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Research Article

Manufacturing and Quality Inspection of an Air Intake Connector used in Missiles

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ABSTRACT

The objective of this work is to manufacture and ensure quality assurance of an air intake connector that is used in missiles. This involved creation of a 3D model and utilizing 3D printing for fabrication, with manufacturing simulation conducted using NX Software. The air intake connector is crucial for air transfer in various systems which is engineered to maintain consistent airflow to the propulsion system, which enhances the aerodynamic stability, minimizes the drag, and improving maneuverability for maximum impact velocity during target or destination approach. The air intake connector is manufactured using manufacturing operations of turning, boring, milling, wire cutting, drilling and tapping by using CNC machines. Inspection and machining of this component in the manufacturing industry are followed by post-processes such as non-destructive testing (NDT) techniques and age hardening. There is huge importance of age hardening in aerospace, automotive, and engineering applications for enhancing material properties and ensuring hardware integrity. Quality control prioritizes defect avoidance or elimination through state-of-the-art NDT techniques like radiographic inspection and dye penetrant testing which are crucial for detecting and addressing defects to prevent potential catastrophic failures during service.

Keywords: Air intake connector, CNC wire cutting, NDT Techniques, Quality control

INTRODUCTION

An air intake connector in a missile is to channel and deliver air to the propulsion system, typically a rocket engine or jet engine. This air is essential for combustion and propulsion, enabling the missile to generate thrust and maneuver through the atmosphere. The intake duct ensures that enough air reaches the engine, optimizing its performance and efficiency. Additionally, the design of the intake duct may also help control airflow characteristics to enhance aerodynamic stability and reduce drag during flight. Overall, the air intake connector plays a critical role in the propulsion system of a missile, ensur- ing its effective operation and maneuverability.

The applications of air intake ducts in missiles are primarily related to optimizing the performance of the propulsion system. Here are some specific applications:

- *Engine Efficiency*: Air intake ducts ensure that the propulsion system receives a steady and controlled flow of air, which is essential for efficient combustion. This helps maximize the thrust produced by the engine, enhancing the overall performance of the missile.

- *Speed and Range*: By carefully designing the intake ducts, engineers can optimize the airflow to achieve the desired speed and range for the missile. Properly designed intake ducts can help minimize air resistance and drag, allowing the missile to achieve higher speeds and longer ranges.

- *Altitude Performance*: Intake ducts can be tailored to maintain optimal engine performance at different altitudes. This is crucial for missiles that operate in a wide range of atmospheric conditions, such as air-to-air missiles or surface-to- air missiles.

- *Maneuverability*: The design of the intake ducts can also impact the maneuverability of the missile by influencing its aerodynamic characteristics. Intake ducts may incorporate features to control air flow and pressure distribution, improving stability and control during flight maneuvers.

- *Stealth and Signature Reduction*: In some advanced missile designs, intake ducts may be optimized to reduce the radar cross-section or infrared signature of the missile. This helps enhance the missile's stealth capabilities and makes it less susceptible to detection by enemy sensors.

- *Environmental Adaptability*: Intake ducts can be designed to adapt to changing environmental conditions, such as variations in air density, temperature, and humidity. This ensures consistent engine performance across different operating environments.

The method for manufacturing an air intake structure for a turbojet engine compris- ing at least two component parts, including at least one air intake lip structure and at least one air intake structure outer cowl [Shaik Mohammed et al., 2019]. The quality inspection for missile components using nondestructive testing methods such as Dye Penetrant test, Magnetic Parti- cle Inspection, Radiography, and Ultrasonic Testing. It targets a 6% defect reduction by pinpointing discontinuity root causes, focusing on welding practices, materials, equip- ment, and human factors affecting component reliability [Jinwei Fan et al., 2013]. The various nondestructive testing methods, including microwave detection, ultrasonic testing, industrial computed tomography (ICT) scan imaging technology, and industrial endoscope detection have been discussed [P. Kavya Sri et al., 2021]. The mechanical properties of maraging 250 steel welded using laser and TIG methods have been analyzed which are crucial for aerospace applications [G. Madhusudhan Reddy et al., 2015]. The various types of welding can make a strong steel that is used in defense weaker over time, specifically due to something called stress corrosion cracking (SCC) [S. Vijay Kumar et al., 2015]. The importance of nondestructive testing (NDT) techniques for ensuring the quality and integrity of rocket motor casings made from ultra high strength materials like mar aging steel, highlighting methods such as radiographic inspection, ultrasonic inspection, and acoustic emission inspection [Guido Kurthand et al., 2008]. The radiographic images of defects in solid propellant rocket motors processed at the Vikram Sarabhai Space Centre. It details methods for defect detection and analysis, highlighting the significance of defect free motors for predictable performance [S. Remakanthan et al., 2015 & Derik Hermann et al., 2007]. The numerical investigations are made and presented for air intake connectors used in missilles. [B.H. da Silveira et al, 2017 & S Pani et al., 2022].

METHODOLOGY

Problem Definition:

Develop efficient manufacturing and quality inspection procedures for air intake connectors in missiles utilizing nondestructive testing (NDT) techniques.

Objectives of the Project:

- Evaluate manufacturing processes for Air Intake Connectors used in missiles.
- Identify Non-Destructive Testing (NDT) techniques suitable for quality inspection.
- Implement selected NDT techniques to ensure the integrity of Air Intake Connectors
- Assess the effectiveness and reliability of NDT techniques in detecting defects.
- Enhance quality control measures to meet stringent standards for missile components.
- Ensure compliance with regulatory requirements and industry best practices.
- Establish a framework for continuous improvement in manufacturing and quality inspection practices. Enhance overall reliability and performance of Air Intake Connectors in missile systems.

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Methodology:

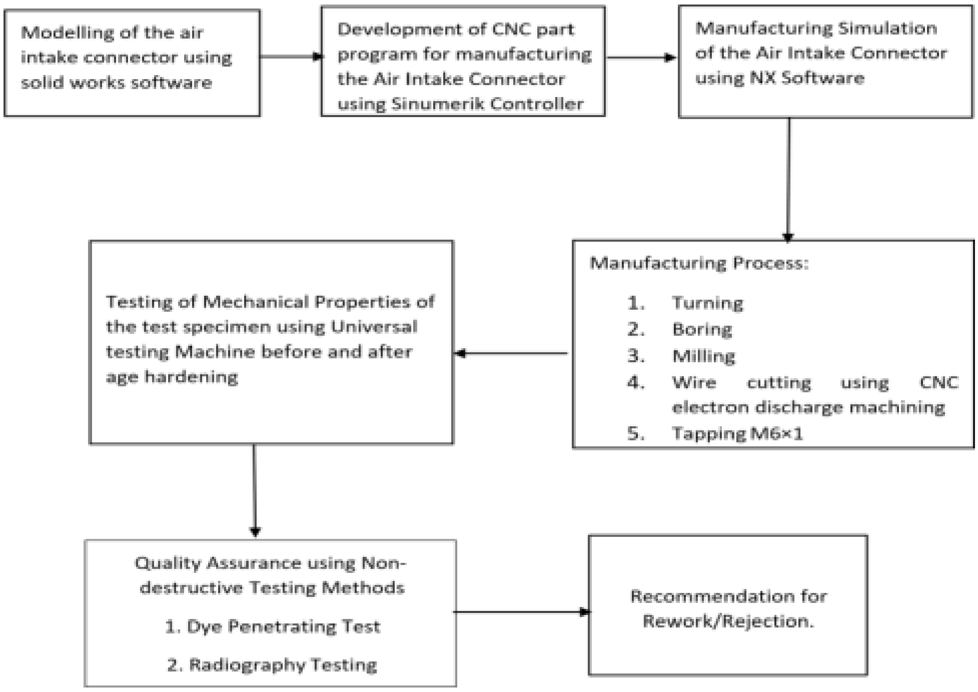

Fig.1. Flow chart of the methodology

MODELLING AND MANUFACTURING

Modelling:

The part model drawings are made by using Siemens NX software and are shown in Fig.2a. The Geometric 3D model is shown in Fig.2b.

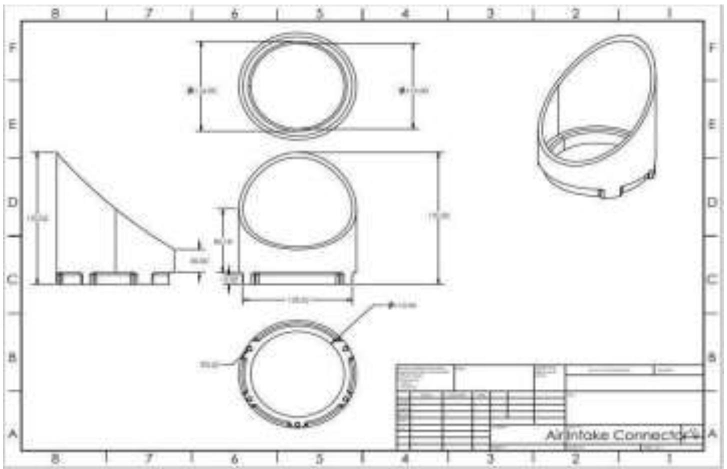

Fig.2a. CAD drawings of the Air intake connector

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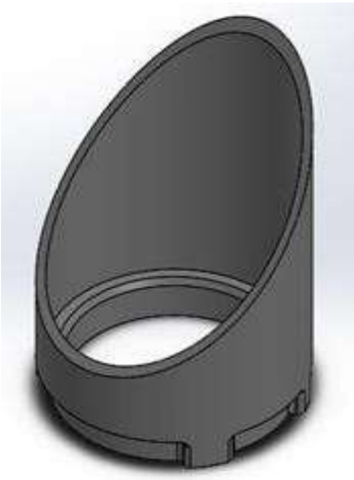

Fig.2b. 3D model of Air intake connector **Fig.3.** 3D printed model of Air intake connector

Manufacturing of the Air intake connector:

Initially the 3D printed model is made by using Fusion Deposition 3D Printing machine and is shown in Fig.3, which is used for a reference. The machining of the component on a CNC turn-mill Center to attain a desirable finish and accuracy requires to follow the following operations: Turning, Boring, Milling, Wire cut using Electric Discharge Machine, Drilling and Tapping.The manufacturing using CNC machine involves the usage of part programming for machining by using Turning cycle, Milling cycle, Drilling cycle and Tapping cycle with the help of Sinumerik controller.

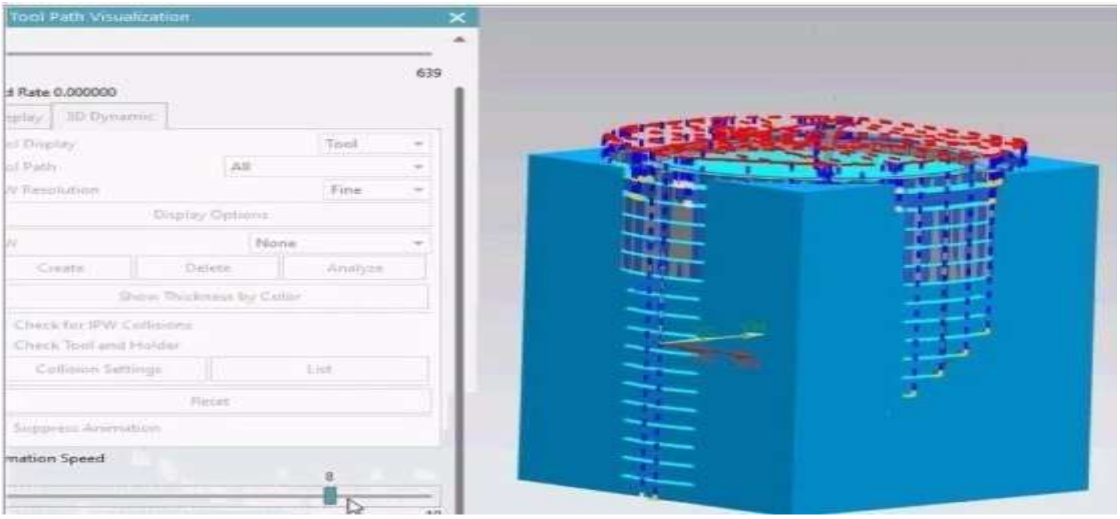

Fig.4. Manufacturing simulation of Air intake connector using Siemens-NX

After successful simulation of manufacturing (Fig.4) of the component using Sinumeric controller, the air intake connector is manufactured by using CNC turn-Mill center.

INSPECTION AND QUALITY TESTING USING NDT

Dimensional accuracy:

The component must be inspected for dimensional and geometrical accuracy for specified tolerances of the component. Prior to being dispatched for inspection the component must be deburred and cleaned to increase the accuracy of the measurements that are taking during inspection, due to methods of machining and parting off the component. The inspection results are tabulated in Table-1.

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Table-1. Dimensional inspection results

Dimensions	Actual Dimension (mm)	Measured dimension (mm)	Measuring Tool
Total Length	170±0.5	170.02	Height Gauge
Inner Base diameter	110±0.3	110	Bore Micrometer
Outer base Diameter	138±0.3	138	Vernier Calipers
Thickness	19	19	Micrometer
Radius	6	6	Radius gauge
Tapping	M 6×1	M 6×1	Tapping Gauge

Dye penetration test

The acceptance Criteria for the Dye Penetrant Testing:

All the weld joints should be subjected to DPT in accordance with ASTM E 1652002,

after flushing out the extra bead. In case of fillet joint where Radiography is not possible, only DPT is carried out. A certified Inspector of ASNT Level 2 shall conduct DPT.

Radiography testing:

- Radiography test can be carried out on full penetration welds Sensitivity level of 2% shall be maintained.
- Radiography should be done with Fe Penetrometer (DIN-ISO-10to 16)
- X-Ray Techniques shall be generated to get density of 2.5
- However, density in the range 2.0 (minimum) & 3.0 (maximum) is acceptable.
    - X-ray film shall be examined in a semi-darkened room using a variable intensity illuminator.

Fig.5. IQI for Radiography

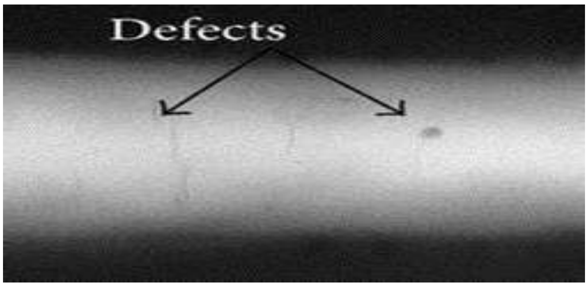

Fig.6. Weld Radiography image with defects: Porosities

The following listed defects are considered unacceptable:

Surface cavities, Cracks, Tears, Lack of fusion, Lack of Penetration, Linear Porosity. Any Porosity greater than 4 is not acceptable. Porosities must be separated by 2T or more. Dark images of generally circular or oval shape shall be interpreted as porosities. Only isolated porosity is permitted. Cluster aligned porosity is not permitted.

The radiography test report must be the type of defects, its dimensions and action taken. A new radiography test report to be submitted in the case of ever repair undertaken.

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RESULTS AND DISCUSSION

Dye Penetrant Test results:

For inspection purposes, each batch consists of 12 components.

Inspection Overview

Three types of assemblies were inspected:

a) **Dome Assembly**
b) Lug brake shoes and brackets are welded to combustion chamber 1

c) Lug brake shoes and brackets are welded to combustion chamber 2

➢ The air intake connector and brackets are welded to the dome. Following the dye penetrant test, 10 components required rework, while the remaining components were accepted for further processing.

➢ The lug brake shoes and brackets are welded to combustion chamber 1. After testing, 5 components were accepted, and 7 required rework.

➢ The lug brake shoes and brackets are added to combustion chamber 2. The test results showed that 4 components were accepted, while 8 required rework.

Dome Assembly Inspection Results

- 2 components were **directly accepted**.
- 10 components were **sent for rework**.

Combustion Chamber-1 Assembly Inspection Results

- 5 components were **directly accepted**.
- 7 components were **sent for rework**.

Combustion Chamber-2 Assembly Inspection Results

- 4 components were **directly accepted**.
- 8 components were **sent for rework**.

Reasons for Rework

- Under cut
- Cracks
- Surface cavities
- Overlap
- Lack of fusion

Process for rework:

The defected area is removed and worked again; the dye penetrant test is carried out.

Radiography Test (X-ray) Results:

For inspection purposes, each batch consists of 12 components.

Inspection Overview

Two types of assemblies were inspected:
a) **Dome Assembly**
b) **Butt-Welded Assembly of Combustion Chambers 1 & 2**

Dome Assembly Inspection Results

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- 6 components were **directly accepted**.
- 5 components were **sent for rework**.
- 1 component was **rejected after rework**.

Combustion Chamber 1 & 2 Assembly Inspection Results

- 8 components were **directly accepted**.
- 3 components were **sent for rework**.
- 1 component was **rejected without rework**.

Reasons for Rework

The components required rework due to the following defects:

- Linear porosities
- Lack of fusion
- Lack of penetration

Reason for Rejection

One component exhibited a **linear porosity defect** and was sent for rework twice. However, excessive welding in the same area resulted in the material becoming thinner than the required thickness, leading to its rejection.

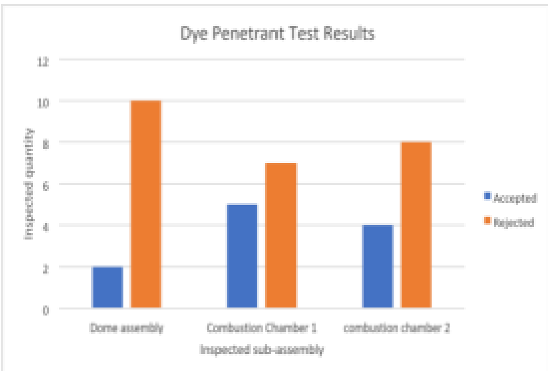

Fig.7. Dye penetration test results

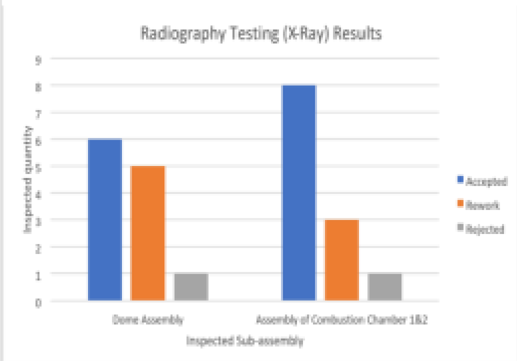

Fig.8. Radiography test results

Table 2. Comparative results of the Test specimen before and after age hardening

Property	Before age hardening				After age hardening			
	1	2	3	Average	1	2	3	Average
Yield strength at 0.2% offset (MPa)	1028.0	998.3	1034	1020.1	1834	1819	1816	1823
Ultimate tensile strength (MPa)	1220.8	1220.3	1218	1219.7	1864	1851	1851	1855.3
% Elongation	6.6	6.4	6.75	6.58	10	12	12	11.3
Hardness (HRC)	28	28	28	28	48	48	48	48

CONCLUSION

The inspection is performed on the manufactured air intake connector and observed the measured dimensions falls within the specified range that are set by the designers.

After the dye penetrant test, 83.3% of components needed rework due to defects like undercutting, cracks, surface cavities, overlap, and lack of fusion. Specifically, for the air intake connector and dome brackets, only 16.7% passed directly, with 58.3% requiring rework. For lug brake shoe and brackets on combustion chamber 1 only 41.7% passed directly, while 58.3% needed rework. Similarly, for lug brake shoe and brackets on combustion chamber 2 only 33.3% passed directly, with 66.7% needing rework.

Following the radiography test, 41.7% of components needed rework due to defects like linear porosities, lack of fusion, and penetration. Specifically, for the dome assembly, 50% required rework, with 8.3% ultimately rejected. For the combustion chambers 1 & 2 assembly 25% needed rework and 8.3% were ultimately rejected. Rework addressed issues such as linear porosity and lack of fusion, while rejection was due to over-welding and insufficient distance between porosities, ensuring compliance with design standards and improving overall component quality and reliability.

Yield strength at 0.2% offset increased substantially from an average of 1020.08 MPa to 1823 MPa, representing a 79.4% enhancement, while ultimate tensile strength rose from 1219.71 MPa to 1855.33 MPa, marking a 52.2% increase. Additionally, hardness notably increased from 28 HRC to 48 HRC, indicating enhanced material strength. The comparative test results before and after age hardening reveals significant improvements in mechanical properties. The age hardening process significantly enhances mechanical properties, including yield and ultimate tensile strength, as well as hardness.

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REFERENCES

[1] Shaik Mohammed Naseeruddin Sha, DR. K. Kalyani Radha, 2019 “Quality Inspection of mis- sile components using Non-Destructive Testing Methods”, Journal of Emerging Technolo- gies and Innovative Research (JETIR), Volume 6, pp. 829-834.
[2] Jinwei Fan, Futao Tan (2013) “Analysis of major defects and Non-destructive testing methods for solid Rocket Motor”, Applied Mechanics and Materials, Vols. 365-366, pp 618622.
[3] Pendakar Kavya Sri, Aarifa, K. Sai Piranha, D. Gowardhan, 2021, “Mechanical Properties of Maraging 250 Steel Welded by Laser and Tig Methodology”, International Journal of Engineering Research & Technology (IJERT), Vol. 10 Issue 05, pp. 997-1003.
[4] G. Madhusudhan Reddy, K. Srinivasa Rao, 2015, “Microstructure and corrosion behaviour of gas tungsten arc welds of maraging steel”, Defence Technology, pp. 48-55
[5] S. Vijay Kumar, K. Rahul, M. V. N Mohan, A. S. Srinivasa Gopal, 2015, “Quality Assurance of Rocket Motor Casings using Non-Destructive Testing”. National Seminar & Exhibition on Non- Destructive Evaluation, NDE 2014, Pune, Vol.20 No.6, pp.1-6.
[6] Guido Kurthand, Christopher Bauer, 2008, “Air intake Development for supersonic Mis- siles, American Institute of Aeronautics and Astronautics”, pp.1-11.
[7] S. Remakanthan, Moideenkutty KK, R Gunasekaran, Cherian Thomas & C R Thomas,2015, “Analysis of Defects in Solid Rocket Motors Using X-Ray Radiography”, National Seminar & Exhibition on Non-Destructive Evaluation, Vol.20 No.6, pp. 1-8.
[8] Derik Hermann, Klaus Triesch, Ali Gulham, 2007,”Experimental study of chin intakes for air breathing missiles with high agility”, Journal of Propulsion and Power, Vol.24, No.2, March-April,2008.
[9] B.H. da Silveira, P.R.C. Souza, O. Almeida, 2017, “Numerical Investigation of a Naca Air Intake for a Canard Type Aircraft”, International Journal of Advanced Engineering Research and Science (IJAERS), Vol-4, Issue-5, May- 2017.
[10] S Pani, K V Muralidharan, Sk Maharana, 2022, “Numerical Study of an Air Intake of a Cruise Missile in Subsonic Mach Regime”, International Journal of Innova- tive Research in Technology, (IJIRT), Volume 9, Issue 1, June 2022.