

Design and Finite Element Analysis of a Front Floor Body in White (BIW) Welding Fixture

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ABSTRACT

The automotive industry requires high precision and dimensional accuracy in Body-in-White (BIW) assembly operations to ensure product quality, structural stability, and manufacturing efficiency. During welding operations, improper positioning and inadequate clamping may lead to dimensional variations, deformation, and welding defects. Therefore, the development of a rigid and reliable welding fixture is essential to maintain assembly accuracy and improve production consistency.

The present work focuses on the design and finite element analysis of a Front Floor Body-in-White (BIW) welding fixture used in automotive manufacturing applications. Initially, detailed study of the front floor assembly geometry, welding sequence, locating requirements, and manufacturing constraints was carried out. The fixture design was developed using the 3-2-1 locating principle to restrict all six degrees of freedom of the workpiece and ensure accurate positioning during welding operations. The complete fixture assembly, including base unit, clamp unit, riser unit, pin unit, and support structures, was modeled using CATIA V5 software. During the design process, important factors such as weld gun accessibility, manufacturability, structural rigidity, assembly tolerance, operator safety, and ease of maintenance were considered.

Keywords: Body-in-White (BIW), Welding Fixture, Finite Element Analysis, ANSYS, CATIA V5

Introduction

In modern automotive manufacturing industries, Body-in-White (BIW) welding fixtures are essential tools used for accurate positioning, clamping, and support of sheet metal assemblies during welding operations. The front floor assembly is one of the most critical structural components of a vehicle body because it supports seat mounting structures, reinforcement members, center tunnel regions, and load transfer paths. Improper positioning or insufficient rigidity of the welding fixture may lead to dimensional inaccuracies, welding distortion, residual stresses, and poor assembly quality.

To overcome these issues, welding fixtures are designed using accurate locating and clamping principles such as the 3-2-1 locating principle. Modern fixture systems integrate CAD-based modelling, robotic welding simulation, and finite element analysis techniques to improve productivity, repeatability, and manufacturing quality. Advanced software tools such as CATIA, ANSYS, and Process Simulate are widely used in the automotive industry for fixture design and structural validation.

1.2. World Wide Scenario

Globally, the automotive industry is moving toward automation and flexible manufacturing systems. Companies such as Toyota, BMW, Tesla, Volkswagen, and Ford use highly advanced robotic welding fixture systems integrated with CAD/CAM and simulation software.

Modern BIW fixtures are developed using:

- CATIA
- Process Simulate

- DELMIA
- Siemens NX
- ANSYS

The global trend focuses on:

- Lightweight fixture structures
- Modular fixture design
- Reconfigurable manufacturing systems
- Industry 4.0 integration
- Digital twin technology
- AI-based process optimization

Researchers worldwide are focusing on fixture optimization using topology optimization, finite element analysis, and sensor-based adaptive clamping systems.

1.3. Scenario in India

India is one of the fastest-growing automobile manufacturing hubs in the world. Automotive companies such as Tata Motors, Mahindra, Maruti Suzuki, Hyundai India, and Tata Auto Comp heavily depend on BIW fixture systems.

Indian industries are rapidly adopting:

- i. Robotic welding systems
- ii. Pneumatic clamping mechanisms
- iii. Modular fixture concepts
- iv. Digital manufacturing techniques
- v. CAD-based fixture development

The increasing demand for electric vehicles (EVs) is also driving innovation in lightweight and flexible fixture systems.

LITERATURE REVIEW

This chapter presents a review of existing research related to design and finite element analysis of a front floor body in white (BIW) welding fixture. It summarizes previous work carried out using analytical, experimental, and finite element approaches. Based on the literature, key research gaps are identified, and the objectives of the present study are defined.

Author	Methodology	Key Findings	Research Gap
Elangovan et al. [1]	Flexible welding cell	Improved productivity	Limited stress analysis
Yadav [2]	3-2-1 fixture design	Reduced fouling errors	No FEA validation
Yang [3]	Modal analysis	Improved stiffness	No fixture optimization
Wagner et al. [4]	FE adhesive modeling	Improved durability	Limited fixture study
Zamri et al. [5]	Flexible framing review	Modular fixture concept	No structural validation
Khanse et al. [6]	Stiffness testing	Better CAE correlation	No welding analysis

Kuigang Yu [7]	Flexible fixture design	Reduced setup time	No stress analysis
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2.3. Research Gap

From the literature review, it is observed that most researchers focused on flexible fixture systems, robotic welding simulation, weld accessibility analysis, and dimensional accuracy improvement in Body-in-White assemblies. Several studies investigated vibration characteristics, thermal deformation, and modular fixture concepts using CAD and CAE tools. However, limited research has been carried out specifically on the structural analysis and optimization of Front Floor BIW welding fixtures subjected to high clamping and welding loads.

Most of the previous studies concentrated on general BIW assemblies rather than front floor subassemblies, which are structurally critical regions in automotive body structures. In addition, very few researchers performed detailed finite element analysis considering stress distribution, deformation behavior, structural rigidity, and load transfer simultaneously in a single fixture system. Limited work has also been reported on the integration of CAD-based fixture design with ANSYS-based structural validation for front floor welding fixtures.

2.5. Problem Definition

In the modern automotive industry, the manufacturing of Body in White (BIW) structures requires high dimensional accuracy, repeatability, and production efficiency. The front floor assembly of a vehicle is one of the most critical structural components because it supports the cabin structure, seat mounting points, and load transfer paths. During welding operations, improper positioning or inadequate clamping of the front floor panel can lead to dimensional deviations, distortion, residual stresses, and assembly errors. These defects directly affect vehicle quality, safety.

2.6. Objective

1. To study the geometry, welding sequence, load paths, and locating requirements of the Front Floor BIW assembly.
2. To design and develop the Front Floor BIW welding fixture and create its 3D CAD assembly in CATIA V5.
3. To perform finite element analysis (FEA) of the welding fixture using ANSYS software to evaluate stress, deformation, and structural rigidity under working conditions.

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