ISSN (Online) 2581-9429
IJARSCT
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
Impact Factor: 6.252
Volume 2, Issue 3, May 2022

Design and Analysis of Distortion in Welding Fixture for Frame Assembly

Yuvraj R. Vadaje[1], Dr. H. A. Chavan[2], Dr. S. R. Suryawanshi[3]
Department of Mechanical Engineering[1,2,3]
MET's Institute of Engineering, Nashik, Maharashtra, India
Savitribai Phule Pune University, Pune, Maharashtra, India

Abstract: *This paper focuses on the Design and Analysis of Welding Fixture for Anti-vibration under carriage Bogie Frame Assembly for Compact Track Loader. The application of a Bogie assembly is to offering smoother transitions over uneven terrain, and the ability to travel at higher speeds with better materials retention. Due to the nature of welding process involving localized heat generation from moving heat source, rapid heating in the welded structures, and subsequent rapid cooling, problems such as residual stresses and distortions of welded structures remain important challenges in the industry. To assemble the respective child parts and to meet the required tolerances on the bogie frame assembly welding fixture specially designed with the help of CAD Software. In practice, welding distortion creates unwanted effects on manufacturing accuracy, appearance and strength of welded parts. By using Finite Element Analysis (FEA), the analysis is carried out to find welding distortion of Bogie Frame assembly. Along with optimum clamping force has been calculated which required for controlling the welding distortion. After successful Design and Analysis, the Welding fixture has been manufactured and has been implemented at shop floor. This welding fixture used for accurate assembly of the child parts with required tolerances , as well as helps in reduction of production loss and also manufacturing lead time for welding, positioning and holding parts.*

Keywords: Welding Fixture, Finite Element Analysis (FEA), ANSYS Software, Catia, Welding, Distortion, Clamp

I. Introduction

Welding is the process of joining metal parts using heat. Some welding processes use pressure as well. Melting point, thermal conductivity, electric resistance, and surface condition of the metal to be joined are all important considerations when designing a welded joint [1]. A large number of controlled parameters go into producing a defect-free weld joint. Otherwise, flaws in welded joints are unavoidable. Another critical aspect to consider when obtaining a weld joint is the correct welding technique. Excess fusion, lap, undercut, improper fusions, and other defects are the result of poor welding techniques. Other defects, such as distortion or warpage, are also observed in a welded joint as a result of poor welding techniques [2].

Mass production is dependent on interchangeability, which allows for easy assembly and lower unit costs. Mass production methods necessitate a quick and simple method of positioning work in order to perform accurate operations on it [3]. If a component is to be produced in small quantities, the procedures used are marking out, setting on the machine, clamping on the machine table, and then carrying out the operation. However, for economic reasons, it would not be suitable for producing the same component in large quantities. In the fabrication industry, specially designed tools known as welding fixtures are used to overcome problems in welded parts caused by improper work holding [4].

On which the components can be quickly positioned in the correct relationship to the geometry and quickly clamped before operation. Correct relationship and the alignment between the all child parts must be maintained. Welding Fixtures are designed to hold, support, and locate every part to ensure that part geometry within the specified limits and then welding (i.e. Spot welding/ Arc welding/ MIG welding) is performed using welding gun [5].

In the past there was limited research and applications in the welding sector. But, due to importance of welding for sheet metal in automobile and aerospace industries, the importance of welding has received special attention from designers, manufacturers and researchers [6]. A weld fixture is often developed to reduce the deformation of each work piece due to heat and residual stress in the welding process to reduce the dimensional variation of the assembly. Thus deformation analysis must be done to enhance the ability of the fixture on deformation controlling [7].One of the most common automated processes in an assembly line is welding. Automated welding is used by many companies around the world because the process is easily automated and more efficient than a professional welder. The main benefits of an automated welding process are, improved weld quality, increased productivity, decreased waste production, decreased costs associated with labour. An automated welding operation, on the other hand, may not be appropriate for every application. When deciding whether a robotic operation is appropriate for their application, a company must consider a number of factors[8]. In the manufacturing industry, a fixture is a work-holding or support device. Fixtures are used to securely locate (position in a specific location or orientation) and support the work, ensuring that all parts produced using the fixture are conformant and interchangeable. In order to accommodate welding operations, locating and supporting areas must typically be large and very sturdy; strong clamps are also required.

Welding fixtures for high-volume automated processes typically use hydraulic or pneumatic clamps [9]. In this project, we will be modelling a welding fixture by using CAD software. While the modelling of the components the material selection will be carried out simultaneously based on the design considerations related to loads, environmental conditions, availability and cost, etc [10].

II. Problem statement

In this project we have to design and make analysis of arc welding fixture for "Bogie assembly anti-vibration frame". With considering Cycle time, Material, Environmental conditions, Cost etc.

2.1 Objective

1. To design welding fixture as per requirement.
2. To analyze and investigate stresses and deformation using structural analysis for various fixture parts.
3. To analyze welding fixture with respect to all environmental conditions.
4. To validate the design of welding fixtures.

2.2 Scope

While designing the welding fixture we have to perform following operations.

- To decide no. Of stages for welding
- To calculate cycle time required for welding
- To decide locating scheme for child parts as per 3-2-1 principle
- Select material for all fixture parts
- Select suitable clamps required to hold the part
- Select standard parts like bush, pins bolts etc. as per availability
- To prepare 3D CAD model and 2D drawings for fixture.
- To perform FEA using software like Ansys
- To check accessibility while Loading and unloading of parts on fixture.
- To decide no. Of persons required to carry out fixture operations like loading and unloading.
- To prepare standard operating procedure chart

The initial step is start with the material information of the part, welding specification, geometric dimensions and tolerances required to achieve on the part, and different child parts and their cad drawing. Then we have to collect all the 3D and 2D data required for designing the fixture as per the requirement. Next we have to prepare design of the fixture with help of CAD software which we are going to use CATIA V5R20, after completion of 3D cad model we have to analysis the fixture for accessibility and To validate fixture part design for various load condition using FEA software like Ansys. When it is satisfied then we have to start manufacturing of fixture. After manufacturing and assembly inspection is carried out to check functional accuracy of fixture. If needed correction in design made and implemented in manufacturing accordingly.

III. Design

Fixture has to be designed for batch production of respective assembly within accepted tolerance with good quality and repeatability and interchange ability at a competitive cost. The design conditions include the following; degree of freedom,

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
Impact Factor: 6.252
Volume 2, Issue 3, May 2022

reconfigurability, maintenanceability, durability and manufacturability [11]. The special characteristics particularly suited to the robotic welding application such as the critical speed of maintain accuracy and part repeatability in an environment exposed to elevated heat and weld spatter. There are few aspects to keep in mind while designing a fixture.

3.1 Factors to be considered while Fixture Design

Following are the factors to be considered while fixture design:

- **Flexibility:** It has to flexible to different multiple welds without the need for multiple setups. The design need to be suitable for different joint types and joining processes. Design will have enough degree of freedom to complete all weld operation.
- **Productivity:** It should be able to process, load, unload and clamp as quickly as possible. It has to be designed to be effective than previous model. The clamping has to be suitable to control distortion.
- **Cost Efficiency:** One of the main aspects of design is to keep the cost as low as possible while ensuring necessary operation requirement is fulfilled. Material cost, operational and maintenance cost need to be considered in designing phase. The higher production rate, scrap reduction and less setup time will ensure to keep unit price at minimal.
- **Material Properties:** Generally, the robotic welding are more productive than manual or semiautomatic welding. The level of efficiency depends upon the thoughtful design of the fixture for optimal productivity. The welding can be inefficient and cost prohibitive when simple design considerations are overlooked. The selection of fixture material depends upon the welding applications and processes. The square or rectangular structural steel tubing is used for the frame work to reduce the initial cost. Mild steel, high-carbon steel, aluminum, stainless steel and copper are used generally for designing of fixture [12]. Each material has different characteristics that can impact productivity and quality. Considering wear and tear of fixture components like resting pads, locating pins, bush etc. has to be manufacture with harden material like En24,En8 and OHNS.
- **Thermal conductivity:** Thermal conductivity refers to a material's ability to conduct heat. Copper and aluminium are frequently used as heat sinks to conduct heat away from the work piece and spread the heat over a large surface area, reducing work piece distortion. In a welding operation, a fractional change in length and volume at elevated temperatures has a significant impact on work piece dimensional accuracy [13].

- **Electrical Conductivity:** The main driving force in the welding operation is the electric circuit. It has the potential to negatively impact productivity, weld quality, and equipment service life. To allow free flow of current to the circuit, electrical conductivity is dependent on material conductivity or resistance. Because they provide a good balance of cost and conductivity, copper, aluminum, and other metals are used in welding equipment. The copper facilitates the flow of electric current. Although, there is the little amount of resistance inherent in the properties of the material, but it is not enough to interfere with the welding operation [14]. Excessive resistance in the circuit can result in weld defects, decreased productivity, and premature equipment failure.

3.2 Input Data

We have to develop a welding fixture for the given part. Part details are as follows:
Part name: Anti-vibration under carriage Bogie Frame Assembly, for Compact Track Loader
Part No.: AT-494492
Part position on assembly: As shown in figure 1

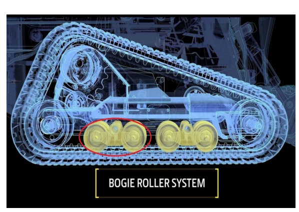

Figure 1: Part position on assembly 3D model

IJARSCT

ISSN (Online) 2581-9429

International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)

Impact Factor: 6.252

Volume 2, Issue 3, May 2022

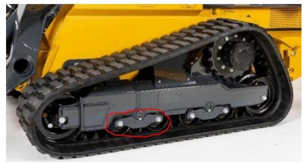

Figure 2: Part position on assembly actual image

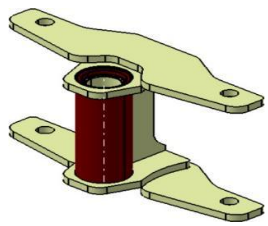

Figure 3: Part 3D CAD model

3.3 No. of stages defined for Welding

Round bush with flange at both end and central support will come as sub assembly. We have to weld horizontal plates at both end using new welding fixture.

We have defined 2 stages for welding fixture. Welding operation will be carried out in 2 stages. Figure 4 shows these 2 stages of welding. At stage 1 plate at one end will get weld, and second plate will be weld in next station.

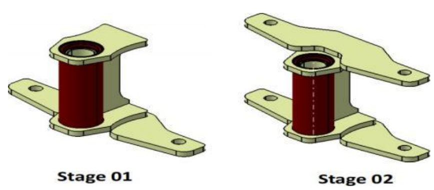

Figure 4: Two stages of welding

3.4 Define Part Location on Fixture

3-2-1 Principle of Location used in Jig & Fixtures, It is also referred to as the six pin or six point location principle. In this case, the three adjacent locating surfaces of the blank (work piece) are resting against three, two, and one pins, preventing six degrees of freedom. Three external forces, usually provided directly by clamping, arrest all degrees of freedom.[15]

According to the 3-2-1 principle, the six locators are sufficient to limit the required degree of freedom of any work piece. In this, clamps and locators are used to restrict the motion.

3.5 Design of Fixture (3D Model)

The final design is a product of the several different ideas and components originally created in the design phase. A better understanding of the best features to incorporate in the final design has been developed after the brainstorming and design formation phases were completed.

Figure 5 shows conceptual model of welding fixture. The focus of the design was to make it flexible, durable as well as adaptive to the different kind of welding operations. The fixture has to be easily manufacturable and capable of producing the precise joint. The design consists of Base plate, Clamp and central locating pin [16]. The horizontal plates will be welded to the hollow cylindrical bush.

IJARSCT
ISSN (Online) 2581-9429
IJARSCT
Impact Factor: 6.252
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
Volume 2, Issue 3, May 2022

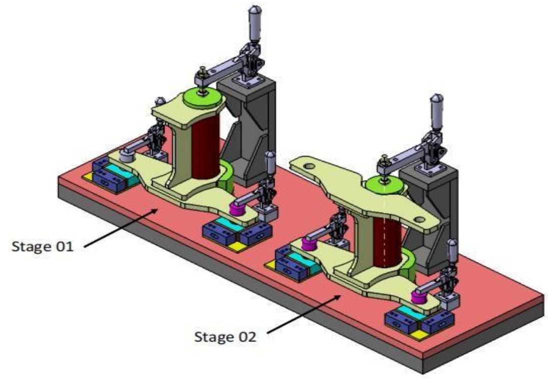

Figure 5: CAD model of welding fixture

At stage 1 the downside horizontal plate will get weld to the middle sub assembly. And then at stage 2 this stage 1 assembly will plate reverse vertically and second horizontal plate will get weld at stage 2.

Before starting welding clamps with force 500 & 700 Kgf are applied to confirm the location of all child parts. At each stage we have to apply 3 clamps which are two HTC clamp of model no. HV-BII- 300 and one HTC clamp of model no. HV-BII-200.

After applying clamps a robotic welding arm comes into action and welding operation gets performed [17].The importance of these fixture is the cost effectiveness and quality effect they have on the completed (welded) item. This is especially true for smaller, close tolerance assemblies. Although the fixture has been designed for Metal inert gas welding robot, it can be used in manual welding also.

3.6 Preparation of General Assembly Drawing

After completion of 3d modeling general assembly drawing with overall dimension of fixture is prepared for customer approval. This is used to check the available space and environment for installation of in plant.

While defining overall dimensions we have to define position of fixture on standard welding table. Standard welding table is a table on which fixture will be mounted and the robotic welding operation will be carried out. This table is a part of robotic cell. A single robotic cell can consist of 3 or 4 working station. Our new designed welding fixture will be part of the robotic cell.

3.7 Preparation of Bill of Material

After completion of design bill of material is generated. Bill of material also refereed as BOM. BOM shows the list of parts, material and quantity of each part.

A bill of materials (BOM) is an extensive list of raw materials, components, and instructions required to construct, manufacture, or repair a product or service.A bill of materials is typically presented in a hierarchical format, with the finished product at the top and individual components and materials at the bottom.

A bill of materials (BOM) is a centralized source of information used in the production of a product. It is a list of the items required to make a product, as well as instructions on how to put that product together. Manufacturers begin the assembly process by referring to a bill of materials (BOM). It is critical to create an accurate bill of materials (BOM) because it ensures that parts are available when needed and that the assembly process is as efficient as possible.

IV. Analysis of Welding Fixture

In the present paper, finite element procedure was employed to simulate the thermo-mechanical response of welding distortion problem. In the procedure, two sequenced thermal and mechanical analyses were carried out to obtain the total or desired response of the Stage 01 and Stage 02 welding structure modeled [18].

In the first stage, a transient thermal analysis was performed to determine the temperature distribution over the structural model. In the following step, a structural analysis was performed to determine the welding distortion of the structural model, with the temperature history obtained in the first step serving as a thermal load in the analysis [18]. In practice, welding distortion has a negative impact on manufacturing accuracy, the appearance, and the strength of welded parts. The analysis is carried out using Finite Element Analysis (FEA) to determine welding distortion of the Bogie Frame assembly. In addition, the optimum clamping force required for controlling welding distortion has been calculated. Welding distortion should be less than 1mm according to the assembly drawing.

In Static Structural analysis,Imported Body Temperature from the transient thermal analysis applied and we calculate the Welding distortion.[19].

We calculate the welding distortion for three types of clamps, named as Toggle clamps of model no. HV-BII- 100 BS, HV-BII-200 BS, HV-BII-300 BS as per their clamping force. We consider the three clamping forces of values 658 N, 1634 N and 2295 N in Static Structural analysis.

Table 1: Welding Distortion Values

Sr. No.	Clamp	Stage _01 Welding Distortion (mm)
1	HV-BII- 100 BS	1.0526
2	HV-BII-200 BS	0.9876
3	HV-BII-300 BS	0.6516

Distortion of the welding structure as per application of the Clamping force obtained in the Ansys software as shown in the figure 6.

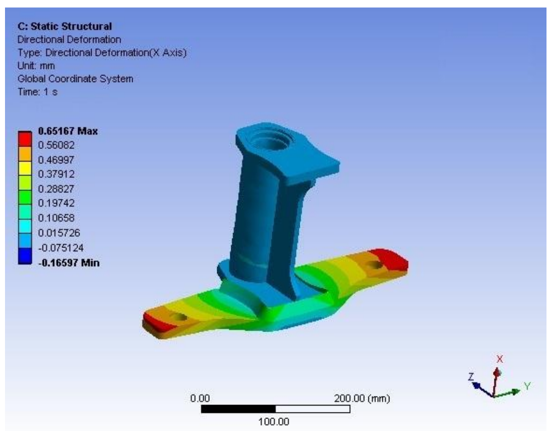

Figure 6: Stage_01 Welding distortion with the application of HV-BII- 300 BS

Distortion of the welding structure as per application of Toggle clamp HV-BII- 200 BS obtained in the Ansys software as shown in the figure 7.

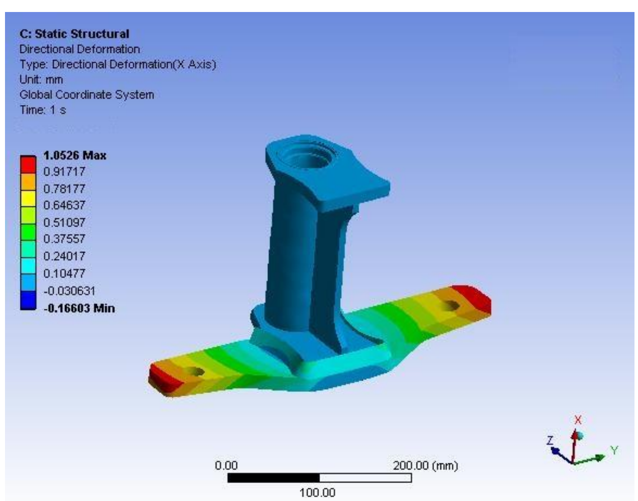

Figure 7: Stage_01 Welding distortion with the application of HV-BII- 100 BS

Distortion of the welding structure as per application of Toggle clamp HV-BII- 200 BS obtained in the Ansys software as shown in the figure 8.

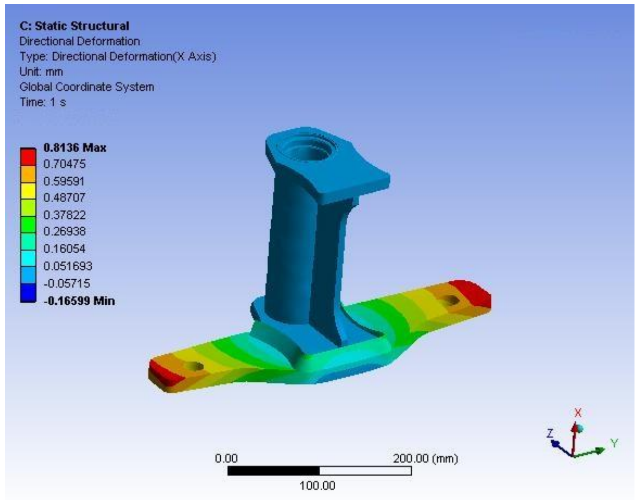

Figure 8: Stage_01 Welding distortion with the application of HV-BII- 200 BS

From above Welding distortion values shown in the figures with the application of 3 Types of Toggle clamps, Welding distortion value with HV-BII- 300 BS is lesser as compared to other two toggle clamps, so we select that clamp for our welding fixture in Stage_01 and controlled the welding distortion and kept within the tolerance as per drawing.

Stage_02 Welding distortion of the welding structure as per application of the Toggle clamp HV-BII- 300 obtained in the Ansys software as shown in the figure 9.

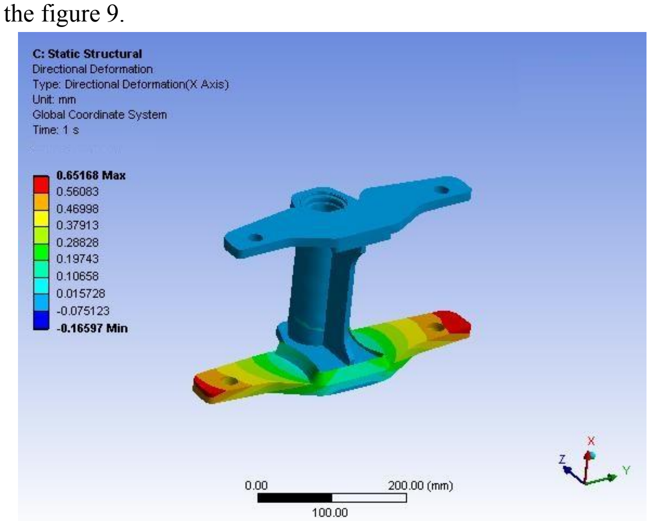

Figure 9: Stage_02 Welding distortion with the application of HV-BII- 300 BS

Stage_02 Welding distortion of the welding structure as per application of the Toggle clamp HV-BII- 100 obtained in the Ansys software as shown in the figure 10.

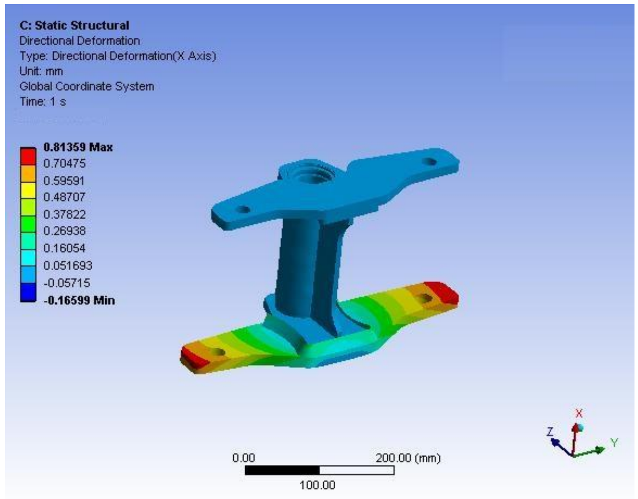

Figure 10: Stage_02 Welding distortion with the application of HV-BII- 100 BS

Stage_02 Welding distortion of the welding structure as per application of the Toggle clamp HV-BII- 200 obtained in the Ansys software as shown in the figure 11.

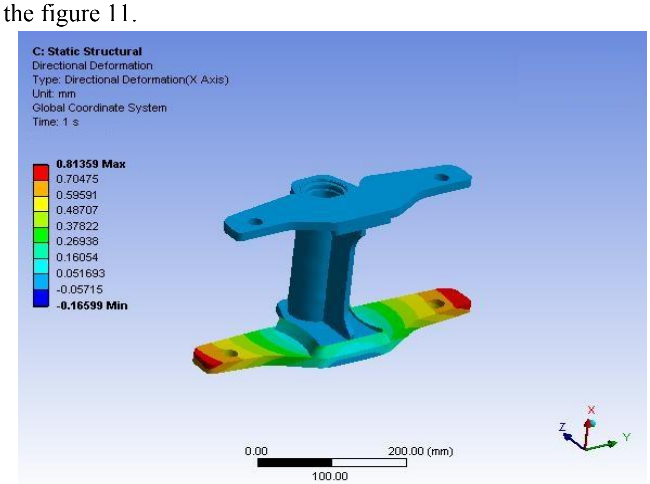

Figure 11: Stage_02 Welding distortion with the application of HV-BII- 200 BS

TABLE II

STAGE_02 WELDING DISTORTION VALUES

Sr. No.	Clamp	Stage _02 Welding Distortion (mm)
1	HV-BII-100 BS	1.0527
2	HV-BII-200 BS	0.8136
3	HV-BII-300 BS	0.6517

From above Stage_02 Welding distortion values shown in the above table with the application of 3 Types of Toggle clamps, Welding distortion value with HV-BII- 300 BS is lesser as compared to other two toggle clamps, so we select that clamp for our welding fixture in Stage_02.

V. MANUFACTURING OF WELDING FIXTURE

After Analysis of welding fixture, design validation process completed and Design is approved. For manufacturing we prepared detailed 2d drawings. (Manufacturing drawings)

Those Manufacturing drawings sent to tool room for manufacturing process. Sub assemblies including many components were manufactured with individual tolerances and assembly tolerances. [20]. Actual photo of the fixture shown in figure 12.

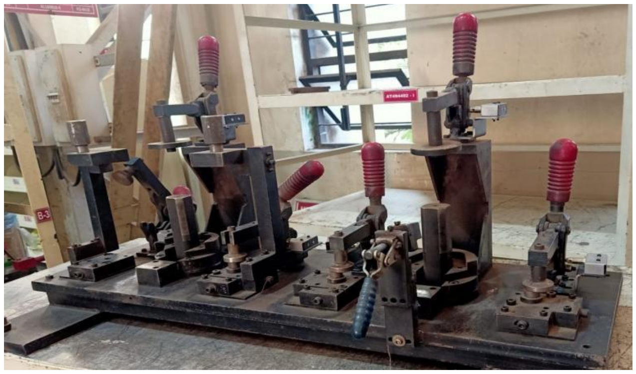

Figure 12: Actual photo of the fixture

With the use of welding fixture assembly of the child parts with required tolerances is done. Actual photo of the assembly of Bogie Frame Assembly is figure 13.

Figure 13: Actual photo of the Bogie Frame Assembly

VI. Conclusion

The effect of clamping on welding distortion of the Bogie Frame assembly is investigated in this paper. Finite Element Analysis (FEA) Analysis predicted an unfavourable welding distortion, and a corrective measure was implemented to control the distortion.Optimum clamping force has been calculated which required for controlling the welding distortion.

Welding distortion analysis can be used to predict behaviour and distorted shape by evaluating the effects of the fixtures. Such forecasting is useful information for the manufacturer in identifying potential distortion issues and making decisions about manufacturing strategy and fixture structure during the design phase.

After successful Design and Analysis, the Welding fixture has been manufactured and has been implemented at the shop floor. This welding fixture used for accurate assembly of the child parts with required tolerances , as well as helps in reduction of production loss and also manufacturing lead time for welding, positioning and holding parts.

Acknowledgment

Every work is source which requires support from many people and areas. It gives us proud privilege to complete the Project on “Design and Analysis of Welding Fixture for Anti-vibration under carriage Bogie Frame Assembly for Compact Track Loader” under valuable guidance and encouragement from MET’s Institute of Engineering,(Nashik) and UV Knowledge Link Pvt. Ltd.,Nashik

We also wish to express our deep sense of gratitude to Dr. V.P. Wani, Principal, MET’s Institute of Engineering. We are also extremely grateful to our respected Dr. M. P. Ray, H.O.D. (Mechanical Engineering Department) and Mr. Rajendra J. Pawar for providing all facilities and every help for smooth progress of work.

References

[1]. Chirag Singh and Navneet Kumar "Analysis of Strength Parameter of Welded Joint Using Ansys Workbench”, Journal of Advances and Scholarly Researches in Allied Education [JASRAE] (Vol:16/ Issue: 1) DOI: 10.29070/JASRAE. (Jan, 2019).

[2]. Soni, Shakti Singh and Nakul Aggarwal. "Optimization of Distortion in Welding.", International Journal of Enhanced Research in Science, Technology & Engineering ISSN: 2319-7463, Vol. 4 Issue 7, July-2015.

[3]. Prajapati, Rakesh, "Experimental Investigation of MIG Welding for ST-37 Using Design of Experiment", 10.13140/2.1.3744.1602,(2014).

[4]. Kang, Xiumei and Qingjin Peng. "Fixture Feasibility: Methods and Techniques for Fixture Planning." Computer-aided Design and Applications 5 (2008): 424-433.

[5]. Jönsson P G, Westhoff R C and Szekely J 1993, "Arc characteristics in gas-metal arc welding of aluminium using argon as the shielding gas" J. Appl. Phys. 74 5997.

[6]. Y.J. Gene Liao, S. Jack Hu "Flexible multi body dynamics based fixture-work piece analysis model for fixturing stability" International Journal of Machine Tools Manufacture" 40, 2000.

[7]. Park, Jeongung and Gyubaek An. "Effect of welding sequence to minimize fillet welding distortion in a ship's small component fabrication using joint rigidity method." Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture 230 (2016): 643 - 653.

[8]. Mahakalkar, Prashant and S. S. Uttarwar. "Design And Analysis Of Welding Fixture For Combination Of Welding Processes- A Review " , IJARIIE-ISSN(O)-2395-4396,Vol-6 Issue-3 2020.

[9]. Hui Wang, Yiming (Kevin) Rong, Hua Li, Price Shaun, "Computer aided fixture design: Recent research and trends", Volume 42, Issue 12, Pages 1085–1094,December 2010.

[10]. Yogesh kumar, K. and K. Ramesh Babu. "An advanced method of jigs and fixtures planning by using CAD methods." (2013).

[11]. W.T. Seloane, K. Mpofu, B.I. Ramatsetse, D. Modungwa, "Conceptual design of intelligent reconfigurable welding fixture for rail car manufacturing industry", Procedia CIRP,Volume 91,2020, Pages 583-593,ISSN 2212-8271.

[12]. Wikander, L Karlsson, L,Nasstrom, M,Webster, "Finite element simulation and measurement of welding residual stresses",Modelling and Simulation in Materials Science and Engineering,1994/07/01,IOP Publishing,SP - 845-864,IS - 4,VL - 2,SN - 0965-0393.

[13]. I.A. Daniyan, K. Mpofu, A.O. Adeodu, O.L. Rominiyi," Investigation of Distortion, Stress and Temperature Distribution during Assembly of the Suspension System of a Rail Car", Procedia Manufacturing,Volume 38,2019,Pages 1792-1800,ISSN 2351-9789.

[14]. Taskaya, Semih et al. "Joining of Ramor 500 Steel with SAW (Submerged Arc Welding) and its Evaluation of Thermomechanical Analysis in ANSYS Package Software." Thermal Science and Engineering Progress (2019).

[15]. Ambadas, Berad Somnath et al. "Design Of Brake Pedal Assembly Welding Fixture." International Journal of Advance Research and Innovative Ideas in Education 4 (2018): 1223-1231.

[16]. Kubade, Chintamani et al. "Design and Analysis of Welding Fixture for Automotive Component using FEA." International Journal of Advance Research and Innovative Ideas in Education 2 (2016): 539-546.

[17]. Ordieres, Javier et al. "Determination of the influence of clamping on welding distortion applied to PS2 mock-up using finite element simulations." Fusion Engineering and Design 166 (2021): 112327.

[18]. N. Syahroni, and M. I. P. Hidayat, "3D Finite Element Simulation of T-Joint Fillet Weld: Effect of Various Welding Sequences on the Residual Stresses and Distortions", in Numerical Simulation - From Theory to Industry. London, United Kingdom: IntechOpen, 2012 [Online]. Available: https://www.intechopen.com/chapters/39240 doi: 10.5772/50015.

[19]. Kassab, Rabih Kamal, Champliaud, Henri, Lê, Van Ngan, Lanteigne, Jacques et Thomas, Marc.2012. "Experimental and finite element analysis of a t-joint welding ". Journal of Mechanics Engineering and Automation, vol. 2, nº 7. p. 411-421.

[20]. M. Yuvaraj, H. Karthick,V. Gopalakrishanan and Stanly Wilson Louis, "Design, Fabrication And Analysis Of Welding Fixture Having Higher Accuracy Without sing Robots", Int. J. Chem. Sci.: 14(2), 2016, 1-8, ISSN 0972-768X.