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"Design of Welding Fixtures for Boom Arm Assembly"

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***Abstract: Abstract*— There is a necessity for boom arm assembly which is one of the subassemblies of an ongoing project at L&T Construction Equipment Limited. So it is necessary to develop a tack welding fixture to reduce the cycle time and reduce welding distortions Tack welding is a temporary weld used to create an initial joint between two pieces of metal being welded together .Full welding is a continuous welding of metal joints using electric arc. In this work an attempt has been made to develop, modify and generate concepts to mount the sub-assemblies from the boom arm assembly onto fixtures to perform tack welding and full welding. For developing the welding fixtures some of the important Critical to Quality (CTQ) issues are orientation of the tube, gap between the two sub-assemblies, clamping, land between the mid-plates and the front plate edge in and perpendicularly between mid plates and front plate. After developing this fixture we may save up to 112.3 minutes per boom arm assembly. Assembly of boom arm assembly without using fixture is 45 units per day after developing the fixture it increases to 60 units per day so that the production is increased and the assembly can be carried out faster.**

***Index Terms*—L&T Company, Critical to Quality (CTQ), boom arm assembly welding fixture**

I. INTRODUCTION

1.1 BOOM ARM ASSEMBLY

The boom arm assembly is one of the sub-assemblies of a portable bridge system employed by the defense sector. Currently the project of developing the boom arm assembly is being carried out by L&T Construction Equipment Limited.

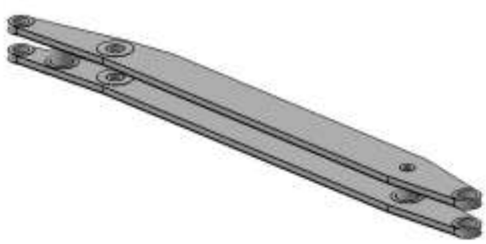


Fig.1: Boom arm assembly

1.2 BOOM ARM ASSEMBLY COMPONENTS

The boom arm assembly mainly consists of the following components:

- Front plates
- Mid plates
- Steel bosses
- Patch plates
- Pitch plates
- Tubes

1.3 TACK WELDING

Tack welding is a temporary type of weld used to create an initial joint between two pieces of metal being welded together. It is an integral part of the welding process and very important to the ultimate success of the welding project.

1.4BENEFITS OF TACK WELDING

- Ease of removal in order to correct any improper alignment of the components to be welded together.
- Stabilizes the overall alignment of components to be welded together.
- Reduces movements during the welding process.

1.5FULL WELDING

Full welding is a continuous welding of metal joints using electric arc. It is a process used to permanently fuse two surfaces together. Here Gas Metal Arc Welding (GMAW) is used for full welding.

Gas metal arc welding (GMAW) is a welding process in which an electric arc forms between a consumable wire electrode and the work piece metal(s), which heats the Work piece metal(s), causing them to melt and join.

GMAW is the most common industrial welding process, preferred for its versatility, speed and the relative ease of adapting the process to robotic automation.

Table 1.1: Weld specification

Welding process	Current (in amps)	Voltage (in volts)	Temperature (in c̊)	Gas
GMAW	280A-340 A	28 V-34 V	150 C̊	Ar + CO_2 (98%+2%)

1.6 BENEFITS OF GMAW

- Gas Metal Arc Welding (GMAW) is fast and economical.
- The electrode and inert gas are automatically fed.
- Weld deposition rate is high due to continuous wire feed.
- No flux is used and hence no slag formation which results in clean welds.
- Thin and thick metals can be welded.
- Process can be automated. figures and tables.

1.7 FIXTURE

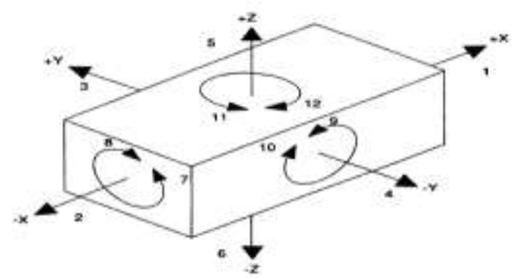
A fixture may be defined as a device, which holds and locates the work piece during the inspection or for a manufacturing operation. A fixture is a device for locating, holding and supporting a work piece during a manufacturing operation. The fixture does not guide the tool. In construction, the fixture comprises different standards or specially designed

Work holding devices, which are clamped on the machine table to hold the work in a position. The tools are set at the required position on the work by using gauges or by manual adjustments. Fixtures are essential elements of production processes as they are required in most of the automated manufacturing, inspection and assembly operation. Fixtures must correctly locate a work piece in a given orientation with respect to a cutting tool or measuring device, or with respect to another component, as for instance in assembly or welding. Such location must be invariant in the sense that the device must clamp and secure the work piece in that location for the particular processing operation. Fixtures are normally designed for a definite operation to process a specific work piece and are designed and manufactured individually. Jigs are similar to fixtures, but they not only locate and hold the part but also guide the cutting tools in drilling and boring operations. These work holding devices are collectively known as jigs and fixtures.

1.8 OBJECTIVES OF DESIGNING FIXTURE

- To eliminate marking, punching, positioning, alignments etc.
- For easy, quick and consistent accurate location, supporting and clamping the job in alignment of the cutting tool.
- To reduce overall machining cost and also increase interchangeability.
- Provide guidance to the cutting tool like drill, reamer etc.
- To increase productivity and maintain product quality consistently.
- To reduce operators labor and skill – requirement.
- To reduce measurement and its cost.
- To enhance technological capacity of the machine tools.

1.9 PRINCIPLE OF FIXTURE



Any rectangular body many have three axis along x-axis, y-axis and z-axis. It can more along any of these axes or any of its movement can be released to these three axes.

At the same time the body can also rotate about these axes too. So total degree of freedom of the body along which it can move is six. For processing the body it is required to restrain all the degree of freedom (DOF) by arranging suitable locating points and then clamping it in a fixed and required position. The basic principle used to locate the points is described below.

Considering the six degree of freedom of a rectangular block as shown in figure

It is made to rest on several points on the jig body. Provide a rest to job on three points on the bottom x-y surface. This will stop the movement along z-axis, rotation with respect to x-axis and y-axis. Supporting it on the three points is considered as better support then one point or two points. Rest the job on two points of side surface (x-z), this will fix the movement of job along y-axis and rotation with respect to z-axis. Provide a support at one point of the adjacent surface (y-z) that will fix other remaining free movements. This principle of location of fixing points on the job is also named as 3-2-1 principle of fixture design as number of points selected at different faces of the job are 3, 2 and 1 respectively..”

1.10ELEMENTS OF FIXTURES

- ***LOCATORS***

A locator is usually a fixed component of a fixture. It is used to establish and maintain the position of a part in the fixture by constraining the movement of the part. For work pieces of greater variability in shapes and surface conditions, a locator can also be adjustable.

- ***CLAMPS***

A clamp is a force actuating mechanism of a fixture. The forces exerted by the clamps hold a part securely in the fixture against all other external forces.

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- ***SUPPORTS***

A support is a fixed or adjustable element of a fixture. When severe part displacement/deflection is expected under the action of imposed clamping and processing forces, supports are added and placed below the work piece so as to prevent or constrain deformation. Supports in excess of what is required for the determination of the location of the part should be compatible with the locators and clamps.

- ***FIXTURE BODY***

Fixture body, or tool body, is the major structural element of a fixture. It maintains the spatial relationship between the fixture elements mentioned above, viz., locators, clamps, supports and the machine tool on which the part is to be processed.

1.11 IMPORTANCE OF FIXTURES IN MANUFACTURING

The use of fixtures has twofold benefits. It eliminates individual marking; positioning and frequent checking before machining operation starts, thereby resulting in considerable saving in set-up time. In addition, the usage of work holding devices saves operator labor through simplifying locating and clamping tasks and makes possible the replacement of skilled workforce with semi-skilled labor, hence effecting substantial saving in labor Furthermore, the use of well-structured fixtures with higher locating and clamping rigidity would allow for increase in cutting speeds and feeds, hence improving production rate.

Besides improving the productivity in terms of the rate of production, there are also other benefits accrued through the use of fixtures. They are:

- Increase machining accuracy because of precise location with fixtures.
- Decreases expenditure on quality control of machined parts as fixtures facilitate uniform quality in manufacturing.
- Widens the technology capacity of machine tools and increases the versatility of machining operations to be performed.

1.12 MEANING OF LOCATOR

The location refers to the establishment of a desired relationship between the job and the fixture. Correctness of location directly influences the accuracy of the finished product. Determination of the locating points and clamping of the job serve to restrict movements of the component in any direction, while setting it in a particular pre-decided position relative to the fixture. Before deciding the locating points it is advisable to find out all the possible degrees of freedom of the job. Then some of the degrees of freedom or all of them are restrained by making suitable arrangements. These arrangements are called locators.

II.MATERIAL PROPERTIES OF BOOM ARM ASSEMBLY

The boom arm assembly is made of High Strength Low Alloy Steel whose specification is as follows.

Table 2.1: Mechanical properties of boom arm

Yield strength	700 MPA
Ultimate tensile strength	780-930 MPA
% Elongation	16 %

Table 2.2: Chemical composition of boom arm

Carbon(C)	0.20%
Phosphorous(P)	0.02%
Manganese(M n)	1.60%
Silicon(Si)	0.60%
Copper(Cu)	0.30%

Table 2.3: Physical properties of boom arm

Impact toughness	Charpy v-notch at minus 40 degrees Celsius
Energy absorption in joules	27 JOULES –Average taken for 3 specimens

III. PROBLEM DEFINITION AND OBJECTIVES

3.1 PROBLEM DEFINITION

Presently the boom arm is manufactured using first principles of engineering, where all the measurements are done manually, dimensions are measured every time and positioning or fixing of each component is with the help of material handling system which leads to increased manufacturing lead time and so it is necessary to develop a fixture to reduce the cycle time of a boom arm assembly.

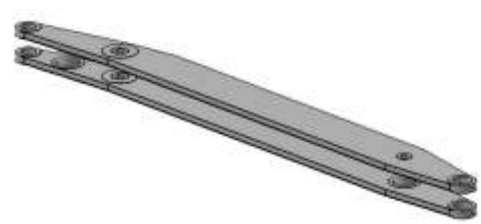

Fig.3.1: Boom arm assembly

During the continuous welding, due to distortion, the gap between the two arms is not maintained as per requirement. As per specifications the gap is 192mm with a tolerance Up to ±2mm is acceptable but currently a gap of 186 to 189mm is

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only achieved. So it is necessary to maintain dimensions as per specifications

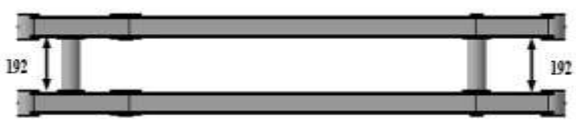


Fig.3.2: Top view of boom arm assembly

3.2OBJECTIVES

- To increase the productivity by designing tack welding and full welding fixtures.
- Study of the current cycle or process time for tack welding and comparison of the same after designing a fixture.
- To reduce or control welding distortion by proposing a full welding fixture.

VI. METHODOLOGY

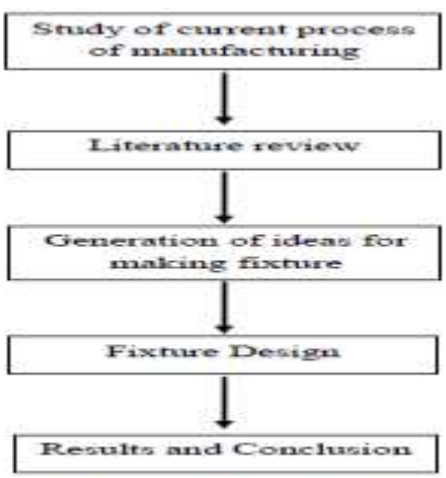


Fig 4.1: Flowchart

Process study: The development of tack welding and full welding fixture started with the study of the existing process used for tack welding and full welding of boom arm assembly. Currently boom arm assembly is being manufactured using first principle of engineering, where all measurements are done manually & positioning or fixing of each component takes a lot of time. Literature review: Based on the problem definition some papers related to fixture design are collected and the papers are studied. After considering the literature gap the further action is to be taken.

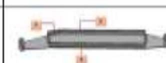
Fixture concepts: In this step study related to fixture, types of fixture, and elements of fixture and also fixture design concepts.

Fixture Design: In this stage study the component drawing of boom arm assembly and collect the data like component material, thickness of components and some of the mechanical properties. After collecting the above inputs some ideas are to be generated and using the best suitable idea some initial drawings are developed in CATIA-V5R20 software.

Results and Conclusion: Time comparison is made without using fixture and with using fixture and then results are tabulated. Based on the results, conclusions are made.

V. PROCESS SHEET WITHOUT USING FIXTURE

5.1 TACK WELDING PROCESS SHEET

Opn. No.	Operation Description	Op. Time (min)		Special Instructions
1	Remove Front plate from storing rack and keep it on Table ensuring a uniform height of 6.5mm from the table.	8.2		Use packing pieces of 6.5mm
2	Place the steel bosses A, B,C and D at respective places.	25		Tack weld the steel bosses and maintain perpendicularity with respect to front plate using trisquare.
3	Place the mid plates A, E & F over the front plates with a land of 6mm from plate ends.	15		End plates not to be put as there is inside welding of steel bosses
4	Tack weld the mid plates to the front plate. (no. of tacks=9)	15		
Description Boom Arm Assembly				Sheet 1 of 6

Opn. No.	Operation Description	Op. Time (min)		Special Instructions
5	Remove another front plate from the storing rack.	1		
6	Cover the top of the subassembly with the 2nd front plate and tack weld the front plate.	12		
7	Tack weld the patch plate A at the top of the steel boss D.	4.6		
8	Weld inside the steel bosses A,B and C.	20.2		Weld dimension (6*6)
9	Rotate the subassembly.	10		
10	Weld inside the steel bosses A,B and C	20.2		
Description Boom Arm Assembly				Sheet 2 of 6

Opn. No.	Operation Description	Op. Time (min)		Special Instructions
11	Tack weld the other patch plate to the opposite side of the steel boss D.	4.6		
12	Tack weld the remaining four mid plates (B, C, D & G) to the front plate.	28.8		
13	Full weld all around the steel boss C.	7.8		Weld dimension (6*6)
14	Rotate the subassembly	10		
15	Full weld the other side of the steel boss C	7.8		Weld dimension (6*6)
16	Tack weld the remaining mid plates to the other front plate.	8		

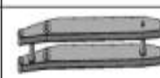
Description	
Boom Arm Assembly	Sheet 3 of 6

Opn. No.	Operation Description	Op. Time (min)		Special Instructions
17	Prepare two subassemblies.	396.4 (198.2×2)		
18	Place one subassembly on the table.	4.1		Provide packing if necessary.
19	Remove two tubes from the storing rack.	4.1		
20	Place one tube over the first subassembly. Maintain a centre to centre distance of 267mm between the steel boss A and the tube.	20		Ensure the tube is perpendicular to the sub assembly.
21	Place the other tube concentrically with the steel boss C and tack weld the tubes to fix their positions.	5		Use strong tacks for tack welding.

Description	
Boom Arm Assembly	Sheet 4 of 6

Opn. No.	Operation Description	Op. Time (min)		Special Instructions
22	Tack weld pitch plates to the subassembly around the bottom of both the tubes.	4		
23	Insert two other pitch plates each through one of the tubes.	0.8		
24	Insert two pins through the steel bosses A and B.	5.3		
25	Place the other subassembly on top by locating the bores with the help of the pins.	10		Maintain parallelism between the two sub-assemblies and ensure a distance of 192mm between them.
26	Tack weld the tubes to the other subassembly.	4.6		Use strong tacks for tack welding.

Description	
Boom Arm Assembly	Sheet 5 of 6

Opn. No.	Operation Description	Op. Time (min)		Special Instructions
27	Tack weld the previously inserted pitch plates to the other subassembly.	4		
28	Remove the pins and prepare the boom arm assembly.	5		

Description	
Boom Arm Assembly	Sheet 6 of 6

Standard time	436.3 min
Setup time	15 min
Total time	478.3 min

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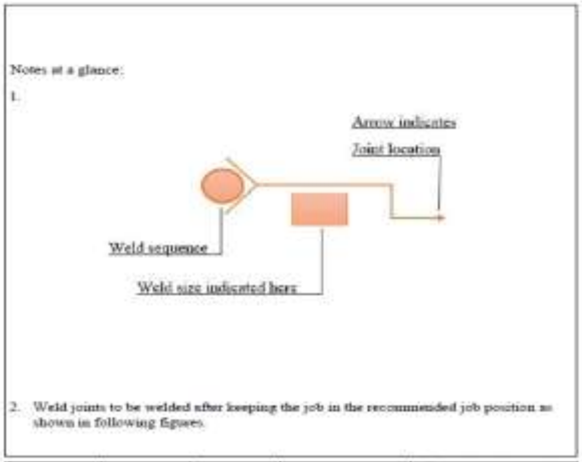
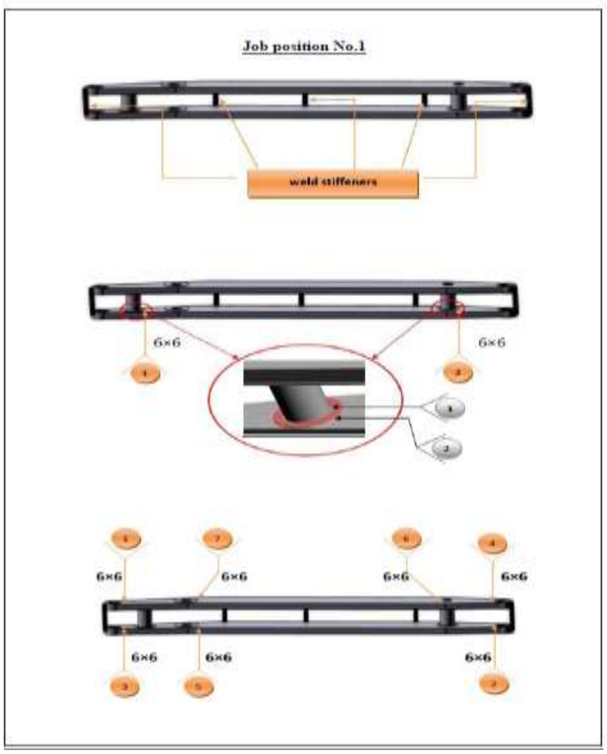
5.2 FULL WELDING PROCESS SHEET



Welding process	Current (in amps)	Voltage (in volts)	Temperature (in ℃)	Boom Arm Assembly Full welding
GMAW Consumable Dia 1.2mm Solid Wire	280-340	28-34	150 ℃	Sheet 1 of 6



VI. FIXTURE DESIGN AND DEVELOPMENT

6.1 FIXTURE DESIGN CONCEPTS

Fixture planning is to conceptualize a fundamental apparatus arrangement through examining all the accessible data in regards to the material and geometry of the work piece, operations obliged, preparing gear for the operations and the administrator. The following design criteria must be observed during the procedure of fixture design:

- Design specification.
- Factory standards.
- Ease of use.
- Minimum changeover/setup.

6.2 FIXTURE DESIGN

Boom arm assembly has mainly two sub-assemblies, so first develop a tack welding fixture for one sub-assembly. It mainly consists of front plates, mid plates, steel bosses, patch plates and pitch plates. In boom arm assembly following are the Critical to Quality (CTQ) Issues

- Orientation of the Tube
- Gap between the two sub-assemblies
- Clamping
- Land between the mid-plates and the front plate edge in a sub-assembly
- Perpendicularity between mid plates and front plate.

6.3 MATERIAL SELECTION

Material selection is a matter of quality and cost. The properties of the material must be adequate to meet design requirements and service conditions. Selection of material depends upon the function of manufacturing parts.

6.4 MATERIAL USED FOR THE FIXTURES

Hot Rolled, Medium and High Tensile, Structural Steel bearing a code IS 2062 is the material used for the fixture components. These steels are suitable for welded, bolted and riveted structures and for general engineering purposes.

This material is used where welding is employed for fabrication and guaranteed weld ability is required. Its specification is as follows.

Table 6.1: Mechanical properties of fixture

Yield stress (in Mpa)			Ultimate tensile strength (in MPa)	% Elongation
<20mm	20-40mm	>40mm		
250	240	230	410	23%

Table 6.2: Chemical composition of fixture

Carbon (C)	0.23 %
Manganese (Mn)	1.50 %
Sulphur (S)	0.05 %
Phosphorous (P)	0.05 %
Silicon (Si)	0.40 %
Carbon equivalent	0.41%

Table 6.3: Physical properties of fixture

Impact toughness	Charpy v-notch (at room temperature)
Energy absorption (in joules)	27 J

6.5 TACK WELDING FIXTURE

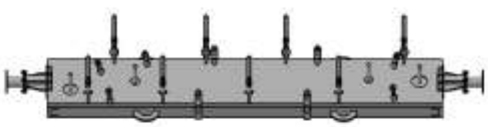


Fig.6.1: Tack welding fixture

Table 6.4 Parts list of Tack Welding fixture

Part no.	Description	Qty.
1	Tack welding fixture bed	1
2	Tack welding fixture support system	1
3	Toggle clamps	8
4	Positioner A	2
5	Positioner E	2
6	Positioner B,C,D,F,G	5
7	Boss clamp bolts	4

6.5TACK WELDING FIXTURE COMPONENTS

Fig.6.1: Tack welding fixture bed

Fig.6.6: Tack welding fixture support system

Fig.6.2:Positioner A (open)

Fig.6.3:Positioner A (close)

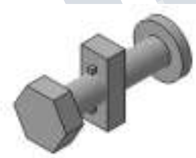


Fig.6.4:Positioner B,C,D,F,G (open)

Fig.6.5:Positioner B,C,D,F,G (close)

Fig.6.6:Positioner E (open)

Fig.6.7:Positioner E (close)

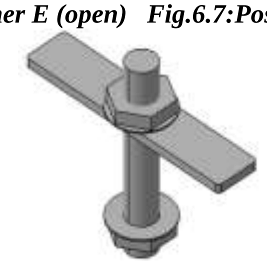


Fig.6.8: Boss clamping arrangement

6.6 FULL WELDING FIXTURE

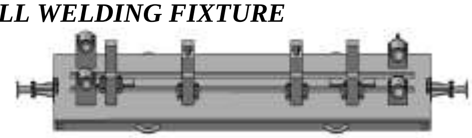


Fig.6.9: Full welding fixture

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6.7 FULL WELDING FIXTURE COMPONENTS

Fig.6.10: Full welding fixture bed

Fig.6.11: Full welding fixture support system

Fig.6.12: Plummer block A assembly Fig.6.13: Plummer block B assembly

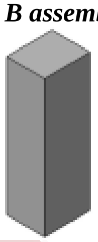


Fig.6.14: Stopper block

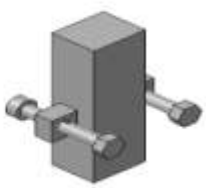


Fig.6.15:Positioner(150)-open Fig.6.16:Positioner(150)-close

Fig.6.17:Positioner(236)-open Fig.6.18:Positioner(236)-close

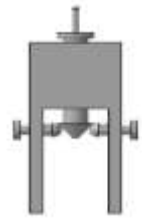
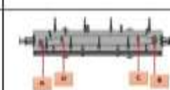
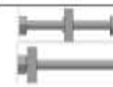
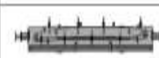


Fig.6.19: Internal stiffener-open Fig.6.20: Internal stiffener-close

VII. PROCESS SHEET AFTER USING FIXTURE

7.1 TACK WELDING PROCESS SHEET

Opn. No.	Operation Description	Op. Time (min)		Special Instructions
1	Remove front plate from storing rack and keep it on the fixture bed by locating bores with the help of the clamping bolts.	5		
2	Place the steel bosses A, B, C & D in the respective holes and tack weld them.	9.1		
3	Bring forward all the 9 positioners by rotating the screw clockwise.	3		

Opn. No.	Operation Description	Op. Time (min)		Special Instructions
4	Place the mid plates A, E & F over the front plate, so that the positioners at that position must support the mid plates placed.	3.6		
5	Tack weld the mid plates to the front plate. (no. of tacks=9)	15		
6	Remove another front plate from the storing rack.	1		
7	Place the 2nd front plate over the mid plates by locating bores with the help of the clamping bolts.	4		
8	Lock all the 8 toggle clamps to securely fix the top plate.	2.5		

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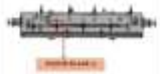
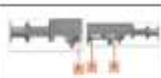
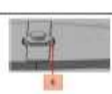
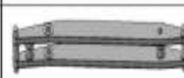
Opn. No.	Operation Description	Op. Time (min)		Special Instructions
9	Tack weld the patch plate A on top of the 2nd front plate around the steel boss D.	4.6		
10	Secure the position of the bosses by means of clamping arrangement.	8		
11	Tack weld the 2nd front plate.	4		
12	Weld inside the steel bosses A, B and C.	20.2		Weld dimension (6*6)
13	Rotate the fixture by 180 deg.	5		
14	Weld inside the steel bosses A, B and C.	20.2		Weld dimension (6*6)

Opn. No.	Operation Description	Op. Time (min)		Special Instructions
15	Place the remaining four mid plates (B, C, D & G) in between the two front plates, so that the positioners at that position must support the mid plates placed.	16		The supporting end of the postioners must be thoroughly in surface contact with the mid plates.
16	Tack weld the remaining mid plates to the front plate.	8		
17	Rotate the fixture back by 180 deg.	5		
18	Tack weld the remaining mid plates to the other front plate.	8		
19	Full weld all around the steel boss C.	7.8		Weld dimension (6*6)

Opn. No.	Operation Description	Op. Time (min)		Special Instructions
20	Prepare two subassemblies	300 (150*2)		
21	Place one subassembly on the table.	4.1		
22	Remove two tubes from the storing rack.	4.1		
23	Place the tube template over the subassembly as indicated.	0.5		
24	Tack weld one tube over the subassembly by locating its position using the tube template.	4		Use strong tacks for tack welding.
25	Tack weld the other tube over the subassembly by locating it concentrically with the steel boss C.	4		Use strong tacks for tack welding.

Opn. No.	Operation Description	Op. Time (min)		Special Instructions
26	Tack weld pitch plates to the subassembly around the bottom of both the tubes.	4		
27	Insert two other pitch plates each through one of the tubes.	0.8		
28	Insert two pins through the steel bosses A and B.	3.3		
29	Place the other subassembly on top by locating the bores with the help of the pins.	7.2		
30	Tack weld the tubes to the other subassembly.	8		Use strong tacks for tack welding.

Opn. No.	Operation Description	Op. Time (min)		Special Instructions
31	Tack weld the previously inserted pitch plates to the other subassembly.	4		
32	Remove the pins and prepare the boom arm assembly.	5		

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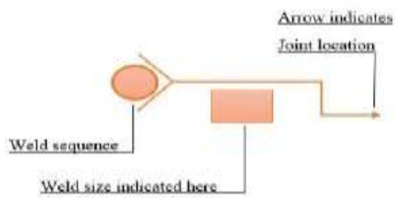
Standard time	351 min
Setup time	15 min
Total time	366 min

7.2 FULL WELDING PROCESS SHEET

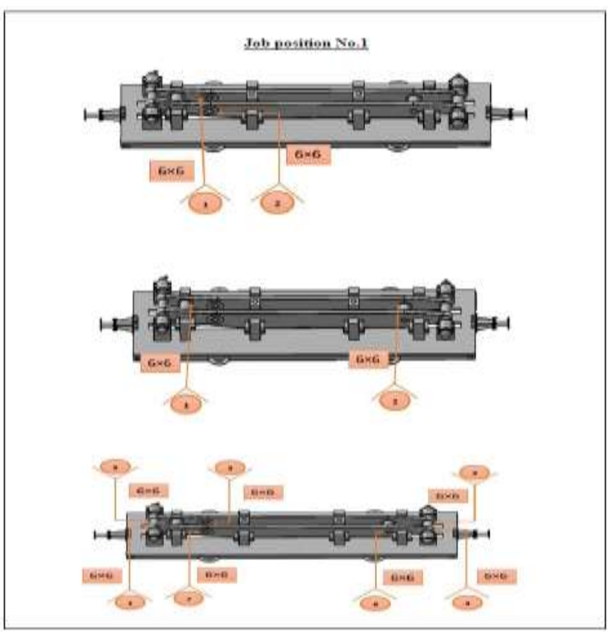
Notes at a glance:

1.



2. Weld joints to be welded after keeping the job in the recommended job position as shown in following figures.

Welding process	Current (in amps)	Voltage (in volts)	Temperature (in ℃)	Boom arm assembly Full welding
GMAW Consumable Dia 1.2mm Solid Wire	280-340	28-34	150 ℃	Sheet 1 of 6



VIII. EFFICIENCY

Following are the approximate results of the designed fixtures and are tabulated and shown in the following figures.

- The total time for boom arm assembly without using fixture is 478.3 minutes and after using the fixtures it may reduce to around 366 minutes thus saving valuable112.3minutes.

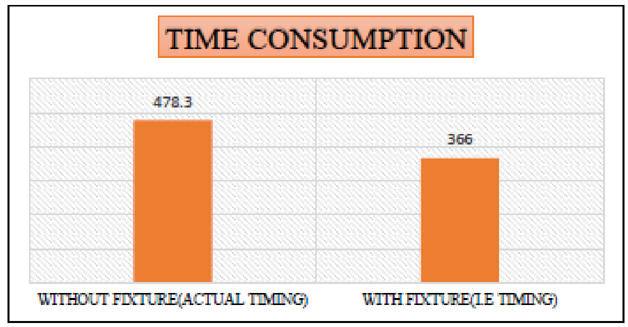


Fig.8.1: Comparison of time consumption

- The productivity of tack welding boom arm assembly without fixture is 45 units per month and after using the fixture it may increase to 60 units per month.

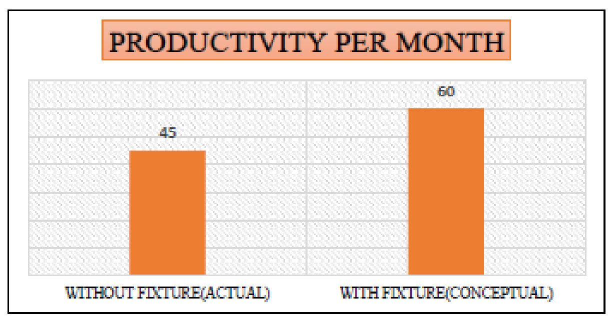


Fig.8.2: Comparison of productivity

- Striking reduction in welding distortion can be achieved due to fixtures and stiffeners designed.

IX.CONCLUSION AND FUTURE SCOPE

9.1 CONCLUSION

In this dissertation work, tack welding and full welding fixtures have been designed to reduce the cycle time and welding distortions for boom arm assembly. Also the 3D model is generated using CATIA-V5R20 modeling software. It is expected that the designed fixtures may satisfy the functional requirements and after implementation of the fixtures the process may be able to produce better product within better time.

In this project the design of fixtures may result in

- Reduced cycle time.
- Increase in production rate.
- Decrease in welding distortions.

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