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Design, Analysis and Simulation of Body in White (BIW) Fixture

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Abstract - *Fixtures are required to hold a part. Primary function of fixture is to hold and lock the part by restricting degrees of freedom. This paper deals with Design, Analysis & Simulation of BIW fixture. These fixtures are used to hold Body in White panels to weld them together with accuracy and productivity. This panels gets welded by robots. So, considering robotic arm moment, panel sizes & weight, cycle time required, a fixture is designed, Analysed, and simulated to achieve given cycle time and part deformation. The parts are sketched with the use of CATIA V5. Fixture Parts like Pins, Mylers, L block, Risers & Cylinders are designed in CATIA V5. Main panel is imported to ANSYS for structural analysis to check deformation of panel. Finally, after modelling and satisfactory result from analysis, robotic simulation is done to check welding gun cloud and total time required for welding. Gun cloud states no fouling with fixture and welding operations completed in given time.*

Key Words: Design, Fixture, Productivity, Cycle Time

1. INTRODUCTION

Vehicle body is made of different panels. This panels before painting in paint shop referred as BIW (Body in White) panels as they are white in colour. There are many manufacturing operations such as spot welding, MIG welding, piercing, bolting, punching etc. are done in weld shop before entering for painting. The main tasks of fixture are to hold and lock part to undergo any operations. To perform such operations on part, part need to be fixed properly for desired result. In any project, Fixture designing is frequent task for designers as well as manufacturing engineers. These tasks demand substantial work and time. Till few years ago, there was a certain flow in part and fixture design. First was part design then fixture design and lastly manufacturing process. This implies while designing a fixture, part is primary, and process is secondary. But now a days these considerations are changing due to diversified products and advance manufacturing processes. Desired outcome of manufacturing process can be achieved by accurate process planning while designing a part. This saves not only cost but also money.

1.1 Problem Statement

To design a Body in White welding fixture for welding panels (Panel A, Panel B, Panel C and Panel D) on a workstation with the help of suitable number of rest units and other components supporting the same. And all this operation should be done within a particular cycle time.

1.2 Objective

Designing a Body in white fixture for welding having minimum possible rest units and components and zero fouling errors. Analysis is to be done to check whether the panel is going into deformation due to its self-weight or not followed by simulation to check fouling errors within the welding guns and arms or any other component in the complete area. Also, for calculating the cycle time, simulation of welding will be done.

1.3 Methodology

- Problem Definition
  Design of BIW fixture with rest units & clamping cylinders ensuring error free robotic arm trajectory.

- Literature survey
  To refer the Research papers based on similar design topics to clarify the basic concepts and methodology.

- Mechanism
  To study the basic working mechanisms using research papers which will lay the guideway for the successful design

- CAD, CAE and Simulation
  To design complete fixture in CAD. With the help of ANSYS, check for deformation. Finally using simulation software, ensure error free trajectory of robotic arm.

1.4 Input Parameters

- Panel Data
  Panel data includes the cad model and 2D data with dimensions of the panel. It also includes the clamping position and the locator pin position of the panel.

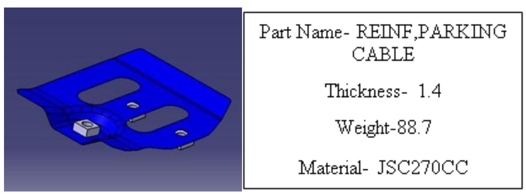


Fig 1. Panel-A

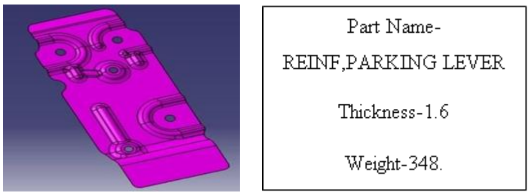


Fig 2. Panel-B

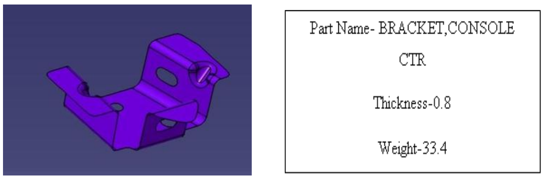


Fig 3. Panel-C

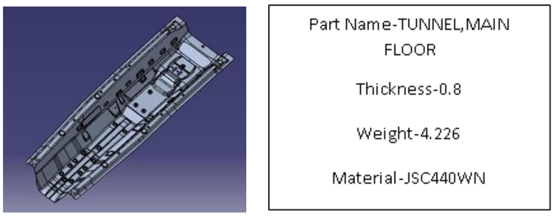


Fig 4. Panel-D

- Welding information
  Types of Welding (Spot, Arc)
  1) For Spot Welding – position and quantity
  2) For Arc Welding – length and position

- Standard library
  Standard Library is a library from where we can directly get the standard parts and it is given by the client. Following are some standard parts.
  1) Locating pins
  2) Mylar
  3) Cylinders
  4) Dolly plate
  5) Riser plate
  6) Sensors
  7) Bushing

- Process document
  Process Document is a document which is created by the process team, and it defines various processes which are to be considered while making the fixture.

Includes-

- JDS - Job Description Sheet

CUSTOMER TOOL NO.-		
FIXTURE NO.-		
FIXTURE DESCRIPTION-		
APPLIED CAR MODE-		
	STATION DESCRIPTION	
1. FIXTURE CONTENT	2. OPERATION DETAILS	3. EQUIPMENT CONTENTS
Clamping sequence	Total weld spots	Weld gun name #1/Qty.
Loading method	Control spots	Weld gun name #2/Qty.
Unloading method	Total stud welds	Weld gun name #3/Qty.
Spot welding	No. of nuts	Weld gun name #4/Qty.
MIG welding	No. of bolts	Weld gun name #5/Qty.
Sealing (mastic/adhesive)	MIG weld length	Weld gun name #6/Qty.
HEMG clinching	Sealing length	MIG weld M/C & Qty.
Punching		Stud weld M/C & Qty.
Checking		Sealer gun Qty.
Base plate		Sealer pump Qty.
Previous fixture		Hoist and hanger
Next fixture (station)		Impact wretch
Rotate equipment		
4. TIME DETAILS	5. STANDARD PARAMETERS	
1. Production volume (JPH)		
Tack time for 1 Job (sec)		
Cycle time for fixture (sec)		
No. of operations (persons)		

Fig 5. Sample JDS Sheet

- BST - Build Sequence

  BST involves panel loading sequence, in which panel loading is decided i.e., which panel should be loaded first, then accordingly all other panels. We have total 4 panels to be loaded and the panels are as follows:

  So, in our case build sequence is as follows-

  Panel C- Panel B- Panel D- Panel A Or
  Panel B- Panel C- Panel D- Panel A

  Because in our case panel C or panel B should be loaded first as they are at the bottom of main panel i.e., panel D. So, there are two ways of panel loading among panel C and panel B. Either first load panel C or panel B. Then after loading them, main panel D should be loaded. After loading these three panels load last panel i.e., panel A as it should be welded on upper part of main panel.

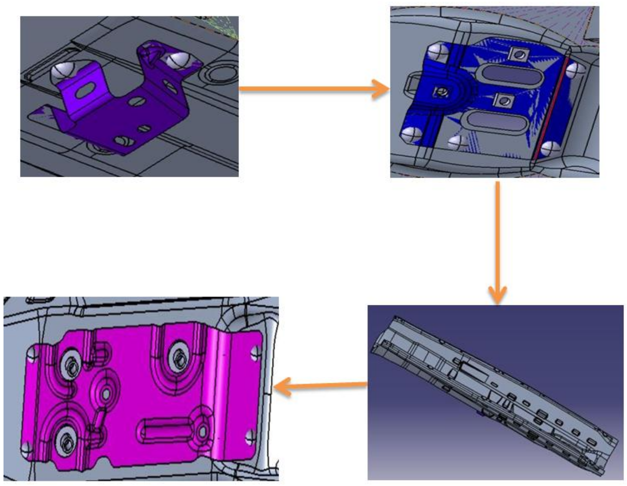


Fig 6. Build Sequence

- PLP - Principle Locating Points

We use 3 2 1 principle to make the degree of freedom of Panel zero. We decide the positions of rest and support. Principle locating points are those points by using which degrees of freedom of panel can be restricted. The most important principle behind any fixture design is 3-2-1. Principle. That is to restrict all 6 degrees of freedom. So, all six degrees of freedom of every panel should be restricted. For that we must choose primary datum and secondary datum. With the help locating pins in primary datum, two degrees of freedoms can be restricted. And by using second pin in secondary datum two degrees of freedom can be restricted. Remaining two degrees of freedom can be restricted by using rest unit. Principle locating points gives position of primary datum and secondary datum. Therefore in our case PLP 's of all 4 panels are decided in such a way that it should restrict all DOF's.

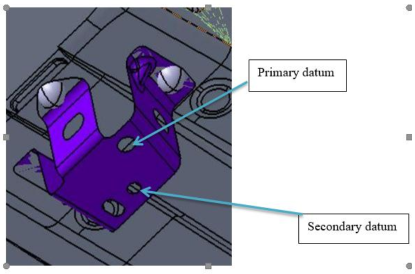


Fig 7. Panel C with Datums

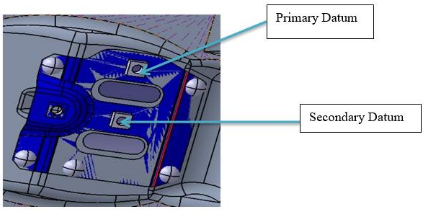


Fig 8. Panel A with Datums

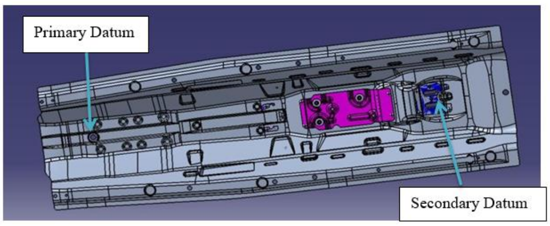


Fig 9. Panel D with Datums

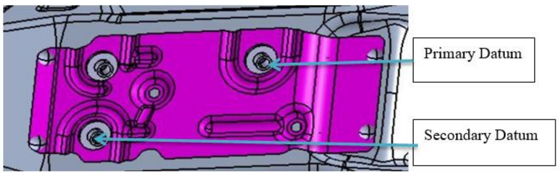


Fig 10. Panel A with Datums

2. STANDARD PART SELECTION

Standard Parts-

Parts that have stood the test of time and have been repetitively used in Designs are made Standard Parts. Like Standard parts, we can have Standard Sub-assemblies, Standard Units and Standard Practices.

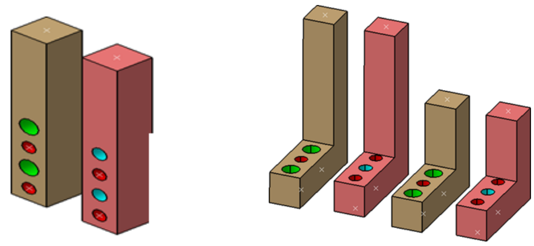
Objective -

- To encourage good Design Practices.
- To cut down Design & Detailing time.
- To cut down manufacturing time.
- To avoid diversity and ensure uniformity & aesthetic look.

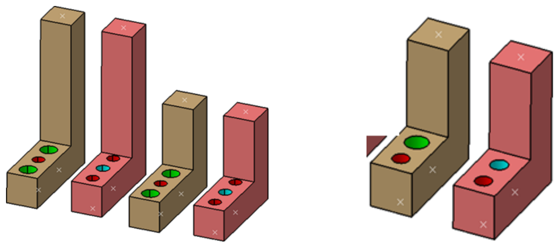
Different components required for BIW fixture.

2.1 Types of Mylar

1) I-Shaped Mylars (4 Holes) 2) L-Shaped Mylars (4 Holes)



3)I-Shaped Mylars (3 Holes) 4) L-Shaped Mylars (3 Holes)



2.2 Types of Standard Pins

1) Round Pins: These can be Screw secured (PNRS) or Grub Screw secured (PNRG) or Thread secured (PNRT) for Prototype build only.

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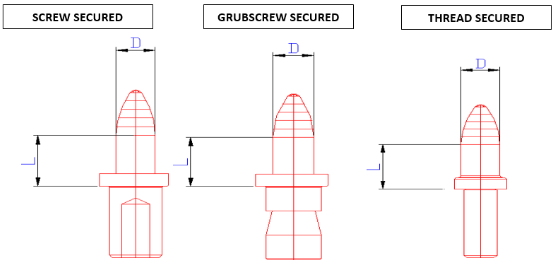
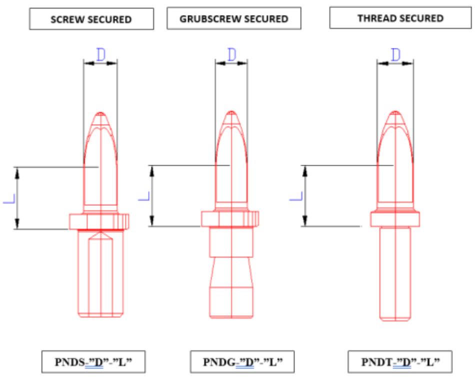


2) Diamond Pins: These can be Screw secured (PNDS) or Grub Screw secured (PNDG) or Thread secured (PNRT) for Prototype build only.



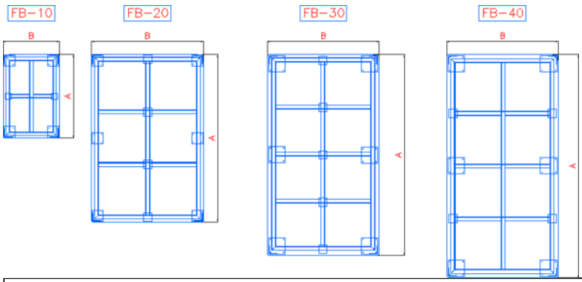
Where ―D‖ stands for hole Dia & ―L‖ for Pin length as shown

2.3 Types of Standard Bases

There are 2 types of Standard Bases we use – Fixed Bases & Rotary Bases

1) Fixed Bases: These bases are of 4 types – FB-10 / FB-20 / FB-30 / FB-40. The first 3 types have provision for Base Legs fitted onto Jacking Pads grouted in the floor for Ergonomic needs. The Last type is directly fitted onto Jacking Pads grouted in the floor.

2) Rotary Bases:



Guidelines for usage of Fixed Bases:	
FB-10: A < 1500	FB-20: 1500 < A < 3000
FB-30: 3000 < A < 3600	FB-40: 3600 < A < 4000

2.4 Types of Standard Risers

The Height of the Dowel on vertical face from the Base changes from 100 mm to 400 mm.

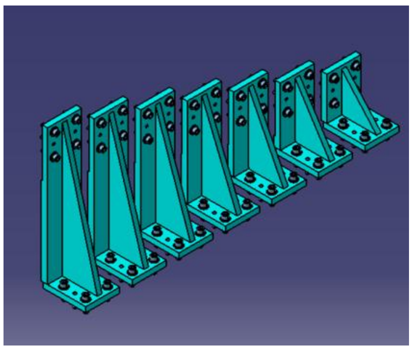


Fig 11. Risers

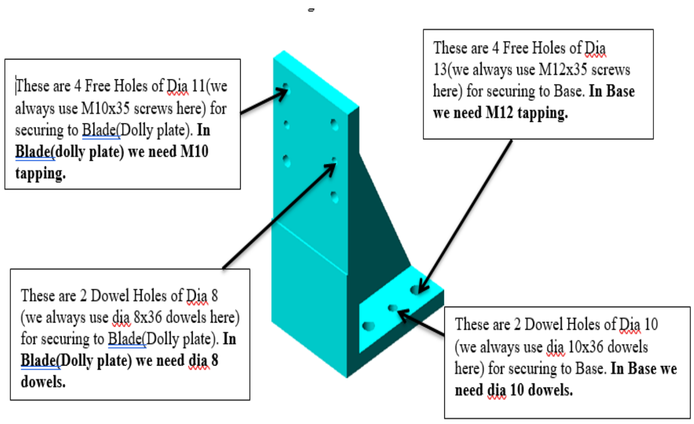


Fig 12. Risers Information

3. CONCEPTS REQUIRED

3.1 Poka Yoke

Poka-Yoke is fool proofing, which is the basis of the Zero Quality Control (ZQC) approach. It is a technique for avoiding and eliminating mistakes. Generally, this technique is used in manufacturing process but has much wider uses, such as; offices - order and invoice processing, hospitals - drug dispensing, aircraft maintenance - particularly with processes having the potential of inducing catastrophic in-service failures. Idea is how can we make errors, defects and mistakes either so 'visible' that we can detect them at source or even better eliminate them altogether? The answer is by applying Poka Yoke techniques. The term Poka Yoke is derived from the Japanese words _Poka meaning inadvertent mistake and _yokeru ‘meaning to avoid.

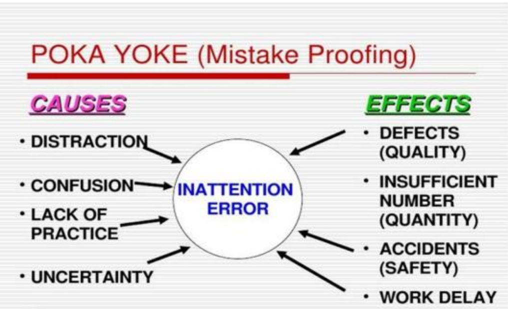


Fig 13. POKA YOKE

3.2 3-2-1 Principle

It is principle of clamping widely used. Every Part has 6 DOF (3linear + 3rotary) which need to be arrested to ensure proper location of the part inspect

3- 3 rests with a clamp to restrict 1 up down +2 rotary motions

2 – round locating pin in a round hole to restrict a motion in 2 directions.

1- round locating pin in a slot, that restricts the rotary motion in established plane.

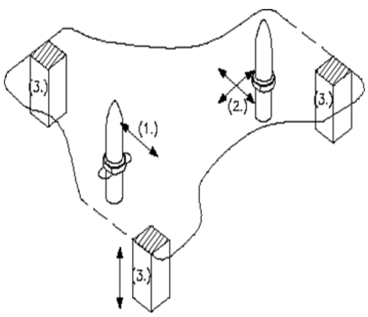


Fig 14. 3-2-1 Principle

4. SELECTION OF CYLINDER

Table -1: Comparison – Hydraulic Vs Pneumatic

Hydraulic Cylinder	Pneumatic Cylinder
1. Working Fluid is Oil	1.Working Fluid is air
2. It can operate at high pressures	2.It can operate at low pressures
3. Operation is Slow	3.Operation is quick
4. System is unsafe for fire hazard	4.System is free from fire hazard

Hence, we selected Pneumatic cylinder after surveying among the various range of hydraulic and pneumatic cylinders. And the following cylinder has been chosen for the purpose of clamping:

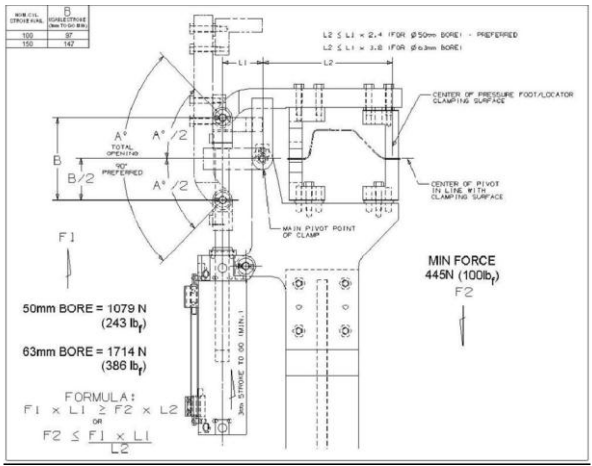


Fig 15. Clamping Force

F1 = Actuating Force of Cylinder L1 = Distance from cylinder clevis to clamp arm pivot F2 = Clamping Force 445N (100lb f) L2 = Distance from clamp arm pivot to center of pressure foot/locator Formula:

F1L1 ≥F2L2 OR L2 ≤F1L1/F2
Cylinder Calculations:
Tunnel 3:
L1:47.5mm L2: 107mm (From CAD)
F1× L1 = F2 × L2
For 50mm bore, F1 = P × A
(5.5 bar) × (3.14) × (25mm)2
= (3.14) × (25mm)2 × (550,000 Pa)
= (3.14) × (25mm)2 × (550,000 Pa) × (1m/1000mm2)
= 3.14 × (343.75N)
= 1079 N
Therefore, 1079 × 47.5 = F2 × 107
F2 = 445 N ≤ 478.99 N
For 63mm F1 = P × A

= 1714 N
1714 × 47.5 = F2 × 107
F2 = 445 N ≤ 760.88 N

Here, we can select any one of cylinder as both are passing minimum requirement of 445N.

5. DESIGN MODELLING

5.1 Basic Steps

- Call all panels.
- Fix with pin and rest units
- Design pin retainer
- Decide principle locating points
- Starting from mylar followed by arms, weldmates, dolly plate and riser, design the entire rest unit.
- 3D Finishing.
- Check for Fouling.

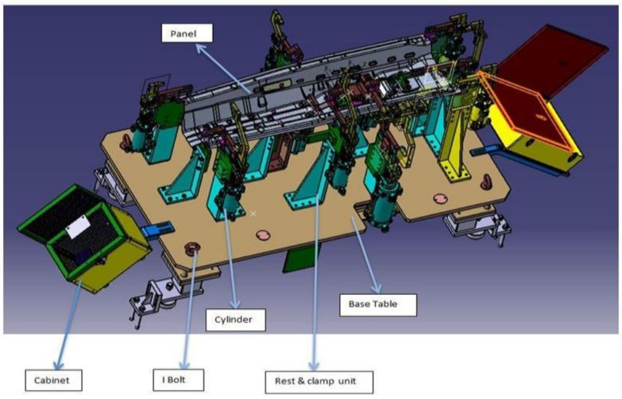


Fig 16. Complete Assembly

5.2 Specifications

- Weight of Panel- 4.226 Kg
- Dimensions of Total Assembly- 3104.128 x 1079.08 x
- 1450.402 mm
- Number of Rest & Clamp Units-13
- Number & Type of Cylinders used-8
- Number of I bolts-4

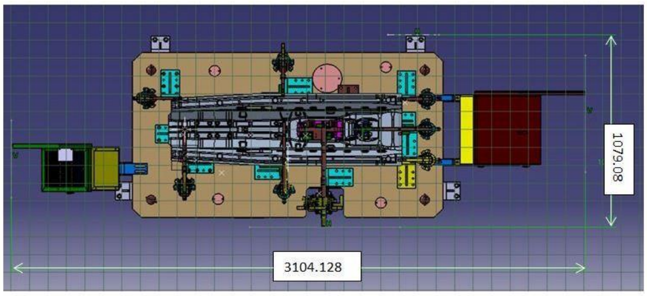


Fig 17. Top View

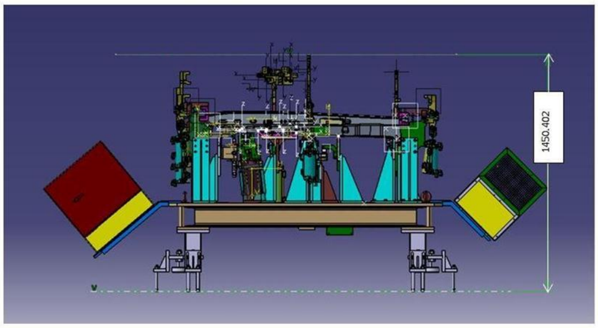


Fig 18. Sideview

6. ANALYSIS BY USING ANSYS

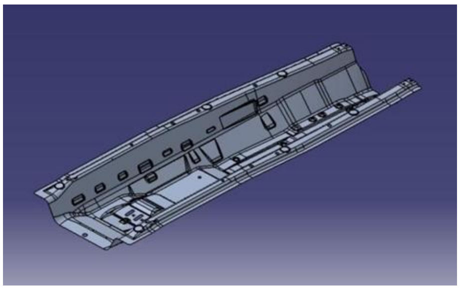


Fig 19. OP10 CAD Panel for CAE

Initially, analysis on OP10 Panel was performed with 6 fixed supports at the edges of the panels, which represents Principle Locating Points (PLP), against panel's self- weight, in which force due to earth's gravity was considered i.e., 9.81m/s2.

Table: CAE Details

Sr. No.	Parameter	Value
1	Mesh Size	3mm
2	Mesh Quality	0.85
3	Force	Due to Earth 's Gravity
4	Constraints	6 fixed supports at the edges
5	Total Deformation	0.21325mm
6	Equivalent Stress	32.579MPa

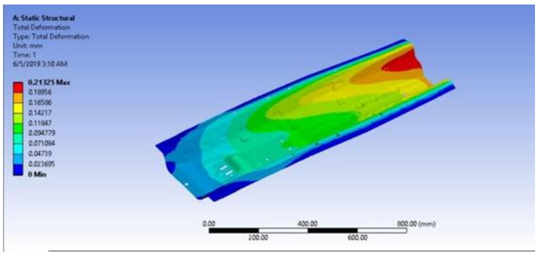


Fig 20. CAE of Main Panel

After obtaining the upper mentioned results, 7 more rest units were step by step added in the center of the panel as well as the locations where panel is supposed to be welded. Hence, with the same force, mesh quality and mesh size, just constraints were changed and following results were obtained.

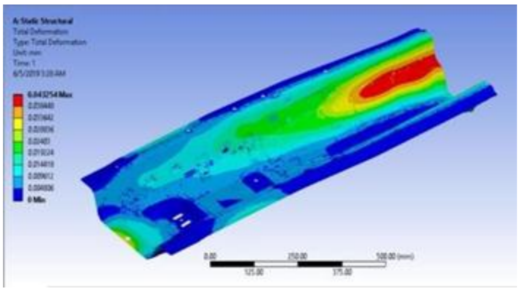


Fig 21. CAE of Main Panel

Table: CAE Details

Sr. No.	Parameter	Value
1	Mesh Size	3mm
2	Mesh Quality	0.85
3	Force	Due to Earth 's Gravity
4	Constraints	13 fixed supports
5	Total Deformation	0.0432mm
6	Equivalent Stress	18.248MPa

Here, we have managed to reduce equivalent stress and total deformation of panel due to force.

7. ROBOTIC SIMULATION

Computer simulation plays an important role in analyzing engineering problems. In the past 2 decades, finite element analysis (FEA) has become an increasingly useful tool for the prediction of the stress Here simulation is used to study the validating the strength of the fixture. Robotic simulation tools like ROBCAD, IGRIP have replaced traditional techniques and have become inevitable in process simulation because of their rapid, accurate calculations which saves huge amount of time and money. Reference introduced virtual design in the body welding line, discusses the feature and key technique of designation in the Virtual Manufacturing & Assembling environment, points out the virtual design is the direction of body welding line in China. The weld cell and fixtures developed were to be validated for its compatibility to handle multiple part varieties in virtual environment using such simulation tools. Based on the detailed literature review, the purpose of this study is laid-out as follow:

(a) To develop flexible solutions for improving productivity at work cell level for small or medium level BIW assembly environments with low production volume but high part varieties. (b) To provide flexible, cost effective, modular solutions for fixtures to make them compatible for handling multiple part varieties. (c) To simulate the working of work cell and fixtures in virtual environment and check for its compatibility to handle multiple part varieties.

- Output –

1) Process Video – From this, we got time taken to weld assembly.
2) Gun Cloud – From this, we got gun position to check fouling.

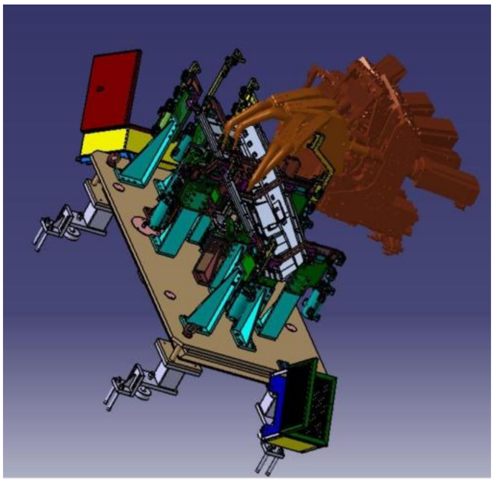


Fig 22. Gun Cloud

8. Result

- From ANSYS – We managed to restrict part deformation to 0.0432mm against given specification of 0.1mm

- Cycle Time – Given Vs Actual

Table: Given Time

SR. NO.	PRODUCTION REQUIREMENT VARIABLES	MIN
1	Yearly Volume Requirements (Net)	129500
2	Additional Volume by Percentage	20%
3	Additional volume units	25900
4	Yearly Volume Requirements (Total)	155400
5	Number of working Days per year	280
6	Number of Shifts per Day	2
7	Number of minutes per year	257600
8	Efficiency	85%
9	Available number of Minutes per year	218960
10	Available number of Seconds per year	13137600
11	Number of Components per day	555
12	Cycle Time (Sec)	85

Table: Welding Time from Simulation

Operation	Qty	Time (Sec)
Move to/from fixture	1	
Weld Spot simple GEO spot weld with robot	12	
Move to/from fixture	1	44

Table: Part loading time

Operations	Remark	Quantity	Instant Time(Sec)
Manual loading small part	Operators loads panel	1	1
	Check for sensor signal	1	2
Walking (1m, one operator)	Walks to bin	1	2
Walking (1m, one operator)	Walks to fixture	1	3
Manual loading small part	Operators loads panel	1	4
	Check for sensor signal	1	6
Walking (1m, one operator)	Walks to start / stop box	1	6
Push button	Operators push button	1	7
			9

Table: Result Table

Parameter	Time given	Time achieved
Panel loading time	--	9
Welding time	--	44
Total Time	85	53

9. Conclusion –

Machining on Body in White (BIW) is mainly of sheet metal type, which are critical and crucial to handle for the machining processes like welding, blanking, bending, etc. The project was based on welding a body in white panel, which were four in numbers, and to design the components to fix the panel for these machining processes.

According to the methodology, first a basic rest unit were added to the base plate on the edges of the panel. Followed by analysis, where panel was observed undergoing into deformation due to self-weight. And so, more rest units at the center were added, and the analysis was performed again. By checking the gun cloud, which was shared by the company, several changes in the dimensions of components like arms, mylars and rest units were done to ensure zero fouling during the welding process. And so, successful simulation was done, and the project concluded having optimum cycle time from 85 seconds to 53seconds.

10. References–

[1] Design method and information representation for computer aided welding fixture design Yi Zhang School of software engineering Chongqing University Chongqing, China cquzhangyi@cqu.edu.cn Jun Zeng School of software engineering Chongqing University Chongqing, China zengjun@cqu.edu.cn Junhao Wen School of software engineering Chongqing University Chongqing, China jhwen@cqu.edu.cn Qingyu Xiong School of software engineering Chongqing University Chongqing, China 1040944072@qq.com

[2] Development of a Fixture for Robotic Assembly Station for an Automotive BIW (Body in White) Line Vijay Patel, Nilesh Ghetiya, Jatin Dave,and Sandip Shah

[3] Application of CAD Techniques in Design of Automobile Body Welding Line Guiying Tong School of Mechatronics and Automobile Engineering Yantai University Yantai, China Xiaomei Shao Yantai Engineering & Technolage College Yantai, China

[4] Design for Automation: The Rapid Fixture Approach R. Förstmanna,*; J.Wagner a;

K. Kreisköther a; A. Kampker a; D. Busch a aRWTH Aachen University, Templergraben 55, 52062 Aachen, Germany

[5] Design of flexible spot welding cell for Body-In-White (BIW) assembly Sadasivam Narayanan1, M. Elangovan2, Prabha Shankar3 M. Thenarasu2 1 Whirlpool of India Limited, Pune, Maharashtra, India 2Department of Mechanical Engineering, Amrita School of Engineering, Coimbatore, Amrita Vishwa Vidyapeetham, India 33D Concept Analysis & Development (India) Pvt Ltd, Bangalore, India

[6] Design and Analysis of Welding Fixture for Automotive Component using FEA C.
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[7] Design of Machine Elements, V.B.Bhandari

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