International Journal of Leading Research Publication (IJLRP)

E-ISSN: 2582-8010 ● Website: www.ijlrp.com ● Email: editor@ijlrp.com

Design and Development of 3d Printed Jigs & Fixtures Using FDM Technique

D. Harshavardhan Rao[1], Y. Sudheer[2]

[1,2]Department of Mechanical Engineering (CAD/CAM)
Tadipatri College of Engineering, Tadipatri.

Abstract:
Jigs and fixtures are essential tools used in manufacturing industries to improve accuracy, maintain product quality, and reduce production time. This project focuses on the design and development of a 3D printed inspection fixture using the Fused Deposition Modeling (FDM) technique for a car back seat supporting wire structure. The fixture is designed to inspect the wire diameter, frame profile, and assembly fitment according to specified design requirements. In conventional manufacturing environments, manual inspection of wire components is time-consuming and may lead to measurement errors and inconsistencies. To address these issues, a dedicated inspection fixture has been developed to simplify the inspection process and enhance dimensional verification.The fixture was designed using CATIA V5 R20 software based on the geometry and assembly requirements of the component. A prototype was fabricated using a 3D printer to evaluate its performance and functionality. The developed fixture enables rapid inspection of wire dimensions and shape, reducing inspection time and improving production efficiency. The application of FDM technology provides a cost-effective and flexible approach for manufacturing inspection fixtures with reduced development time. The project demonstrates the suitability of 3D printed jigs and fixtures for quality control and productivity improvement in automotive manufacturing industries.

Keywords: Inspection Fixture, 3D Printing, Fused Deposition Modeling (FDM), CATIA V5, Jig and Fixture, Automotive Manufacturing, Quality Control, Wire Frame Inspection, Rapid Prototyping, Production Efficiency.

I.INTRODUCTION

The increasing demand for flexible manufacturing systems, rapid product development, and cost-effective production methods has accelerated the adoption of additive manufacturing technologies across various industrial sectors. Among these technologies, Fused Deposition Modelling (FDM) has emerged as one of the most widely utilized additive manufacturing processes due to its affordability, ease of operation, and capability to fabricate complex geometries directly from digital models. The technology has found significant applications in aerospace, automotive, healthcare, consumer products, and industrial tooling. In particular, the development of jigs and fixtures using FDM technology has gained considerable attention as industries seek lightweight, customizable, and rapidly deployable tooling solutions.Jigs and fixtures are essential components in manufacturing systems, serving to locate, support, and secure workpieces during machining, assembly, inspection, and quality control operations. Conventional jig and fixture manufacturing typically relies on machining, welding, and fabrication processes using metallic materials such as steel and aluminum. Although these methods provide excellent mechanical strength and durability, they often involve high production costs, long lead times, and limited design flexibility. Furthermore, modifications resulting from product design changes frequently require extensive rework or complete replacement of the tooling, thereby increasing manufacturing expenses and reducing operational efficiency.Additive manufacturing offers a viable alternative to traditional tooling production by enabling layer-by-layer fabrication of components directly from computer-aided design (CAD) models. This approach eliminates many of the constraints associated with conventional manufacturing techniques and allows the creation of complex geometries, internal structures, and customized designs without additional tooling requirements. As a result, additive manufacturing significantly reduces production time, material waste, and overall manufacturing costs. These advantages make FDM particularly attractive for producing low-volume, customized, and application-specific jigs and fixtures.The utilization of FDM technology in fixture development provides several functional and economic benefits. Lightweight fixtures improve operator ergonomics and facilitate easier handling during manufacturing and inspection operations. The ability to rapidly prototype and manufacture tooling allows organizations to respond quickly to design modifications and changing production requirements. Moreover, the digital workflow associated with additive manufacturing supports seamless integration between design, analysis, and fabrication stages, thereby enhancing overall productivity and reducing development cycles.Material selection plays a crucial role in determining the performance and durability of FDM-fabricated jigs and fixtures. Thermoplastic materials such as Polylactic Acid (PLA), Acrylonitrile Butadiene Styrene (ABS), and Polyethylene Terephthalate Glycol (PETG) are widely used due to their favorable processing characteristics, dimensional stability, and cost-effectiveness. PLA is preferred for applications requiring high dimensional accuracy and ease of fabrication, whereas PETG offers improved toughness and chemical resistance. ABS provides enhanced thermal stability and impact resistance for more demanding industrial environments. Recent advancements in material science have also introduced fiber-reinforced composite filaments, including carbon fiber and glass fiber reinforced polymers, which exhibit superior stiffness, strength, and wear resistance compared to conventional thermoplastics.The mechanical performance of FDM-manufactured components is strongly influenced by process parameters such as layer height, raster angle, build orientation, nozzle temperature, printing speed, and infill density. These parameters affect interlayer bonding, dimensional accuracy, surface finish, and structural integrity. Consequently, optimization of printing conditions is essential to achieve reliable and repeatable fixture performance. Several researchers have reported that appropriate selection of process parameters can significantly enhance the load-carrying capacity and service life of FDM-produced tooling components.To ensure structural reliability, computational design and simulation techniques are increasingly integrated into the fixture development process. Finite Element Analysis (FEA) enables the prediction of stress distribution, deformation behavior, and failure mechanisms under operational loading conditions. Through virtual testing, designers can evaluate multiple design alternatives and optimize structural performance before physical fabrication. This approach minimizes trial-and-error experimentation, reduces development costs, and improves product reliability.Topology optimization has emerged as a powerful methodology for designing lightweight and efficient additive-manufactured structures. The technique identifies regions of material that contribute minimally to structural performance and systematically removes them while maintaining required strength and stiffness characteristics. The resulting organic and geometrically complex designs are particularly suitable for additive manufacturing processes, which can fabricate such structures without the limitations associated with traditional machining methods. The integration of topology optimization with FDM technology enables the production of highly efficient jigs and fixtures that exhibit reduced weight, lower material consumption, and improved functionality.In automotive manufacturing environments, 3D-printed jigs and fixtures are increasingly utilized for assembly operations, dimensional inspection, welding support, drilling guidance, and component positioning. Their adoption contributes to reduced tooling costs, shorter lead times, and enhanced production flexibility. Additionally, modular fixture designs facilitated by additive manufacturing allow rapid adaptation to different product configurations, supporting the growing trend toward mass customization and flexible manufacturing systems.Recent advancements in smart manufacturing have further expanded the capabilities of additively manufactured tooling. The incorporation of embedded sensors within fixtures enables real-time monitoring of load conditions, temperature variations, and operational performance. Furthermore, data-driven optimization techniques and machine learning algorithms are being explored to improve print quality, predict component behavior, and optimize manufacturing parameters. These developments align with Industry 4.0 objectives by promoting intelligent, connected, and adaptive manufacturing systems.Therefore, the design and development of 3D-printed jigs and fixtures using FDM technology represent a promising approach for achieving lightweight, cost-effective, and high-performance tooling solutions. By combining advanced design methodologies, material optimization, computational analysis, and additive manufacturing techniques, industries can significantly improve manufacturing efficiency, reduce operational costs, and enhance product quality. The present research focuses on the design, analysis, fabrication, and evaluation of FDM-based jigs and fixtures, contributing to the advancement of additive manufacturing applications in industrial tooling and production engineering.

II.LITERATURE SURVEY

The literature shows significant progress in the development of additively manufactured inspection fixtures from 2024 to 2026, with increasing focus on optimization, materials, and smart manufacturing systems. [1] (2024) focuses on topology optimization of additively manufactured fixtures for automotive applications. It improves structural efficiency by removing unnecessary material while maintaining required stiffness and load-bearing capability. The study demonstrates that optimized designs reduce weight without affecting performance. It also supports better material utilization in fixture design. Overall, it enhances the efficiency of automotive inspection tools. [2] (2024) evaluates the mechanical performance of PLA and PETG materials used in FDM-based fixtures. The results show that both materials are suitable for low to medium load applications. However, limitations are observed under high stress and elevated temperature conditions. The study also compares strength and durability characteristics. It helps in selecting appropriate materials for fixture development. [3] (2024) introduces smart inspection fixtures integrated with embedded sensors. These sensors enable real-time monitoring of load and operational conditions. The system improves reliability and reduces manual inspection errors. It also supports predictive maintenance in manufacturing environments. The study highlights the move toward intelligent fixture systems. [4] (2025) presents a comparison between conventional fixtures and 3D printed fixtures in automotive assembly. The findings show that additive manufacturing reduces production time significantly. It also offers greater design flexibility and customization. Accuracy levels are found to be comparable to traditional methods. The study confirms the industrial advantage of 3D printed fixtures. [5] (2025) investigates optimization of FDM process parameters such as layer height, infill density, and print orientation. The study shows that parameter tuning directly affects strength and dimensional accuracy. Improved settings lead to better mechanical performance. It also reduces defects in printed parts. The research enhances process reliability in fixture production. [6] (2025) applies finite element analysis to study stress distribution in FDM printed fixtures. The results help in predicting deformation under working loads. It reduces the need for repeated physical testing. The study improves design validation before manufacturing. It supports safer and more efficient fixture development. [7] (2025) explores modular additive manufactured fixtures for flexible manufacturing systems. These fixtures can be easily reconfigured for different inspection tasks. The approach improves adaptability in dynamic production environments. It reduces downtime during fixture changeover. The study supports flexible and scalable manufacturing. [8] (2026) examines carbon fibre reinforced thermoplastic fixtures for industrial use. The material shows higher stiffness and improved wear resistance. It is suitable for demanding operational conditions. The study compares it with standard thermoplastics. It confirms enhanced mechanical performance for advanced applications. [9] (2026) focuses on machine learning-based optimization of FDM parameters. The approach improves printing accuracy and consistency. It reduces trial-and-error in process selection. The model helps achieve better quality control. The study demonstrates the role of AI-based methods in manufacturing optimization. [10] (2026) presents the design and development of automotive inspection fixtures using FDM technology. It integrates material selection, simulation, and process optimization. The approach ensures cost-effective and efficient fixture production. It improves accuracy and performance reliability. The study provides a complete framework for modern fixture development.

III.SYSTEM MODULE

EXISTING SYSTEM

In the existing manufacturing system, inspection of car back seat supporting wire structures is carried out using conventional manual measurement methods and standard mechanical gauges. Operators typically use tools such as callipers, templates, and Vernier instruments to verify wire diameter, profile accuracy, and assembly fitment. These inspection processes are performed individually for each component, requiring significant manual effort and time. The fixtures used, if any, are generally conventional metal-based tools designed for fixed geometries and limited flexibility. Design changes or product variations often require modification or replacement of these fixtures, which increases cost and downtime in production.

Disadvantages

- Inspection process is time-consuming due to repeated manual measurements.
- High chances of human error lead to variation in measurement accuracy.
- Lack of flexibility makes it difficult to handle different product variants or design changes.
- Conventional fixture manufacturing involves high cost and longer lead time.
- Dependency on skilled operators reduces overall production efficiency and consistency.

PROPOSED SYSTEM

The proposed system focuses on the design and development of a 3D printed inspection fixture for a car back seat supporting wire structure using Fused Deposition Modelling (FDM) technology. The fixture is designed based on the exact geometry of the wire component to inspect parameters such as wire diameter, frame profile, and assembly fitment. The design is created using CATIA V5 R20 software and then converted into a physical prototype using a 3D printer. The fixture allows quick and accurate inspection of components by providing dedicated locating and checking features. It replaces manual inspection

International Journal of Leading Research Publication (IJLRP)
E-ISSN: 2582-8010 ● Website: www.ijlrp.com ● Email: editor@ijlrp.com

methods with a structured and repeatable checking process, improving consistency and reducing dependency on operator skill.

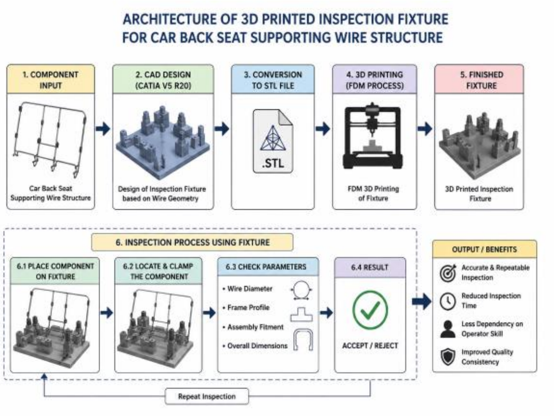

Figure: Proposed System Architecture for 3D Printed Inspection Fixture Development

Advantages

- Reduces inspection time by enabling quick and direct verification of wire components.
- Improves measurement accuracy and reduces human errors during inspection.
- Provides a customized fixture design suitable for specific component geometry.
- Offers flexibility to modify design easily using CAD software when product changes occur.
- Lowers manufacturing cost and lead time compared to conventional metal fixtures.
- Enhances productivity by simplifying the inspection process and improving consistency.

IV.MATERIALS AND METHODS

The present work focuses on the design and fabrication of an inspection fixture for a car back seat supporting wire structure. The wire component was first studied to identify the important inspection parameters such as wire diameter, frame profile, and assembly fitment. The dimensions of the wire structure were measured and used as input for fixture design. CATIA V5 R20 software was utilized to create a three-dimensional model of the inspection fixture with suitable locating and checking features to ensure accurate positioning and inspection of the component. After completing the design, the model was converted into STL format and prepared for additive manufacturing. A prototype of the fixture was then produced using a 3D printer based on Fused Deposition Modelling (FDM) technology. The fabricated fixture was used to inspect the wire structure by placing the component on the designated locating points and verifying its dimensions and shape against the checking features provided in the fixture. The developed fixture enables quick identification of dimensional and profile deviations, reduces inspection time, improves consistency in quality checking, and minimizes dependence on manual inspection methods, making it suitable for production environments.

V.EXPERIMENTAL PROCEDURE

The experimental procedure began with the collection and measurement of the car back seat supporting wire structure to identify its critical dimensions and inspection requirements. Based on these measurements, a three-dimensional model of the inspection fixture was developed using CATIA V5 R20 software. The fixture was designed with appropriate locating and checking features to inspect the wire diameter, frame profile, and assembly fitment. After the design was finalized, the model was converted into STL format and fabricated using a 3D printer through Fused Deposition Modelling (FDM) technology. The manufactured fixture was then tested by placing the wire structure on the designated locating surfaces and checking points. The component was inspected for dimensional accuracy, shape conformity, and proper fitment within the fixture. Any deviation from the required geometry was identified through the inspection process. The results obtained from the fixture were compared with the design requirements to evaluate its effectiveness in reducing inspection time, improving accuracy, and ensuring consistent quality verification during production.

VI.RESULTS

The inspection fixture developed for the car back seat supporting wire structure was successfully designed and fabricated using FDM-based 3D printing technology. The fixture accurately accommodated the wire component and enabled effective inspection of wire diameter, frame profile, and assembly fitment. During testing, the locating and checking features ensured proper positioning of the component, allowing deviations in shape and dimensions to be identified easily. The use of the fixture reduced the time required for inspection when compared with conventional manual methods. The inspection process became more consistent and less dependent on operator skill. The fabricated prototype demonstrated sufficient dimensional accuracy and structural stability for inspection purposes. The results indicate that the developed fixture can improve quality control by providing a reliable and repeatable method for checking wire structures used in automotive seat assemblies, thereby supporting efficient production operations.

VII.CONCLUSION

A 3D printed inspection fixture for a car back seat supporting wire structure was successfully designed and developed using CATIA V5 R20 and FDM technology. The fixture provided an effective method for inspecting wire diameter, frame profile, and assembly fitment. The developed system reduced inspection time and improved consistency in quality verification. The use of dedicated locating and checking features enabled accurate identification of dimensional and shape deviations. The study demonstrated that additive manufacturing can be used to produce low-cost inspection fixtures suitable for production environments. The developed fixture contributes to improved inspection efficiency and enhanced product quality in automotive manufacturing applications.

FUTURE SCOPE

The developed inspection fixture can be further improved by incorporating advanced inspection and measurement techniques. Future work may include the integration of digital sensors to automatically detect dimensional deviations and generate inspection reports. The fixture design can also be optimized for different types of automotive wire structures and seat assemblies. The use of stronger and more durable printing materials can enhance fixture life for industrial applications. In addition, computer vision and image-processing techniques may be integrated to perform automated profile inspection. The combination of 3D printing and smart inspection technologies can lead to faster, more accurate, and fully automated quality control systems in modern manufacturing industries.

REFERENCES:

1. Zhang Wei, Liu Jian, Wang Hai, "Topology Optimized Additive Manufactured Fixtures for Automotive Applications," IEEE International Conference on Industrial Engineering and Applications (ICIEA), 2024.
2. Kumar, S. Patel, R. Singh, "Mechanical Performance Evaluation of PLA and PETG for FDM-Based Inspection Fixtures," IEEE Access, Vol. 12, 2024.
3. J. Lee, H. Kim, S. Park, "Smart Additive Manufactured Inspection Fixtures with Embedded Sensors," IEEE Transactions on Industrial Informatics, Vol. 20, No. 4, 2024.
4. M. Rodriguez, F. Garcia, P. Hernandez, "Comparative Study of Conventional and 3D Printed Fixtures in Automotive Assembly," IEEE International Conference on Manufacturing Systems, 2025.
5. S. Verme, P. Sharma, A. Gupta, "Optimization of FDM Parameters for Precision Inspection Fixtures," IEEE Access, Vol. 13, 2025.
6. Y. Chen, X. Zhao, L. Wang, "Finite Element Analysis of FDM Printed Industrial Fixtures," IEEE International Conference on Advanced Manufacturing Technology, 2025.
7. P. Anderson, M. Brown, T. Wilson, "Modular Additive Manufactured Fixtures for Flexible Manufacturing Systems," IEEE Transactions on Automation Science and Engineering, Vol. 22, No. 2, 2025.
8. K. Ramesh, V. Kumar, N. Prakash, "Carbon Fiber Reinforced Thermoplastic Fixtures for Industrial Applications," IEEE International Conference on Mechanical Engineering and Materials Science, 2026.
9. H. Takahashi, Y. Mori, K. Sato, "Machine Learning-Based Optimization of FDM Parameters for Tooling Applications," IEEE Access, Vol. 14, 2026.
10. S. Narayanan, R. Krishnan, M. Bali, "Design and Development of Automotive Inspection Fixtures Using FDM Technology," IEEE International Conference on Smart Manufacturing and Industry 4.0, 2026.