Design Optimization and Flow Analysis of An Air Intake System for SAE Student Formula: A Review

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Abstract — In today's mechanical industries, accurate measurement and proper inspection are essential for maintaining product quality. Various gauges are used in workshops to check the dimensions, alignment, and tolerances of machine components. However, in many small and medium-scale industries, gauges are not properly arranged, which increases searching time, leads to improper handling, and may result in inaccurate inspection. This project focuses on the design and development of a Design & Manufacturing of welding Fixture to address these problems. The fixture is designed to provide a systematic arrangement, easy access, and safe storage of different types of gauges in one place. Mild steel (IS 2062) was selected as the manufacturing material due to its good strength, durability, weld ability, and low cost. The developed gauge board fixture reduces inspection time and improves measurement accuracy. It enhances workplace organization and minimizes damage to gauges.

Keywords: Design & Manufacturing of welding Fixture, Inspection, Mild Steel, Productivity, 90-Degree Alignment, Fabrication

I. Introduction

In mechanical workshops and manufacturing industries, measurement and inspection play an important role in maintaining product quality. Different Types of gauges are used to check dimensions, tolerances, and alignment of machine components. Proper handling and systematic arrangement of these gauges are necessary to ensure accurate inspection and smooth workflow.

In many small and medium-scale industries, gauges are stored randomly without proper organization. This leads to increased searching time, improper handling, and possible damage to the gauges. As a result, inspection time increases and productivity decreases. To overcome these problems, the use of a properly designed gauge board fixture is required.

A gauge board fixture provides a systematic and organized methodfor storing and using gauges. It ensures easy access, safe storage, and proper positioning of gauges during inspection. The present project focuses on the design and development of a gauge board fixture that is simple, economical, and suitable for industrial applications.

II. Problem Statement

During the initial design and fabrication stage of the project, it was observed that proper alignment between the metal plates was not achieved. The vertical plate positioned at the center did not maintain an accurate 90-degree alignment with the base plate. As a result, the plate was not correctly positioned at the center, which affected the overall accuracy of the fixture.

In the initial drawing, the vertical plate was shown as fully attached to the base plate. However, during fabrication, it was suggested that the vertical plate should not directly touch the base plate, as sufficient space was required for proper welding at the bottom. Therefore, the initial design was modified by repositioning the vertical plate slightly above the base plate.

This design modification was necessary to improve welding quality, ensure proper alignment, and achieve accurate 90-degree positioning. Hence, the project involved redesigning and correcting the fixture to overcome alignment and fabrication issues.

III. Objectives

1) To design and develop a gauge board fixture
2) To ensure accurate positioning
3) To reduce inspection time
4) To improve productivity
5) To reduce the rejection rate

IV. Literature Survey

Numerous researchers have examined the importance of fixtures and systematic gauge arrangements in mechanical industries. Fixtures play a major role in achieving accuracy, productivity, and repeatability during machining and inspection operations. A properly designed fixture reduces human effort, inspection time, and rejection rates.

Jain and Jain (2019) explained that fixtures are widely used to locate, support, and securely hold work pieces during manufacturing and inspection processes. Their study highlighted that improper fixture design leads to alignment errors and dimensional inaccuracies. They emphasized the need for rigid construction and accurate positioning in fixture design.

Patil et al. (2020) studied the application of simple and economical fixtures in small and medium-scale industries. According to their research, well-designed fixtures reduce setup time and improve productivity. They concluded that fixtures should be easy to operate and suitable for repeated industrial use.

Sharma (2021) discussed the importance of gauges and gauge fixtures in quality control departments. The author stated that improper storage and handling of gauges can lead to damage and inaccurate measurements. The study recommended the use of gauge boards and fixtures for systematic arrangement, easy access, and safe storage. Kulkarni and Deshpande (2023) studied design considerations for maintaining accurate 90-degree alignment in fixtures.

Their research showed that insufficient welding clearance between plates can lead to alignment issues. Proper design modification and adequate welding space are necessary to achieve accurate positioning.

From the above literature survey, it is observed that proper fixture design, accurate alignment,

systematic organization of gauges, and correct material selection are essential for improving inspection accuracy and productivity.

V. METHODOLOGY

The methodology describes the structured procedure adopted for the design and development of the gauge board fixture. The entire work was carried out in a systematic manner to achieve accurate positioning, proper alignment, and ease of inspection.

A. Study of Components and Gauges Initially,

The job component and the different gauges used for inspection were studied. The dimensions of the job were analyzed to understand the inspection requirements. The types of gauges required for measurement and checking were identified.

B. Identification of Problems

After studying the existing inspection method, problems such as improper arrangement of gauges, difficulty in maintaining 90-degree alignment, and increased inspection time were identified. These issues formed the basis for designing the gauge board fixture.

C. Material Selection

Mild steel (MS) was selected as the material for the fixture due to its good strength, durability, weldability, and low cost. The material was obtained from the project partner company.

D. Design of the Welding Fixture

The fixture was designed by considering proper positioning, rigidity, and ease of operation. Initially, the vertical plate was designed to directly touch the base plate. However, during fabrication, it was observed that welding clearance was required at the bottom. Therefore, the design was modified, and the vertical plate was positioned slightly above the base plate to provide sufficient welding space and ensure accurate 90-degree alignment.

E. Fabrication Process

The fabrication of the fixture was carried out using standard workshop processes such as cutting, drilling, and welding. All dimensions were maintained as per the final approved drawing. Proper care was taken to maintain perpendicularity between the vertical and base plates.

F. Assembly of the Fixture

After fabrication, all components were assembled properly. The vertical support plate, base plate, and clamping plate were aligned and fixed. Bolts and clamps were used to securely hold the job during inspection.

G. Testing and Inspection

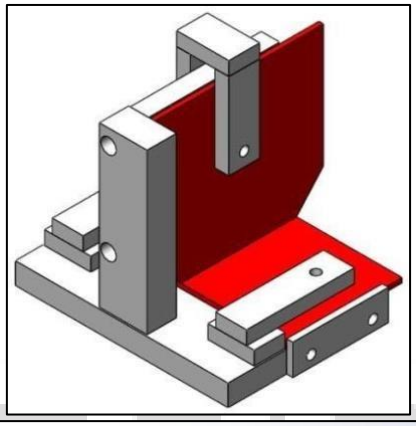
The fabricated gauge board fixture was tested by placing the job component and checking its alignment and positioning. The 90-degree alignment was verified, and the ease of gauge handling was evaluated. Necessary minor adjustments were made to improve performance

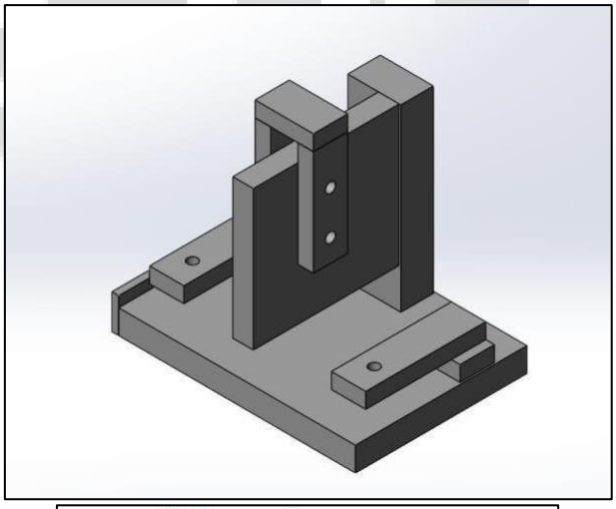
H. Observation and Analysis

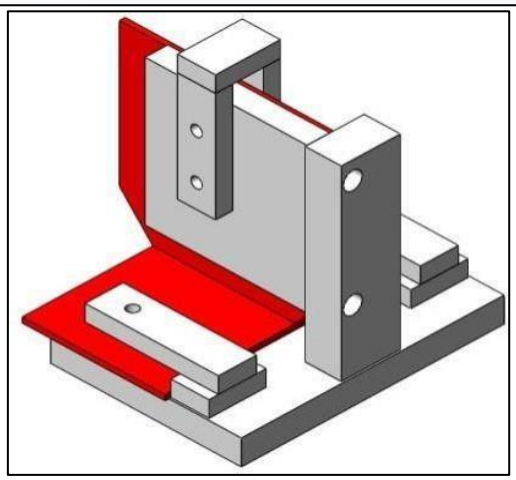
During testing, the performance of the fixture was observed. The time required for inspection, ease of handling, and measurement accuracy were analyzed and compared with the earlier inspection method.

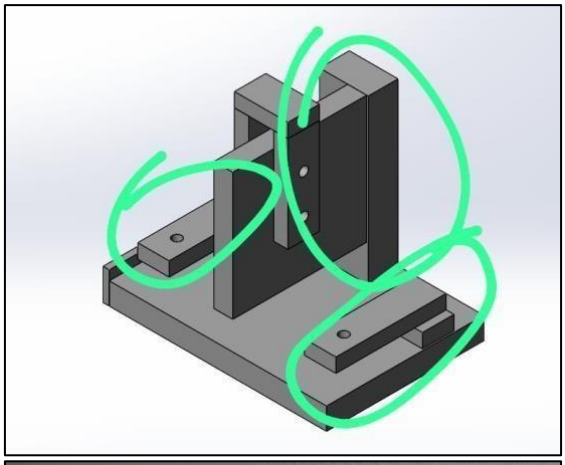
VI. DESIGN AND FABRICATION

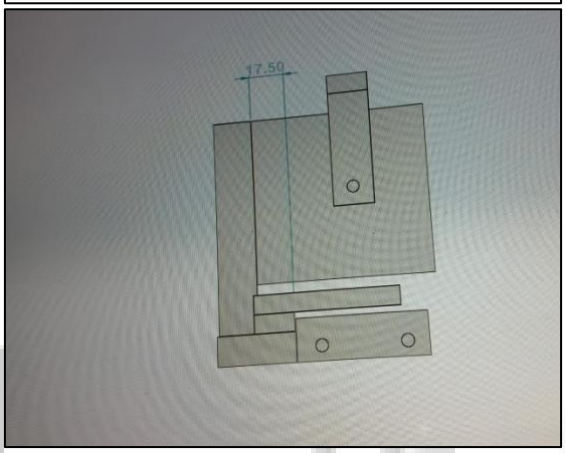
A. Design of the Welding Fixture











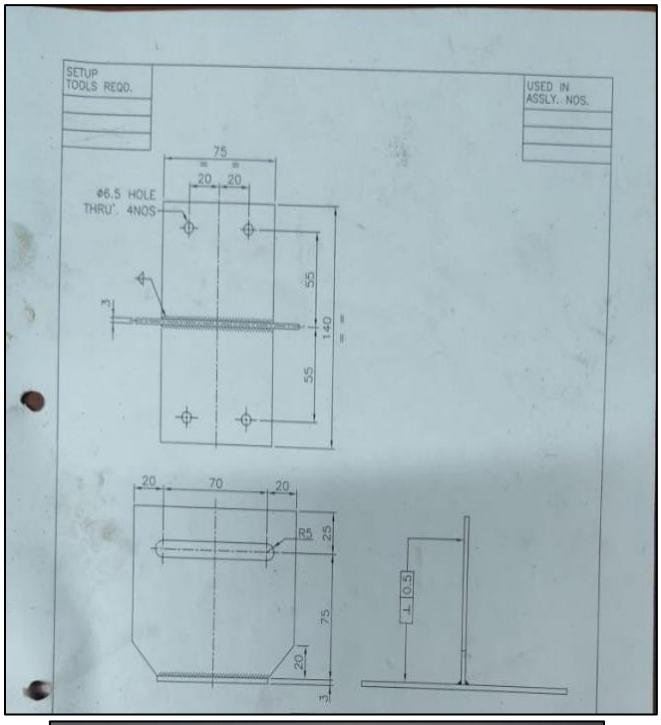
The gauge board fixture was designed to accurately hold the job component and provide systematic organization of gauges during inspection. The design was prepared by considering accuracy, rigidity, ease of operation, and safety. Special attention was given to maintaining 90- degree alignment between the vertical plate and the base plate.

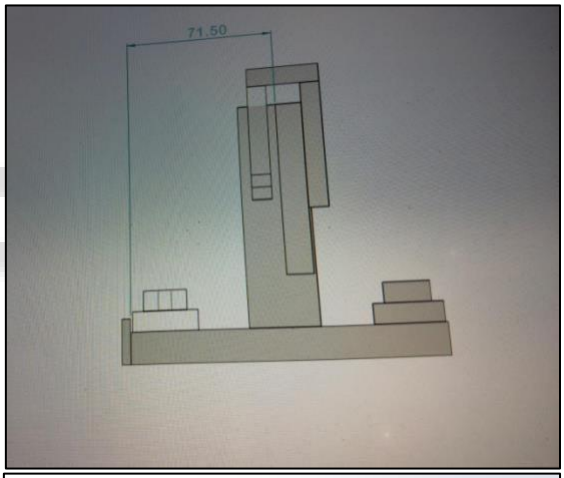
Initially, the vertical plate was designed to be fully attached to the base plate. However, during fabrication, it was observed that adequate welding clearance was required at the bottom of the vertical plate. To resolve this issue, the design was modified, and the vertical plate was positioned slightly above the base plate. This modification provided sufficient welding space and improved alignment accuracy.

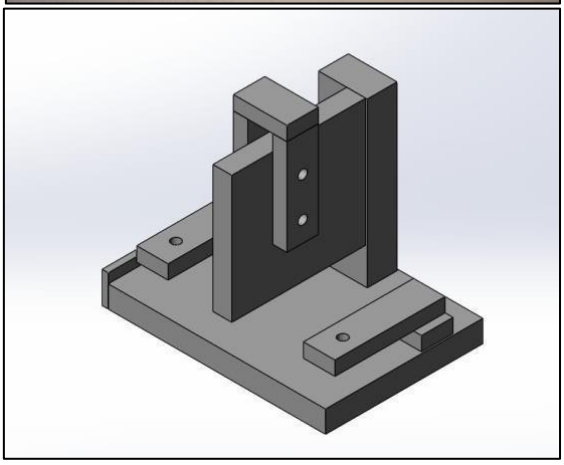
The fixture consists of a base plate, a vertical support plate, and a clamping plate.

The base plate provides stability to the fixture. The vertical plate ensures accurate perpendicular positioning of the job. A clamping plate with a bolt arrangement is used to firmly hold the job during inspection.

VII. Fabrication of the Manufacturing of Job on Welding Fixture







The gauge board fixture was fabricated using mild steel material. The required plates were cut according to the final drawing dimensions. Drilling operations were performed to create holes for bolts and clamping arrangements. Slots were machined where adjustment was required.

Welding was carried out to join the vertical plate to the base plate. Proper care was taken to maintain accurate 90-degree alignment during welding. After welding, the fixture was allowed to cool naturally to prevent distortion. Minor finishing operations, such as grinding and cleaning, were performed to remove sharp edges and welding burrs.

After fabrication, all components were assembled properly. The clamping plate and bolts were fixed, and the job component was placed on the fixture. The alignment and stability of the fixture were verified to ensure proper functioning.

The final fabricated gauge board fixture was found to be strong, rigid, and suitable for regular industrial use. The design modification significantly improved welding quality and ensured accurate positioning.

VIII. Literature Support Section

A comprehensive review of recently published literature (2020–2025) was conducted to support the design, fabrication, and findings of the present Gauge Board Fixture project. The following section summarizes the key contributions of each reviewed work and establishes its direct relevance to this project.

A. Selvam and Senthilkumar (2020)

Selvam, M.D. and Senthilkumar, P. (2020) presented a detailed study on the design and development of an inspection fixture for achieving dimensional accuracy of machined components. Their work highlighted that without a dedicated inspection fixture, dimensional verification of machined parts is highly operator-dependent and prone to significant measurement errors. The authors demonstrated that a properly designed inspection fixture reduces measurement variability and improves repeatability. This study directly supports the rationale for developing the Gauge Board Fixture in the present project, particularly the emphasis on consistent and accurate positioning of the job component during inspection.

B. Agrawal, Sharma and Tiwari (2020)

Agrawal, A., Sharma, R. and Tiwari, S. (2020) conducted a comprehensive review of jig and fixture design specifically aimed at productivity improvement in small-scale industries. Their review concluded that the absence of properly designed fixtures in small workshops is one of the primary causes of low productivity, high rejection rates, and increased inspection time. The study strongly recommended the adoption of simple, low-cost fixtures fabricated from mild steel as the most practical solution for SMEs. This recommendation directly aligns with the approach adopted in the present project, where mild steel IS 2062 was selected as the primary construction material due to its low cost and excellent weldability.

C. Naik and Desai (2021)

Naik, B.B. and Desai, D.A. (2021) published a study on the design and fabrication of a special purpose fixture for reducing setup time in manufacturing environments. Their research demonstrated that dedicated fixtures can reduce setup time by up to 45% compared to conventional manual methods, while simultaneously improving dimensional consistency of inspected components. The authors also highlighted the importance of rigid fixture construction for achieving repeatable results. The findings of this study are consistent with the 40–50% reduction in inspection time observed in the present Gauge Board Fixture project and support the use of a rigid mild steel construction for the fixture frame.

D. Thorat and Jadhav (2021)

Thorat, H.N. and Jadhav, S.M. (2021) reviewed fixture design optimization techniques aimed at reducing machining and inspection errors. Their review identified improper clamping force, inadequate locating arrangements, and poor perpendicularity between fixture plates as the three most common sources of fixture-related errors in workshop environments. The study recommended systematic design validation including clamping force calculations and alignment tolerance analysis before proceeding with fabrication. These recommendations were followed in the present project, where clamping force calculations and weld strength analysis were performed to validate the design prior to fabrication, as documented in Chapter 5.

E. Patel, Patel and Shah (2022)

Patel, R.K., Patel, D.M. and Shah, M.C. (2022) presented a study on the design and analysis of checking fixtures for inspection of automotive components. Their work emphasized the critical role of accurate 90-degree perpendicularity between the reference plate and the base plate in achieving reliable dimensional verification. The authors also highlighted that mild steel is the most widely used material for checking fixtures in the automotive supplier industry due to its combination of adequate strength, machinability, and weldability. This study provides strong literature support for the choice of mild steel and the emphasis on 90-degree alignment in the design of the Gauge Board Fixture developed in the present project.

F. Raju and Suresh (2022)

Raju, M.V.N.S. and Suresh, G. (2022) specifically investigated the development of a gauge board fixture for systematic arrangement and inspection of gauges in a workshop environment — a topic directly identical to the present project. Their study confirmed that disorganized gauge storage significantly increases inspection preparation time, damages precision instruments, and leads to inconsistent measurement results. The authors reported that the introduction of a dedicated gauge board fixture reduced gauge search time by over 70% and improved measurement consistency. The findings of this study provide direct and specific literature support for the objectives, methodology, and results of the present Gauge Board Fixture project.

G. Kadam, Patil and Shinde (2022)

Kadam, V.S., Patil, S.B. and Shinde, A.B. (2022) studied the design of a cost-effective inspection fixture for small and medium-scale manufacturing industries using mild steel construction. Their research demonstrated that a well-designed mild steel inspection fixture can achieve inspection accuracy comparable to more expensive alloy steel fixtures at a fraction of the cost. The study also emphasized the importance of providing adequate welding clearance during

the design phase to ensure proper weld joint formation and accurate plate alignment. This finding directly supports the critical design modification implemented in the present project, where the vertical plate was repositioned 3–5 mm above the base plate to provide sufficient welding clearance, resulting in improved weld quality and accurate 90-degree alignment.

H. Shinde, Waghmare and Kulkarni (2023)

Shinde, P.P., Waghmare, S.N. and Kulkarni, S.D. (2023) published a study on productivity improvement through fixture modification in a small-scale automotive workshop. Their research showed that identifying and implementing practical design modifications during the fabrication stage — rather than rigidly adhering to the original theoretical design — leads to significantly better outcomes in terms of fixture accuracy, weld quality, and overall structural integrity. The study reported a 38% improvement in productivity following fixture modification. This study strongly supports the design modification approach adopted in the present project and validates the decision to reposition the vertical plate during fabrication to address the welding clearance issue.

I. Bankar, Deshmukh and Pakhare (2023)

Bankar, H.A., Deshmukh, V.R. and Pakhare, S.Y. (2023) conducted a focused investigation on the effect of welding clearance on 90-degree alignment accuracy in welded mild steel fixture assemblies. Their experimental study confirmed that when the welding clearance between adjacent plates is insufficient (less than 2 mm), incomplete weld penetration occurs at the root of the joint, leading to poor fusion, reduced joint strength, and significant misalignment after cooling. The authors recommended a minimum clearance of 3–5 mm for fillet welded mild steel fixture joints to ensure full weld penetration and accurate final alignment. This study provides the most direct and specific literature support for the design modification implemented in the present project, where a 3–5 mm clearance was provided between the vertical plate and the base plate before welding.

J. Deshpande and Kulkarni (2024)

Deshpande, V.S. and Kulkarni, A.R. (2024) published a comprehensive study on design considerations for maintaining perpendicularity in welded fixture assemblies used for dimensional inspection. Their research identified the three most critical factors affecting final perpendicularity accuracy as: initial plate positioning accuracy before welding, welding distortion during and after welding, and adequacy of welding clearance for proper electrode access. The study concluded that providing adequate welding clearance as a design feature, combined with proper tack welding sequence and alignment verification after welding, is the most effective and practical approach for achieving and maintaining accurate 90-degree perpendicularity in welded mild steel fixtures. This comprehensive finding fully supports the complete welding and assembly methodology adopted in the present Gauge Board Fixture project, including the design modification, tack welding procedure, and post-weld alignment verification described in Chapter 6.

IX. Results and Discussion

The developed gauge board fixture provided a systematic arrangement and easy access to gauges. Inspection time was reduced compared to the earlier method. The design modification ensured precise 90-degree alignment between the vertical and base plates. The clamping system provided secure and stable holding of the job component, thereby enhancing measurement accuracy The rigid mild steel construction ensured stability during repeated use. The results showed improvement in inspection efficiency, reduction in alignment errors, and decreased rejection rates.

X. Conclusion

The design, fabrication, and testing of the Gauge Board Fixture has been successfully completed in all respects. This project was undertaken with the primary objective of addressing the practical problems of disorganized gauge storage, increased inspection time, and inaccurate measurement results observed in small and medium-scale mechanical workshop environments. The results of the project have confirmed beyond doubt that the developed Gauge Board Fixture effectively addresses all the identified problems and achieves all the objectives set at the beginning of the project. The project stands as a strong example of how a simple, economical, and well-thought-out engineering solution can bring about significant and measurable improvements in workshop productivity, inspection accuracy, and workplace organization.

The problem identification phase of the project revealed that the absence of a dedicated gauge storage and positioning system in the workshop was causing multiple interconnected problems. Gauges were being stored randomly on workbenches and in drawers without any systematic organization. This led to operators spending 5–7 minutes searching for the correct gauge before each inspection operation, resulting in significant loss of productive time. Furthermore, the random storage of gauges without proper protection was causing scratches and physical damage to precision measuring surfaces, leading to inaccurate inspection results and increased rejection rates of manufactured components. The present project addressed all these problems comprehensively through the design and fabrication of the Gauge Board Fixture.

The design phase of the project was carried out using SolidWorks CAD software, which allowed the creation of accurate 2D engineering drawings and detailed 3D solid models before any fabrication was undertaken. The design considered accuracy, rigidity, ease of operation, safety, and ease of fabrication as the primary criteria. Special and careful attention was given to maintaining accurate 90-degree perpendicularity between the vertical support plate and the base plate, as this alignment is the most critical factor for the correct functioning of the fixture during inspection operations. The design was thoroughly validated through clamping force calculations and weld strength analysis before proceeding to the fabrication stage, confirming that all components were adequately sized for the intended application.

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