Experimental and Analytical Study of weld Distortion for Dumper Skip

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Abstract. This paper investigates the capability of virtual analysis to predict the welding distortion that occurs during welding process due to improper heat input. Distortion is considered as the major obstacle that can adversely affect the dimensional accuracy and thus lead to expensive corrective work. Hence, forecast of distortion is crucially needed and distortion to be determined in advance to minimize the negative effects, improve the quality of welded parts and finally to reduce the production costs. In this study, the welding deformation was simulated by using relatively new welding simulation software SYSWELD by ESI Group& fatigue validation is done with FEM software by ANSYS. This research study of Welding Simulation Solution was employed to predict welding distortion induced in dumper skip which involve various weld joints like butt and T-joints with thickness varies like 4 mm, 5mm, 6mm. steel material was used for the simulation and experimental study. A series of experiments using fully automated welding process were conducted for verification purpose to measure the distortion. By comparing between the simulation and experimental results, it was found out that this program code offered fast solution analysis time in estimating weld induced distortion within acceptable accuracy. In this work T joint sections are consider to see effect of weld parameters change and learning from this is applied to full dumper skip components.

This research will aid in the CAE simulation of Weld Simulations to predict weld distortions & to address manufacturing issues or assist in the part development process. This research also assures that weld simulation with help of virtual simulation software is performed in a consistent manner.

Keywords — Simulation, Finite element analysis, welding deformation, SYSWELD, UGNX, MIG

I. INTRODUCTION

Fabrication by welding is finding increasing use in many types of industrial construction. Heavy machine building industry and the manufactures of material handing equipment's have become major users of welding processes in addition to processes equipment manufactures. The obvious advantage of welding has led to this change. Associated with this are certain shortcomings of the techniques which have continuously troubled the fabricators and the research work have directed their efforts towards providing solution to these.

Since welding is one of the most widespread technological processes, this technology has also received a lot of attention when developing modern simulation tools. The problem with the simulation of this process is the fact that the moving heat source is the reason for the uneven distribution of displacements and stresses in welded elements. However, they are not only dependent on the moving heat source itself. Their values and distributions are also strongly dependent on many other technological factors such as clamping condition, mechanical and thermal properties, type of the welding technology and welding parameters, preheating temperatures, weld joints design, temperature of surroundings, etc. The residual stresses in the structure after welding have a negative influence on the durability of the structure and its reliability under various

Operating conditions. The degree of complexity of the process itself and the non-linearity of phenomena that occur in the welded element during its heating and cooling, and their dependence on the type of material and technology used, significantly increase the degree of complexity of numerical analyses.

The use of numerical analyses today allows for a better understanding of the production process, finding relationships that connect individual process parameters to its results and increases product quality. It also leads to a significant cost reduction in the production preparation

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stage by limiting and often excluding costly prototypes. This is particularly important when making samples or prototypes involving a lot of material, time and are energy consuming. Based on the results of numerical simulations, it is possible to determine the optimal solution, even if their results are not 100% consistent (in terms of value) with the results of real tests. Thanks to the constant development of modern simulation software, it offers us today various possibilities of approach to the issue of numerical analyses.

Finite element method (FEM) is very useful for predicting distortion and residual stresses in welded plates. The non-uniform temperature distribution produced during welding give rise to incompatible strains which in turn results in generation of self-equilibrating residual stresses and its distribution that remain in the structure after cooling down to ambient temperature. In weld simulation, computational software like ANSYS, ABAQUS and SYSWELD are popular. ANSYS and ABAQUS require complex subroutines programming, whereas SYSWELD is specially designed for heat treatment and welding process. It is functional specific FEA package, which includes heat source geometry definition, moving heat source function, heat treatment and phase transformation of material during heating and cooling

This paper also includes the outcomes of a case study, as well as the variability in results due to weld heat influence. It is important to emphasize that the process described in this article is the best interpretation based on experience, existing regulations, and suggested practices, and does not claim to be the only or even the best way to comply with existing regulations. The problems of residual stresses & distortion are interlinked but, in this paper, only distortion part is included & remaining residual stress part will be covered later

II. PROBLEM STATEMENT

Virtual weld distortion simulation helps to understand effect of various parameters like current, Voltage, Weld Size, flow rate etc. at early stage of part development. If we use this virtual simulation tools at early stage, it will reduce part development cost, reduce physical weld trails also development time is got reduced.

While developing any new component in industry various cost are associated with it like design cost, tooling cost, prototyping cost, tooling cost. If we use this virtual weld simulation software at early stage, it will increase production rate, reduce scrap, eliminate weld rework, reduces material manpower tooling cost etc. The main goal of this research is to provide a quick prediction distortion and solution to reduce the distortion by using virtual simulation.

The objective of this project is to re simulate the distortion failure of product in weld simulation software and optimize the require welding parameters in such a way that it will reduce the overall distortion on the product. Weld parameters optimization of skip can be done using the Sysweld tool.

Dumper skip is one of the strongest Structural members in material carrying Product range, Due to some wrong heat input approx. 10 mm distortion was observed on dumper skip. Hence to reduce this overall distortion in dumper skip some proposals are made like changing from full welding to stich welds & by changing some weld parameters.

Weld simulation using sysweld tool will help to minimize the dumper skip distortion, In this Project Software which used are UG NX, Sysweld and Ansys 19

UG NX software is used for creating models of Dumper skip Concepts. Ansys software is used for meshing and analysis. Sysweld software is used for predicting weld distortion & for getting improved weld parameters results.

III. PASSING CRITERIA

For the safe design point of view the weld distortion after the welding should not more than 4mm. If the weld distortion value is more than 4mmany that point, then there will be part rejection in quality will take place.

1. Weld distortion - should be less than 4 mm for thought out the component.
2. No weld imprints on dumper skip is allowed.

IV. DESIGN AND SIMULATION SETUP

CAD modeling for Dumper skip is carried out in UGNX, and then same model is transferred to Ansys 19 for FEA modeling, all parts are meshed with 3D mesh tetra mesh with 2 layers in critical area. Similar component is used for sysweld setup with shell model & 2D quad mesh with perfect node to node connectivity & zero error is created throughout the component. Welding trajectory is created for each weld by picking start & end nodes with continuous line. Clamping & unclamping conditions are created by picking nodes.

A. Simulation Setup:

The weld process setup can be completed using the 'Welding Advisor' tool from 'Advisors' Tab on the top of the Visual Weld GUI. The Welding Advisor consists of nine steps to be completed sequentially to complete the setup. Following are the steps and input parameters that need to be completed.

1. Project Description: In this step the file name and Working directory needs to be defined as shown Below
2. Global Parameter: In this step the computational alternative for the project can be chosen such as solid, shell-solid, shell, 2D Cross Section, 2D In-Plane and 2D Rotational. In most of the cases the

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alternative is automatically recognized

3. Component Properties: In this Step, material definition can be applied to every single component present in the model. The nomenclature for naming parts helps to identify the parts easily. Once the material is assigned for all components, select 'Joints with Filler' option to assign materials for weld beads. Again, the nomenclature for naming the weld beads helps to identify the weld beads easily.
4. Welding Process: In this Step , the welding process type can be chosen among different welding process as shown below. For all the simulations, the General arc or MIG welding process needs to be used.
1. Cooling Condition: In this Step focuses on cooling condition. Welding advisor allows creating a cooling condition by selecting the air heat exchange collector that can be cooled down by forced cooling or free cooling. It is possible to specify the initial ambient temperature as shown below.
2. Clamping Condition: In this Step, Clamping conditions need to be specified choosing the clamping collectors, previously created in Visual-Mesh, and choosing for how long the clamps are held. Different types of Clamp definition can be defined such as Elastic, Rigid, Symmetric, Stops and Unclamped.

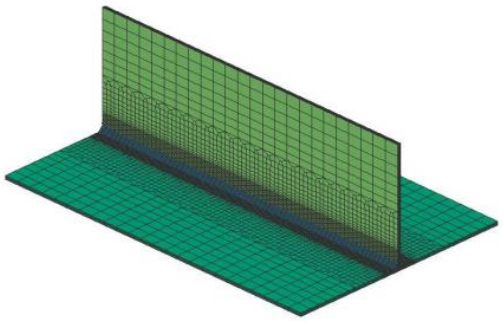

Fig 1. Sysweld Meshing Image

3. Loads and Deformations: This step focuses on external loads and deformations that need to be applied in the model. This step is skipped since we do not generally have cases where external loads are to be applied.
4. Contact Definition: This step focuses on contact definition. This step can also be skipped since we are creating a node to node connected model there is no need to define contacts.
5. Solution Parameter: In this Step, ambient condition is defined and the type of solution. It is possible to choose just a Thermo-Metallurgical analysis or the coupling between Thermo-Metallurgical analysis and mechanical analysis. Advanced solution parameters can be added to specify the desired post-processing files and the disk spaced as shown below.

Analysis is performed with current welding parameters and 2proposals with reduced weld distortion as shown in Fig. 3. Following are the design for current design and proposal for skip. In proposal 1 stich weld are proposed over full weld and for Proposal 02 various weld trials are carried out to get desired passing criteria results. Solution Parameter: In this Step, ambient condition is defined and the type of solution. It is possible to choose just a Thermo-Metallurgical analysis or the coupling between Thermo-Metallurgical analysis and mechanical analysis. Advanced solution parameters can be added to specify the desired post-processing files

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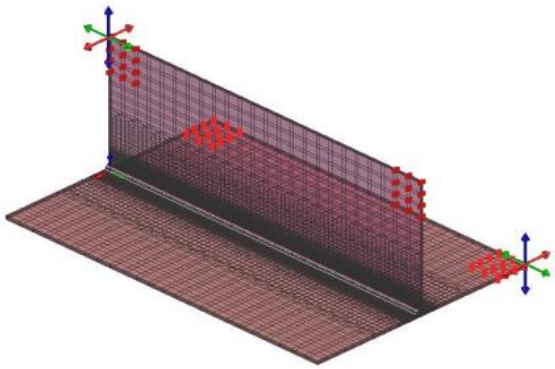

Fig 2 Position of clamp for simulation

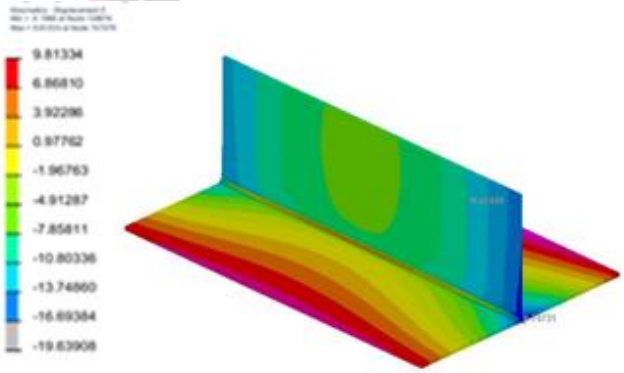

Fig 3 Weld Simulation results with current parameters

B. Material Properties for Dumper skip

Young's modulus	200 GPa
Poisson's ratio	0.3
Density of material	7850 kg/m³
Yield strength - tensile	355 MPa
Ultimate strength - tensile	640 MPa

Table 1.Material Properties used in simulation

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C. Simulation Results

a. In current dumper skip, at 360 A current & 36V Voltage 9.5 mm deformation is observed which is visible to naked eye hence this part is got rejected in quality acceptance criteria. Hence to avoid this weld deformation help of virtual software is taken which already exists in CE industry.

b. When we run the weld simulation with above mention parameters we get almost 9.81 mm distortion on dumper skip. The percentage error in result is about 3.2% means our software results are 97% correlating with current condition.

c. Hence to eliminate this weld proposal was suggested in that instead of full weld stich welds are proposed. In this we got almost 2.94 mm distortion on skip which is acceptable but when we did FEA analysis for fatigue life stresses on weld are increased which is not acceptable so this proposal was rejected.

d. So it is decided that stitch weld will not work, we need to do welding with full length only .so various range of current , voltage & weld size are consider & their 16 combination of runs are tried .

e. Out of this combination with 240 A current, 24V Voltage & 3 mm weld size we get almost 3.05 mm distortion on skip which is acceptable. Hence simulation for FEA fatigue analysis is run and we got almost similar stresses on weld which is acceptable so this proposal was accepted.

Parameters				
Voltage (V)	36	32	28	24
Current (A)	360	320	280	240
Weld Size	3	3	3	3

Table 2 .weld parameters used in simulation

D. Experimental VALIDATION

From the CAE simulation Proposal 02 with 240A current & 24V Voltage is selected as best among all other combination. Weld distortion with proposal 2 parameters testing is carried out it in testing laboratory to see weld distortion improvement.

Test Observations

1. Weld distortion for proposal 02 is almost 3.05 mm from virtual software results & we got almost 3.5 mm distortion from actual experimental results

2. No weld imprints are observed on dumper skip

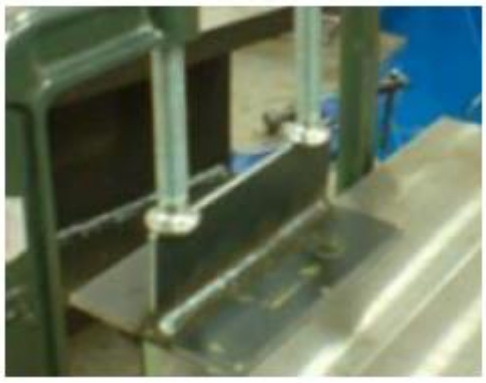

Fig.4. Experimental setup image for l Weld distortion

V. RESULT AND DISCUSSION

1. Proposal 01, Proposal 02 show reduced weld distortion effect compared to current design, hence this concept will produce relatively lower weld distortion on dumper skip.

2. In Proposal 01 shown less weld distortion but are not meeting the acceptance criteria for stress .

3. Proposal 02 showing good result for both weld distortion & equivalent stresses, hence proposal 02 is considered as final Design for dumper skip.

4. CAE results are validated in testing.

VI. Conclusion

1. From table it is observed that on 240 A Current & 24 V Voltage we are getting almost 3.05 mm distortion from virtual analysis & 3.5 mm from experimental analysis in Vertical direction which is less as compare to 360 A current & 36 V Voltage .
2. A principal advantage of using this prediction method is that only a short computational time is required for the simulation analysis.
3. The significant contribution from this is that the distortion which is inevitable can be predicted; thus the control of distortion can be possibly planned in advance prior to the commencement of the actual welding process.
4. Therefore, this software possesses a great potential for identifying distortion in more complex welded joints.
5. The predictive approach can be implemented at various stages in the design and production cycle. In the design stage, welding procedures can be set, and then various geometric configurations investigated.
6. Weld distortion analysis can add immense value in structural development process .

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