Design and Analysis of Welding Fixture for Tacking and Welding of Inner Boom of Loadall Handler

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Abstract
This paper deals with the design and analysis of welding fixture, which can be used for tacking and welding of Loadall inner boom and jib head. The boom is one of the parts of Loadall handlers. The Loadall Boom consists of outer boom and inner boom. The inner boom slides inside the outer boom for the variations in the length of the boom as per the applications. The fixture for Loadall inner boom has some problems. One of them is that, no permanent arrangement provided in fixture for side plates to jib-head alignment. The big clamp unit is required for clamping of side-plates with jib-head. Computer-aided fixture design (CAFD) systems have been developed through the years to assist the designer during the various stages of fixture design. Case based reasoning (CBR) is a method of using previous cases to help aid the development of solutions to new problems. This study has aimed to demonstrate a systematic approach for sheet metal assembly fixturing. The problem has been constrained as fixturing for assembly of sheet metal components of Loadall Inner Boom.
This paper also introduces the Finite Element Analysis of Loadall Inner Boom using ANSYS 14 software. The geometry of Loadall Inner Boom is prepared in CATIA software as per the design considerations. After generating 3D model in CATIA software, convert model in IGES and STEP format and analysesd it using ANSYS 14 software.

Keywords
Case Based Reasoning, Computer Aided Fixture Design, Finite Element Analysis, Fixture, Loadall Inner Boom

I. Introduction

Significant progress has been made in the past years in fixture design. Research has been conducted with regards to each aspect of the design phases, and has also lead to the use of computer aided design (CAD) packages in order to increase efficiency. Currently there has been an increase in the production of fixture design specific programs. Within these programs, generally known as computer aided fixture design (CAFD) packages, efforts have been made to help reduce the amount of initial knowledge required for effective use. The efforts include introducing artificial intelligence, by the use of expert systems, algorithms and case based reasoning. Each method has its benefits and limitations.
Fixtures are tools that are used to hold a workpiece in place while it undergoes a machining or assembly process. Fixtures are used to ensure high quality and low variability in parts. Fixtures can be used in low or high volume fabrication operations. Originally the vast majority of fixtures was dedicated fixtures since they were only created for one workpiece. These fixtures have many benefits due to the high rigidity and the high tolerances that could be achieved but they are also very costly. With the advent of flexible manufacturing systems, setups that are able to change depending on the type of product required to be created, and fixtures that are able to adapt to the changes are the most desirable.

In 1977, JCB pioneered the Loadall handler concept. The Loadall story is one of a versatile concept made even more flexible by JCB's commitment to providing innovative machines that enable to work more efficiently and profitably. The boom is one of the parts of Loadall handlers. The Loadall Boom consists of outer boom and inner boom. The inner boom slides inside the outer boom for the variations in the length of the boom. The Loadall Boom is manufactured from high tensile steel.

II. Problem Definition

This work is carried out to provide an economical and scientific solution to some problems that occurred with existing fixture. The problems related to the Loadall Inner Boom and its Jib Head are mentioned below,

1. No permanent arrangement provided in fixture for side plates to Jib Head alignment.
2. Big clamp unit is required for clamping of Side-plates with Jib-head. (Refer fig. 1)
3. Jib Head dimension variation.
4. Top pressing plate does not fit well with side plates. Top pressing plate requires an additional Toggle Clamp.
5. Top and bottom cross tube of Jib Head does not fit well into the holes of side plate.
6. Additional clamps are required to hold the side-plates and top-pressing plate in proper position. (As shown in fig. 2 and fig. 3)

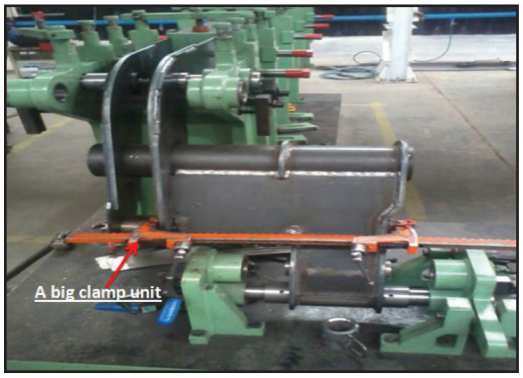

Fig. 1: Big Clamp Unit

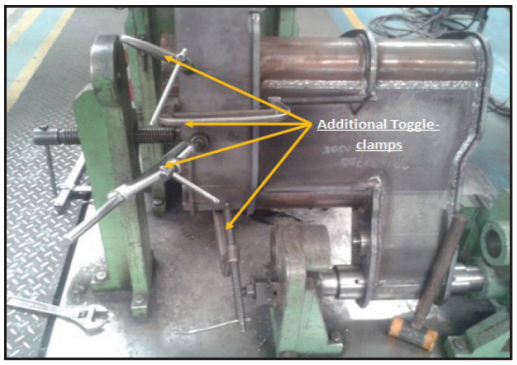

Fig. 2: Additional Clamping for Side-plates and Top-pressing Plate of Model 524/ 527

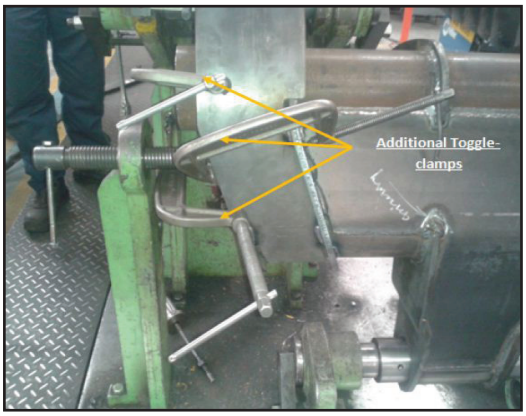

Fig. 3: Additional Clamping for Side-plates and Top-pressing plate of Model 520

III. Design of Fixture For Loadall Inner Boom

The case based reasoning system proposed in this paper will focus on the specific aspects of indexing, representation and searching the database for case information and will not focus very much on the final step of CBR, automated adaptation. The concept behind this system is that in order for case based reasoning to reach its full potential the system requires an all encompassing system to adequately define the cases within the database. The proposed system will mimic the design steps of an experienced designer while integrating information garnered from the CAD package to create a complete assembly case. A model of the methodology can be found in fig. 4.

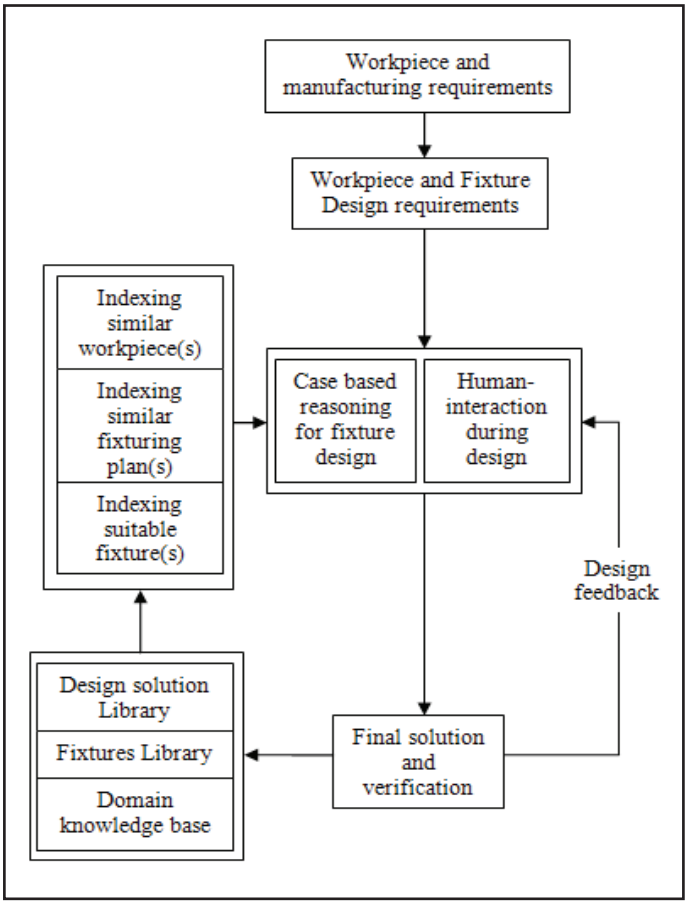

Fig. 4: A General Idea of the Methodology

The model is best read from the top down. This structure shows how the user will interact with the user interface in order to retrieve the most relevant solutions. The first step is for the user to enter the workpiece and manufacturing requirements. This information is entered in boxes that are easily to understand and simple to use. The next step is to enter the workpiece and fixture design requirements. This step is used to aid in the searching process. The CBR system uses this information to retrieve the best solution while incorporating the user feedback during the process. Once this step is complete a final solution is reached and the quality of the solution is then verified.

A. Workpiece

The first subsection of the design case is workpiece. This subsection details all of the information about the workpiece. The first item is the name of the workpiece or the family name of the workpiece. This is to identify the workpiece and help group it into a similar family of parts for easy retrieval. This subsection is further decomposed into workpiece specific information such as the type. The different types that are usually welded are pipe, sheet metal, bulk (large parts), mixed (such as automobile which contains multiple types of parts to be welded). The last subsection under workpiece is the geometric information. This contains the size (dimensions), overall weight, and the shape of the part. This subsection pertains to just the overall assembly, not its component parts.

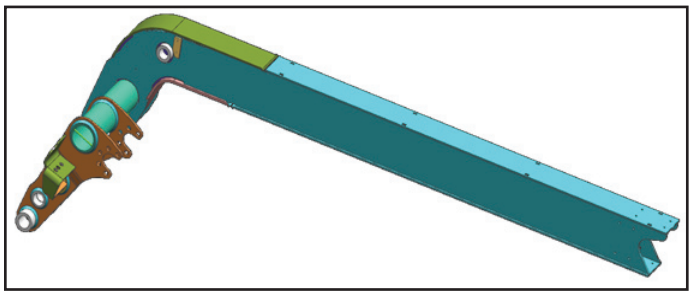

Fig. 5: Workpiece (Loadall Inner Boom)

B. Case Based Reasoning

Case based reasoning (CBR) describes a method that uses previous cases to explain and create solutions to new problems. CBR can be considered reasoning by analogy. Using similar past circumstances to understand and adapt to new issues. There are two major branches of CBR, interpretive and problem solving. A lawyer uses interpretive CBR in daily practice to alleviate or affirm convictions. A lawyer uses previous cases as examples of previous decisions in a court room and tries to connect the current case with the previous ones to prove that the same verdict should be made. Problem solving CBR is using a previous method to help determine solutions to new problems. This is done by drawing similarities between the two cases and analyzing specific actions that lead to a beneficial outcome.

Case based reasoning (CBR) is a method of using previous cases to help aid the development of solutions to new problems. The application of CAFD and CBR system provided an environment that allowed the creation of fixtures for welding assemblies and the retrieval of past cases. The combination of both of these elements allowed the development of a fixture that based on the historical data stored in cases, provided the support and versatility needed for identifying solutions to new cases. CBR allows a user to learn from previous mistakes by keeping them stored and easily available. Users will also be more accepting of solutions proposed by CBR systems because the proof is completely visible in the previous case.

C. Design of Fixture for Components of Loadall Inner Boom

1. General

In this study, a typical Loadall Inner Boom structure is considered to form a basis for the design and analysis studies in fixturing of its components.

The boom is one of the parts of Loadall handlers. The Loadall Boom consists of outer boom. The inner boom slides inside the outer boom for the variations in the length of boom. The Loadall Boom is manufactured from high tensile steel.

Both inner and outer booms are produced through two operations namely,

(i). Tacking operation

(ii). Full Welding operation

In tacking process, the parts of inner boom are fixed in the fixture and then tacked by producing tacks between the parts which are to be weld. The inner boom requires two fixtures for tacking process. Initially, the jib head of inner boom tacked on one fixture and then the jib head tacked with other parts of inner boom on another fixture. The length of each tack is 15-20 mm and thickness is 3mm. In welding process, the welding of tacked jobs are carried out. The inner boom requires one fixture for welding process. The Metal Inert Gas (MIG) technology is used to weld all the parts of Loadall Inner Boom.

There are three different models of Loadall Inner Boom which are classifieds on the basis of the length of side plate, namely,

- Model 520
- Model 524
- Model 527

2. Existing Fixture

The existing fixture is shown in fig. 6. The existing fixture is well suitable for clamping following components of Loadall inner Boom,

- Front sub-assembly
- Patch plate
- RH patch plate
- Bottom plate
- Bottom pressing
- Back plate
- Pressing
- Boss 829/00504
- Boss 829/30848

3. Fixture Design for Side Plates and Top-plates

When the drawings of Loadall Inner Boom are examined, it is necessary to hold the side-plates and top pressing plate in proper position. As per the constraints and requirements, the base-leg with top clamping and side-clamping arrangement are designed as shown in fig. 7.

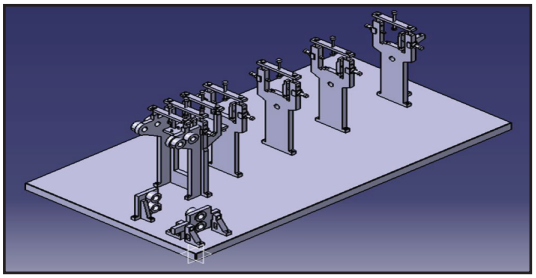

Fig. 6: Existing Fixture for Loadall Inner Boom

(i). Clamp for Side-Plates

This clamp helps to maintain a proper gap between side-plates. It applies force on LH side plate which results in hold out the LH side-plate in proper position. A spacer is used to keep the desired distance between RH and LH side-plates. This clamp also applies the forces on RH side-plate through the spacer. Thus, the RH and LH side-plates are kept in desired position with the help of this clamp. There are two such clamps are used, one for model-524 and other for model-524 & model-527. These clamps are designed as per the designs of side-plates, fixture constrains and fixture requirements. The force on LH side-plate is increased by tightening the nut clockwise.

(ii). Clamp for Top-pressing Plate

This clamping arrangement helps to hold the top-pressing plate in proper location. It defines the solution of problem occurred due to the gap between side plates and top pressing plate. There are two clamping devices, one clamp is used to apply the force on top-pressing plate of model-520 while another clamp is used to apply the force on top-pressing plate of model-524 and model-527. These clamps are designed as per the fixture constraints, fixture requirement and drawings of Loadall inner boom. This mechanism includes a pin and a nut. The pin helps to keep the support-bar in proper position and the nut is used to increase the force on top-pressing plate by tightening it.

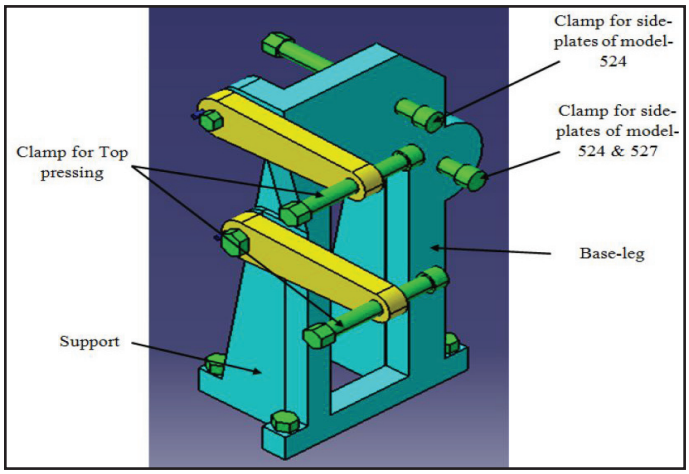

Fig. 7: Fixture for Side-Plates and Top-Pressing Plate

(iii). Base-leg

The function of this base-leg is to provide support to the side-clamps and top-clamps. It also helps to locate top-clamp and side-clamp in proper position. The base-leg gives support to these different clamps.

(iv). Support

It is designed to provide support to the base-leg of fixture. Fig. 8 shows the assembly of new fixture.

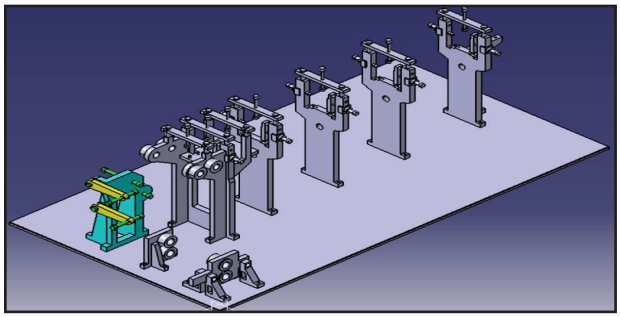

Fig. 8: Assembly of Fixture

IV. Analysis using ansys 14 software

Static analysis used to know the normal stress, maximum principal stress, directional deformation distribution, etc. when applying the static forces. It gives idea only at particular time instant and it won't give the idea at different time instant like transient analysis. The geometry of Loadall Inner Boom is prepared in CATIA software as per design consideration as shown in fig. 9. After generating 3D model in CATIA software, convert model in IGES and STEP format. Material of Loadall Inner Boom is EN10025.

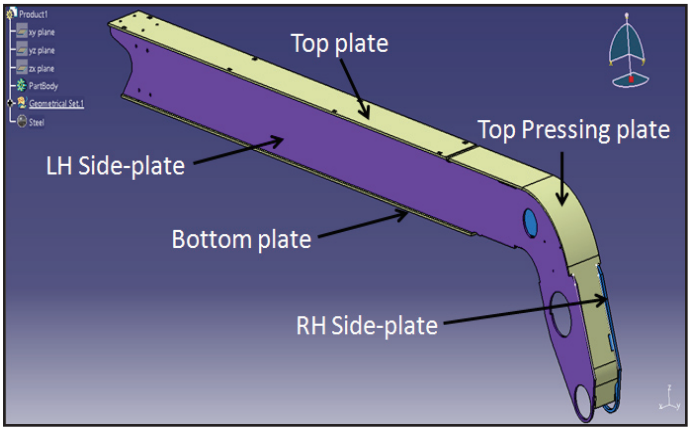

Fig. 9: 3D Model of Loadall Inner Boom

After importing STEP file into ANSYS workbench and selecting static analysis, generate mesh by automatic mesh option. It will select appropriate mesh element and element size as default, as shown in fig. 10. But if necessary changes also could be done in both elements size and mesh element selection. After meshing, the static forces are applied as shown if fig. 11.

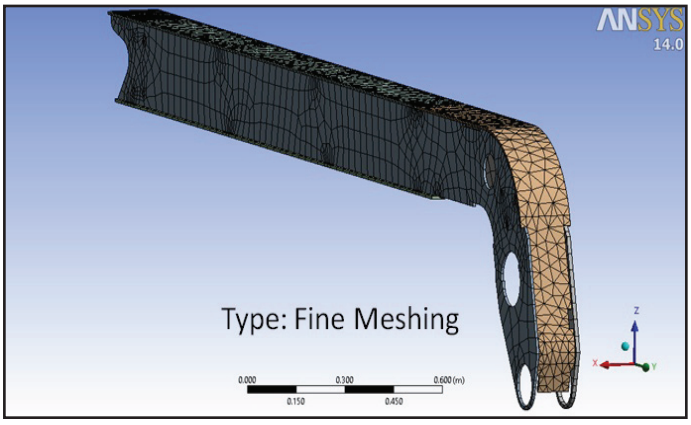

Fig. 10: Meshing of 3D Model

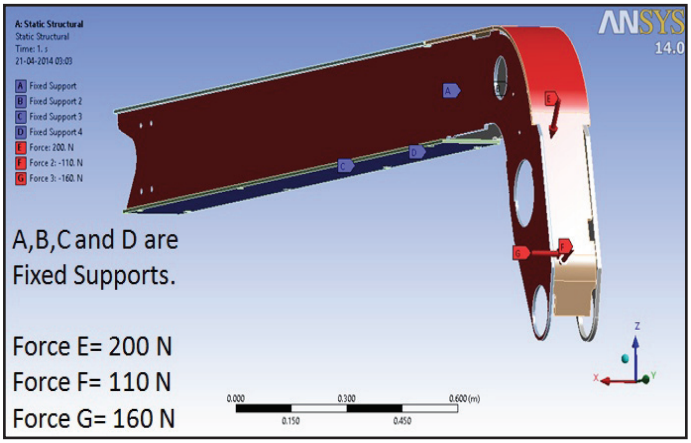

Fig. 11: Static Forces Applied to Loadall Inner Boom

The assumptions and restrictions for the analysis models are given below:

The materials are assumed to be isotropic and the deformations are in linear elastic range.

The dimension and geometric form of the parts are assumed to be in their hypothetically perfect state unless a deviation is specified.

The clamping forces and boundary displacements are assumed to be applied perfectly as ramp functions along the step in which they are initially activated. The effect of the clamping force application sequence within a single step is ignored.

The joining process is assumed to be performed perfectly, causing no deviation or stress concentrations during the assembling and other possible variations due to joining process are neglected.

A. Result

In this static analysis, normal stress and maximum principal stress and directional deformation tests are carried out.

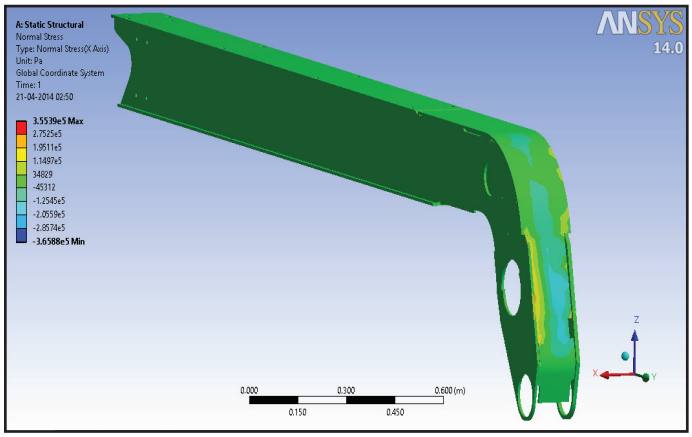

Fig. 12: Normal Stress Distribution

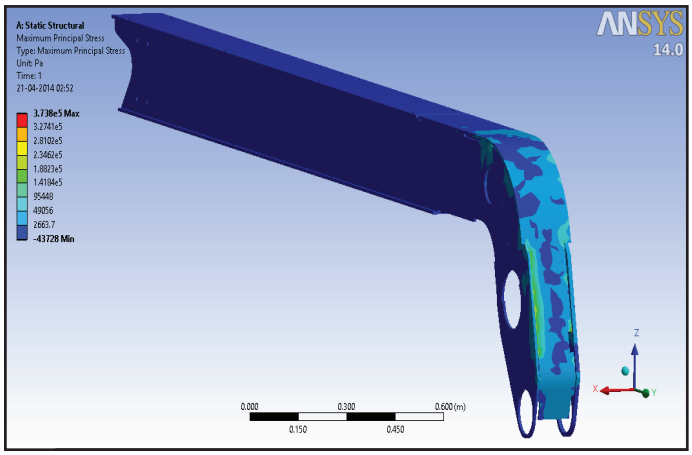

Fig. 13: Maximum Principal Stress Distribution

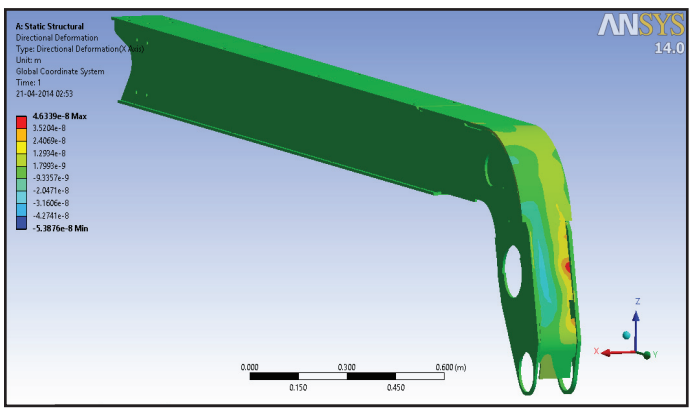

Fig. 14: Directional Deformation

Table 1 shows the results that are obtained from this static analysis of 3D model of Loadall Inner Boom,

Table 1: Results of Analysis of 3D Model

Normal Stress	
Maximum	3.5539 $\times 10^5$ Pa
Minimum	-3.6588 $\times 10^5$ Pa
Maximum Principal Stress	
Maximum	3.738$\times 10^5$ Pa
Minimum	-4.3728 $\times 10^4$ Pa
Directional Deformation	
Maximum	4.6339$\times 10^{-8}$ m
Minimum	-5.3876 $\times 10^{-8}$ m

V. Conclusion

This study has aimed to demonstrate a systematic approach for sheet metal assembly fixturing.

The problem has been constrained as fixturing for assembly of sheet metal components of Loadall Inner Boom. An assembly fixture design study has been done for a particular Side-plates and Top pressing plate assembly. Within the study;

1. Typical parts of Loadall Inner Boom have been introduced,
2. Locating and clamping of these parts have been illustrated,
3. A possible assembly fixture design has been given for the particular side-plates and top-pressing plate.
4. The critical feature of the assembly and the features that may affect the critical feature have been stated.
5. Finite Element Analysis has been used to predict the effect of possible fixture deviations on the deviation of the critical feature of the product.

Assembling of the compliant parts used in automotive industry is a challenging process. Assembly fixtures are quite important tools in this effort and widely used in industry. In fixturing of easily deformable sheet metal parts, besides restraining the rigid body motion of the parts, the possible deformations that may occur during the assembly process. In order to guarantee a successful assembling, in other words, to obtain the final product within specified tolerances, a systematic approach to the fixture design problem is required. The designer should predict the correlation between the input variations and the final assembly variation, especially, for the complex assemblies. The design of an assembly fixture for particular parts has been completed convenient to the existing locating principles. Finite Element Analysis (FEA) has been realized in simulating the assembling process in order to predict the possible variation of the interested feature on a complex assembly due to deformations.

VI. Acknowledgement

It gives me an immense pleasure in submitting the research paper on "Fixture Design for Tacking and Welding of Loadall Inner Boom and Jib Head" I take this opportunity to express my gratitude and indebtedness to all who worked for this concept, my college project guide Dr. R. M. Metkar (Assistant Professor at GCOE, Amravati), company project guide Mr. Ajaykumar Singh (Production Manager at JCB India Limited, Pune), Dr. Subhash Hiwase (Managing Director, Samrachana Software Solutions, Hyderabad), and Prof. Dr. R. S. Dalu (Head, Mechanical Engineering Department, GCOE Amravati) who are a constant source of guidance and inspiration through the project work whose constant help and encouragement guided me to complete my project work.

References

[1] Price S.,"A study of Case Based Reasoning applied to welding Computer Aided Fixture Design", Worcester polytechnic institute, 2000.

[2] Madden J.,"Welding fixture with active position adapting functions", Worcester polytechnic institute, 2007.

[3] Nasr E.A, Al-Ahmari A, Kamrani A, Khan A. A, An integrated system for automatic computer aided fixture design. Proceedings of the 41st International Conference on Computers & Industrial Engineering, 2010.

[4] Bayar F. M,"Design and analysis of fixturing in assembly of sheet metal components of helicopters", 2007.

[5] Ghatpande P, "A study of Fixturing Accessibilities in Computer-Aided Fixture Design", 2008.

[6] Zhang Y, Mu S,"Computer-Aided Design Process and Methods based on Welding Fixture", 2011.

[7] Merkley, K.G,"Tolerance Analysis of Compliant Assemblies", Brigham Young University, 1998.

[8] Camelio, J.A., Hu, S.J., Marin, S.M, "Compliant Assembly Variation Analysis Using Component Geometric Covariance", ASME Journal of Manufacturing Science and Engineering, Vol. 126, pp. 355-360.

[9] Camelio, J., Hu, S.J., Ceglarek, D, "Modeling Variation Propagation of Multi-Station Assembly Systems with Compliant Parts", ASME Journal of Mechanical Design, Vol. 125, 2003, pp. 673-681.

[10] Satyanarayana, S., Melkote, S.N,"Finite Element Modeling of Fixture-Workpiece Contacts: Single Contact Modeling and Experimental Verification", Vol. 44, 2004, pp. 903-913.

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