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Design and Development of Semi-Automatic Full Welding Fixture for Welding the Roller Drum of Vibratory Compactor

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Abstract—*Welding fixtures are normally designed to hold and support the various components (work pieces) to be welded. This work integrates a functional approach and the designed fixture is proved from the fact that a real industrial component was considered for fixture design. The present scenario in the construction equipment industry to manually fabricate the roller drum of vibratory compactor proves to be adversely affecting the health and life of the worker. In order to make the work space human friendly a semi-automatic welding fixture was developed.*

The conceptual design was made using SolidWorks, analyzed with Ansys for structural feasibility and developed according to the design. The semi-automation of the fixture includes the use of induction motor, variable feed drive (VFD), a programmable logic controller (PLC) and a thumb switch to select the various combinations of the welding parameters. The fixture is developed in such a way that it can be used for fabricating the roller drum of diameter 1.23m and 1.5m with length 1.46m and 2.1m respectively without any difficulty. Also a provision for tilting the entire fixture at 30° for containing the molten weld metal at its position

The developed fixture holds and effectively rotates the tack-welded roller drum of both the models considered at required uniform speed. The rotation speed is adjusted according to the MIG welding parameter thus producing a sound weld and minimizing the human involvement making the work space more human friendly.

Keywords*: SolidWorks, roller drum, welding fixture, semi-automation, VFD, PLC*

1. INTRODUCTION

A roller or vibratory compactor is a compactor type engineering vehicle used to compact soil, gravel, concrete, or asphalt in the construction of roads and foundations, similar rollers are used also at landfills or in agriculture.

Roller drum is very important part in a vibratory (roller) compactor. The roller drum is fabricated by bending the rolled steel sheet into cylindrical fashion and then adding certain amount of reinforcements in order to obtain the necessary mass to perform the compaction, in most of the types the roller drum is equipped with a vibrator that continuously vibrates and assists in obtaining greater compaction.The component considered is the roller drum of the vibratory compactor. There are two capacities of the vibratory compactors that are being manufactured in LTCEL they are 11T compactor and 9T compactor, both utilizing different types of rollers i.e. different in dimensional specifications.

Variant	Diameter	Length
9T	1230	1460
11T	1500	2100

The full welding that has to be carried out is number of layers, varying the parameters from layer to layer.

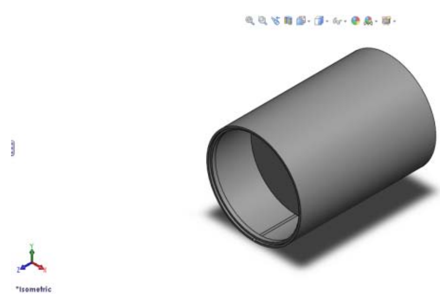

Fig. 1: 3D model of a 9T drum

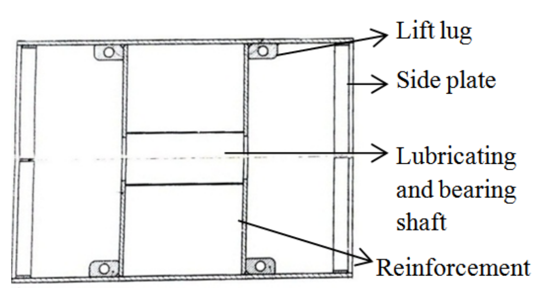

Fig. 2: Areas to be welded in roller drum

1.1. Motivation and problem statement

The motivation in selecting this particular work is because the manual full welding process to fabricate the roller drum seems to be highly dangerous to the welder by the current fabrication process. Also health hazard to the welder is substantial since he is enclosed within the drum itself.

Currently roller drum is fabricated by following process:

- A sheet metal of required thickness is roll bended on a roll bending equipment
- The edges are tack welded
- It is then transferred on to material handling crane, suspended on a couple of stands and full seam welding on the tack welded region is carried out
- Later the various reinforcements inside the drum are tack welded, checked for accuracy and then the full welding is carried out manually by hanging the drum.

1.2. Scope and objectives

The primary objective is to design and fabricate a suitable fixture for carrying out semi-automatic full welding fixture that can hold and weld the available two models of roller drum in a single fixture. The automation should be in such a way that the welder's involvement is reduced to only setting up the roller drum, welding torch and selecting the suitable parameter.

The secondary objectives are:

- To provide a suitable drive to the fixture to rotate the component there by reducing the human effort involved.
- To provide an angle of tilt to the fixture in order to contain the molten metal at the weld pool.

Fig. 3: Current method of full welding process

2. METHODOLOGY

The methodology of this work is followed according to the Phases and the interactions of the design process [1] which is outlined as in Fig. 2.1

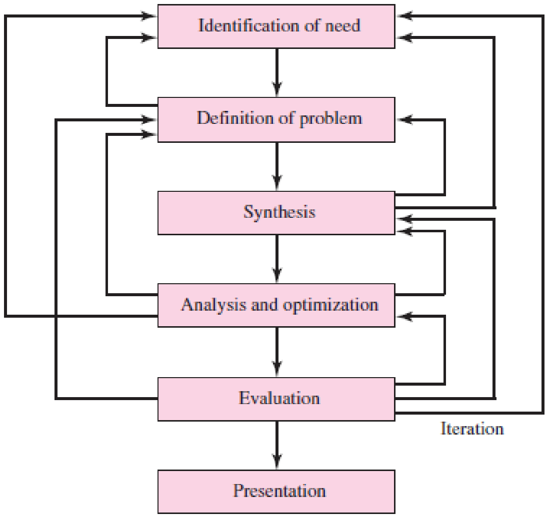

Fig. 3: Methodology

3. DESIGN OF FIXTURE

Computational tools: CAD package - SolidWorks

The design concept was developed considering both the models and the requirements. All the components were first 3D modeled in the software, assembled and checked for the feasibility by carrying out structural analysis and compare the equivalent stress obtained with that of the theoretical yield stress of the material considered to make the fixture.

The various critical components being:

3.1 Base plate

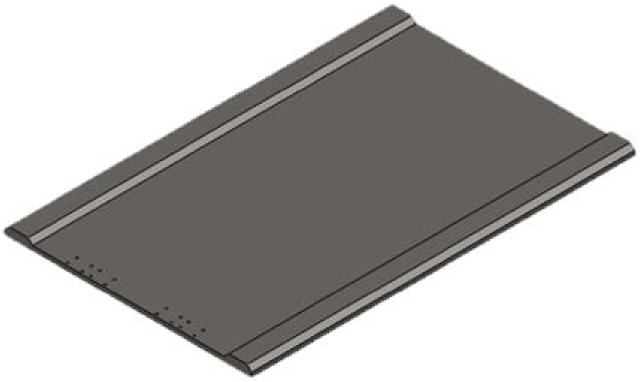

Fig. 4: Base plate of the fixture

Base plate is the platform for all the other fixture components will be mounted on. This is made by cutting a 24 mm thick plate to the dimension about 2100×1350 mm.

3.2 Brackets

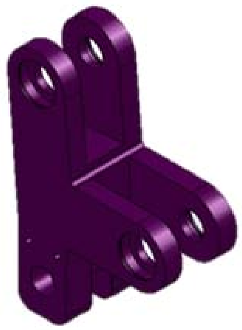

Fig. 5: Brackets to hold the roller wheels

The brackets are the structural member that supports the bearing and the wheels on which the component (roller drum) rotates. A single bracket has a provision to support two roller wheels. The number of brackets needed is four.

3.3 Roller wheels

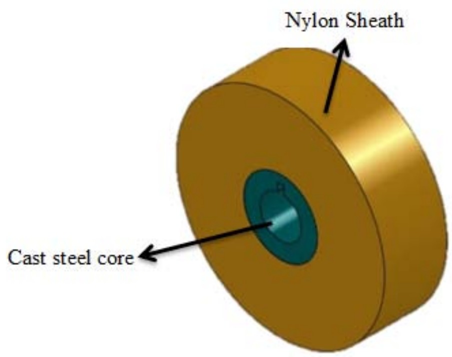

Fig. 6: Roller wheels

The roller wheels are the sub assembly of the main fixture. The wheels are manufactured by covering the steel mass of 90mm outer diameter with nylon material making the final outer diameter to 254mm with a width of 76mm.

These wheels (eight in number) take up the load exerted by the component and transfer to the rest of the fixture.

The component is rotated using these wheels. The two wheels are connected to a motor that drives the drum which has to be welded.

3.4 Hinge pin

A step turned shaft with 50 mm diameter and a step of 60 mm diameter at the end there is a provision of circlips or to provide a lock plate. This ensures the arrest of all the motion to the hinge pins except the rotary motion along its axis that too only when the bracket moves. The hinge pin takes up a cumulative double shearing load of the drum, brackets, shafts and roller wheels.

Fig. 7: Hinge pin

3.5 Assembled fixture

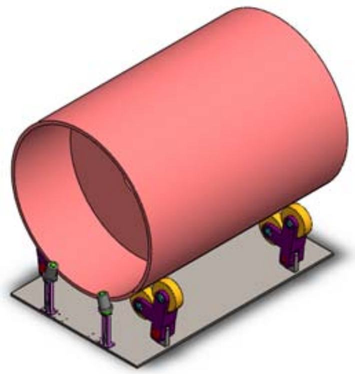

Fig. 8: Assembled model of the fixture

4. STRUCTURAL ANALYSIS OF THE FIXTURE

As a part of analysis of the fixture structural analysis was carried out to test the feasibility of the fixture. The analysis is done in the standard three steps namely[2]

i. Pre-processing
ii. Solution
iii. Post-processing

4.1 Pre-processing

Here the entire model of the structure is imported along the material properties.

Meshing: The process of representing a physical domain with finite elements is referred to as meshing, and the resulting set of elements is known as the finite element mesh. The basic idea of mesh generation scheme is to generate element connectivity data and nodal-coordinate data by reading in input data for a few key points [3]. A free meshing was carried out with relevance of 50 and medium mesh

Meshing attributes:

Mesh type: Automatic

Mesh elements: Tetrahedrons

Number of nodes: 213098

Number of elements: 66666

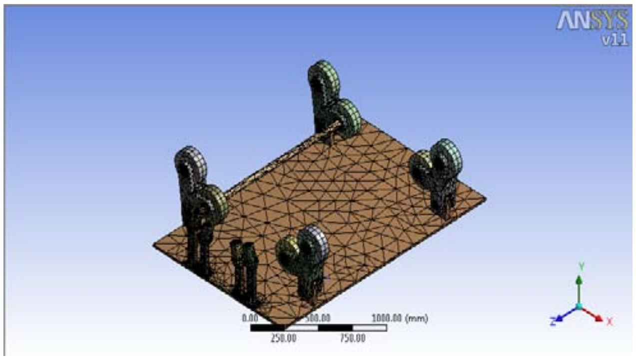

Fig. 9: Meshed fixture

4.2 Solution

This involves application of boundary conditions and computation of results such as displacements, stresses and strains in case of static analysis.

Boundary conditions: The boundary conditions are evaluated by using the force exerted by the fixture considering the dead weight. The lower limit of the boundary condition is zero i.e. fixed surfaces (Base plate) and upper limit is the forces acting on the fixture which was calculated considering the dead weight of the 11T variant drum and is tabulated in table 2.

Table 2: Upper boundary limits

Forces acting (all on the fixture)	Upper boundary (Newton)
F_1	26853
F_2	39806
F_3	39806
F_4	26853
F_5	26853
F_6	39806
F_7	39806
F_8	26853

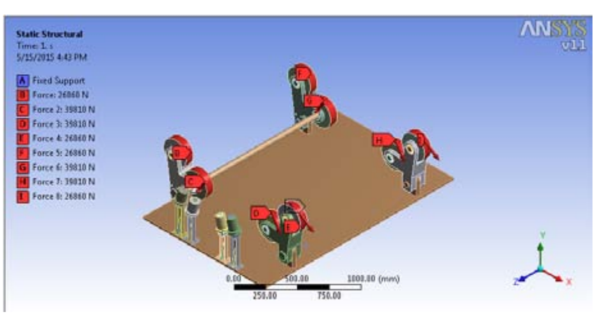

Fig. 10: Applied boundary conditions

4.3 Post-processing

This involves interpretation of results generated during the processing stage Such as deformed shape, graphical representation of total deformation, stress and strain. Here the equivalent stress (Von-Mises) is analyzed as a part of feasibility test for the fixture.

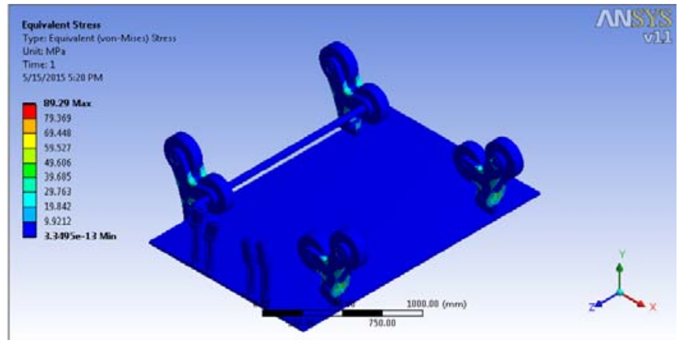

Fig. 11: Equivalent stress obtained

The equivalent stress is majorly considered in the feasibility test of any material and the obtained stress value is compared to the yield stress of the material. The maximum equivalent stress generated in this structural analysis is 89.29 MPa which is observed in the roller brackets. The brackets are made up of low carbon steel which has yield strength of 245 MPa [4]. Thus the generated stress in the member is within the yield stress of the material even by considering the factor of safety 2. Thus the fixture can hold the component and the work can be accomplished without any failure of the fixture

5. DEVELOPMENT OF FIXTURE

The fixture development was carried out according to the designed models and also by salvaging the hydraulic cross-lift from the scrap to tilt the fixture at 30°.

5.1 Mechanism to tilt the fixture

Fig. 12: Hydraulic cross-lift tilting the fixture at 30

In order to tilt the fixture at 30° (for containing the molten weld metal intact in the weld pool) a salvaged hydraulic cross-lift was used.

5.2 Component on the fixture

A trial rotation was carried out using the higher capacity drum (i.e. 11T variant drum) on the fixture.

Fig. 13: Component placed on the tilted fixture

6. SEMI-AUTOMATION OF THE WELDING

The devices that are required for automating the welding process are:

- Programmable Logic Controller (PLC)
- 3 Phase invertor or variable feed drive
- An induction motor
- Parameter switching unit (PSU)

6.1 Programmable logic controller (PLC)

A PLC is a digital computer used for automation of typical electromechanical process, here the welding process. The programs to control the operations are usually stored in non-volatile memory of the PLC. The output of the PLC is produced in response to the input conditions within a limited time.

Fig. 14: A PLC unit used in the welding automation

6.2 Variable Feed Drive (VFD)

It's a speed controlling device for an induction motor. This device controls the speed by varying the input frequency fed to the induction motor thereby giving an output of the desired speed from the motor unit. The instruction set to the VFD is altered using the PLC.

Fig. 15: Variable feed drive used

6.3 Induction motor

This unit is used to rotate the drum at the desired speed with the assistance of the VFD and PLC providing a uniform speed with respect to the optimum weld wire feed rate.

Fig. 16: An induction motor with a worm gear unit

6.4 Parameter Switching Unit

This unit is used to select the desired parameter to feed to the PLC; this unit depicts the user interface for the PLC. This unit can be a push button or a thumb switch.

6.5 Block diagram of control panel

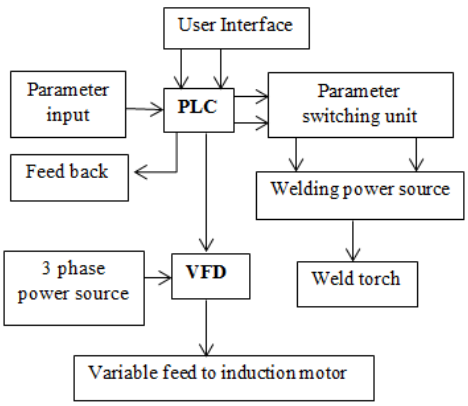

Fig. 17: Block diagram of the control panel to attain semi-automation

7. RESULTS AND DISCUSSION

The analysis result shows that the stress induced within the fixture is at the bracket which is experiencing a stress value of 89.29 MPa (maximum value) under the load considering the dead which is lesser than the material's yield stress being 245MPa. The hydraulic cross-lift can be used to tilt the fixture at desired angle. Desired speed of rotation of the drum can be successively controlled by the use of the control panel starting from the speed of 0.8rpm to the maximum speed being 6rpm considering all the speed reductions in the fixture.

8. CONCLUSION

The fixture thus developed can be used to full weld both the model of the roller drums. The welding can be carried out at 30° angle with the assistance of the hydraulic cross-lift so that the weld metal can be held in the weld spot. The semi-automation desired can be achieved with a suitable program developed after the trial and error method to set the correct manipulating parameter for the welding.

9. ACKNOWLEDGEMENTS

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