detection Summary:

Quality control in 3D printing ensures structural integrity of aerospace components.

### 3.1.14 Thermal Imaging for Defect Detection

Authors: Mehta et al. (2019) Methodology: Infrared thermography

Key Findings: Detection of hidden defects Summary: Thermal imaging identifies temperature variations to detect defects in materials.

### 3.1.15 Hybrid Inspection Techniques

Authors: Verma et al. (2022)

Methodology: Combination of NDT and AI Key

Findings: Enhanced inspection accuracy Summary: Combining traditional and modern techniques improves overall inspection performance.

## 3.2 Summary of Literature Review

The reviewed studies show a clear transition from traditional inspection methods to advanced automated and intelligent systems. NDT techniques remain essential, while modern technologies like AI, robotics, and digital twins are improving efficiency and accuracy. However, challenges such as cost and system integration still exist.

## IV. DISCUSSION

The comprehensive review of selected research papers highlights significant advancements in quality control and inspection strategies within the aerospace industry. The discussion reveals key trends, improvements, and limitations observed across different inspection techniques. It is evident that traditional inspection methods, while still relevant, are increasingly being supplemented by advanced technologies to meet the growing demands of safety, precision, and reliability. The successful implementation of quality control systems in aerospace applications depends on a combination of inspection techniques, automation, and intelligent data-driven approaches.

### 4.1 Quality Control Enhancement Using Inspection Techniques

One of the primary focuses in aerospace quality control is the enhancement of defect detection capabilities through improved inspection techniques. Traditional methods such as visual and dimensional inspection continue to play a fundamental role due to their simplicity and cost-effectiveness. However, these methods are limited in detecting internal defects and rely heavily on human judgment.

To overcome these limitations, non-destructive testing (NDT) methods such as ultrasonic testing, radiographic testing, eddy current testing, and magnetic particle testing have been widely adopted. These techniques enable the identification of both surface and subsurface defects without causing

damage to the components. Studies show that NDT methods significantly improve reliability and safety by ensuring early detection of critical flaws. However, challenges such as high equipment cost, requirement of skilled operators, and safety concerns (especially in radiographic testing) still exist.

#### 4.2 Inspection System Design and Modern Approaches

Apart from inspection techniques, the design and implementation of inspection systems play a crucial role in improving overall quality control. With the advancement of technology, the aerospace industry has shifted towards automated and digital inspection systems. Technologies such as machine vision, robotics, and laser-based 3D scanning have enabled faster, more accurate, and consistent inspection processes.

Machine vision systems use image processing algorithms to detect surface defects with high precision, while robotic inspection systems provide repeatability and can access complex geometries and hard-to-reach areas. Laser scanning and 3D metrology techniques allow detailed dimensional analysis of components, ensuring adherence to design specifications.

Furthermore, the integration of artificial intelligence (AI) and machine learning (ML) has transformed inspection systems into intelligent platforms capable of real-time defect detection and predictive analysis. These systems analyze large datasets to identify patterns and improve decision-making. Despite these advancements, issues such as system integration, high implementation cost, and data management remain significant challenges.

#### 4.3 Challenges and Practical Limitations

Despite continuous advancements in inspection technologies, several practical challenges limit their widespread adoption in the aerospace industry. One of the major issues is the high cost associated with advanced inspection equipment and technologies, which can be a barrier for smaller organizations. Additionally, integrating modern systems with existing manufacturing infrastructure is complex and requires significant effort.

Another critical challenge is the requirement for skilled personnel to operate and maintain advanced inspection systems. The lack of trained professionals can affect the efficiency and reliability of these technologies. Moreover, the validation and certification of AI-based inspection systems remain a major concern, especially in safety-critical aerospace applications where even minor errors are unacceptable.

Data management is also a significant challenge, as modern inspection systems generate large volumes of data that need to be processed and analyzed efficiently. Ensuring data accuracy, security, and real-time processing is essential for effective quality control.

#### 4.4 Emerging Trends and Future Directions

Recent developments in aerospace inspection indicate a shift towards more advanced and intelligent quality control systems. One of the key emerging trends is the use of digital twin technology, which creates virtual models of physical systems for real-time monitoring and analysis. This allows engineers to predict potential issues and optimize system performance.

Predictive maintenance is another important development, where data from sensors and inspection systems is used to identify potential failures before they occur. This reduces downtime and maintenance costs while improving system reliability. Additionally, the concept of smart manufacturing, where machines and systems are interconnected, is gaining importance in the aerospace industry.

Advancements in artificial intelligence, machine learning, and automation are expected to further enhance inspection capabilities. These technologies will enable faster, more accurate, and cost-effective quality control processes. Future research should focus on improving system integration, reducing costs, and developing standardized frameworks for implementing intelligent inspection systems.

## V. RESEARCH GAP & FUTURE SCOPE

The review of existing literature on quality control and inspection strategies in the aerospace industry

reveals several important gaps that need to be addressed. Although significant progress has been made in developing advanced inspection techniques such as non-destructive testing, automation, and artificial intelligence, there are still limitations in their practical implementation.

One of the major research gaps is the lack of effective integration between traditional inspection methods and modern intelligent systems. Many studies focus on individual techniques, but there is limited research on developing hybrid systems that combine the advantages of both approaches. Additionally, the high cost of advanced inspection technologies restricts their adoption, especially in small and medium-scale industries.

Another key gap is related to data management and analysis. Modern inspection systems generate large volumes of data, but efficient methods for processing and utilizing this data in real time are still under development. Furthermore, the reliability and certification of AI-based inspection systems remain a critical concern, particularly in safety-critical aerospace applications where accuracy and consistency are essential.

There is also a lack of standardized frameworks and guidelines for implementing advanced inspection technologies. Variations in methods and lack of uniform standards make it difficult to ensure consistency across different aerospace systems. Moreover, limited research has been conducted on long-term performance evaluation and maintenance of automated inspection systems.

## 5.2 Future Scope

The future of quality control and inspection strategies in the aerospace industry lies in the development of more advanced, integrated, and intelligent systems. One of the key areas of future research is the integration of artificial intelligence and machine learning with existing inspection techniques to create fully automated and self-learning inspection systems. These systems will be capable of real-time defect detection, analysis, and decision-making.

The adoption of digital twin technology is expected to play a significant role in future aerospace

inspection. By creating virtual models of physical systems, digital twins can enable continuous monitoring, simulation, and predictive analysis, leading to improved reliability and reduced maintenance costs.

Another important area of future scope is the development of cost-effective inspection technologies that can be easily implemented across different scales of manufacturing. Research should also focus on improving data processing techniques, including big data analytics and cloud-based systems, to handle large volumes of inspection data efficiently. Furthermore, advancements in robotics, automation, and smart manufacturing are expected to enhance inspection processes by increasing speed, accuracy, and flexibility. The development of standardized protocols and guidelines for implementing advanced inspection systems will also be essential for ensuring consistency and reliability.

Overall, future research should aim at creating integrated, efficient, and scalable quality control systems that can meet the growing demands of the aerospace industry while ensuring safety, reliability, and cost-effectiveness.

## VI. CONCLUSION

This survey paper provides a detailed and systematic review of quality control and inspection strategies in the aerospace industry, emphasizing their critical role in ensuring safety, reliability, and performance. Aerospace systems operate under extreme conditions where even the smallest defect can lead to catastrophic consequences. Therefore, maintaining strict quality standards through effective inspection techniques is not only necessary but essential.

The study highlights the evolution of inspection practices from traditional methods such as visual and dimensional inspection to advanced non-destructive testing techniques. While conventional methods remain useful for basic assessment, they are limited in their ability to detect internal defects and ensure high precision. The adoption of non-destructive testing methods has significantly enhanced defect detection capabilities, enabling thorough evaluation

of aerospace components without compromising their integrity.

Furthermore, the integration of statistical quality control techniques has enabled better monitoring and control of manufacturing processes, reducing variability and improving consistency. The emergence of modern technologies such as machine vision, robotics, and laser-based inspection systems has transformed quality control processes by increasing speed, accuracy, and repeatability.

A major advancement discussed in this study is the application of artificial intelligence and machine learning in inspection systems. These intelligent technologies have introduced capabilities such as real-time defect detection, predictive maintenance, and data-driven decision-making. Such advancements are paving the way for fully automated and smart inspection systems, which are expected to play a vital role in the future of aerospace manufacturing.

Despite these developments, several challenges remain, including high implementation costs, complexity in integrating advanced systems with existing infrastructure, and the need for skilled personnel. Additionally, ensuring the reliability, validation, and certification of AI-based inspection systems is a critical concern, particularly in safety-sensitive aerospace applications.

In conclusion, the aerospace industry is undergoing a significant transformation in quality control and inspection strategies. A balanced integration of traditional methods and advanced technologies is necessary to achieve optimal performance. Future research should focus on developing cost-effective, scalable, and standardized inspection systems that leverage automation and intelligent technologies. The continued advancement in this field will not only improve efficiency and reduce operational risks but also contribute to the development of safer, more reliable, and technologically advanced aerospace systems.

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