DESIGN AND DEVELOPMENT FOR SPOT WELDING JIG FOR WINDOW LOWER AND UPPER OF MIDDLE BLOCK IN SS AC EMU

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ABSTRACT

BEML is a public sector undertaking by Government of India with head quarters in Bangalore. In addition to other equipments, it manufactures SSACEMU coaches (car) for Indian Railways .In metalworking and woodworking, a jig is a type of custom-made tool used to control the location and/or motion of another. Precisely a device that does both functions (holding the work and guiding a tool) is called a jig.

The car body of stainless steel alter SSACEMU consists of five blocks for a side wall i.e. three identical middle blocks and two end blocks. These blocks are constructed on respective jigs. The middle block consists of door post sub-assembly (left hand side and right hand side), window sub-assembly (upper and lower). The manufacturing of middle block is carried out on a single jig. This manufacturing process has a problem has a problem of high distortion and low productivity. The high distortion is due to immense amount of heat dissipation during spot welding process and low productivity is due to assembly of more number of sub-assemblies in and as a single entity.

This paper reports the results in respect of the project, THE DESIGN AND DEVELOPMENT OF JIG FOR WINDOW SUB ASSEMBLY. The study is carried out such that it decreases the distortions and improves productivity considerably. It is achieved by designing sub-assembly jigs for WINDOW LOWER AND UPPER. The design is made by using AUTOCAD and CATIA software’s. As there is localized heat distribution in the separate jigs, the distortion effect is greatly reduced and productivity is improved due to reduction in cycle time and improvement in quality.

Keywords: BEML, Sub Assembly Jig, Window Lower and Upper, Productivity, Quality, Side Wall Structure, Welding, Car Body.
I. INTRODUCTION

BEML is a public sector undertaking by Government of India with head quarters in Bangalore. In addition to other equipments, it manufactures SSACEMU coaches (car) for Indian Railways. In metalworking and woodworking, a jig is a type of custom-made tool used to control the location and/or motion of another. Precisely a device that does both functions (holding the work and guiding a tool) is called a jig.

The car body structure consists of the following main parts namely Underframe structure, Side wall structure, Roof structure, End structure and Cab structure. In which I had studied about the sidewall structure. As a part of the project work I had studied the design and manufacture of sidewall of SSACEMU coach. The BEML had been using single Jig as an entity for the manufacturing of a unit of side wall. During our study in the project I have observed that a sub assembly jig substantially improves the productivity of the company and lowers the cost of the production. This paper reports the results obtained during the course of our project.

II. MATERIALS AND METHODS

Description of Coach/Car

The exterior of the car is of dull finish stainless steel. The appearance of the car exterior is designed to have a modern and aesthetically pleasing profile. The general exterior layout is Driver Trailer car (DT-Car), Motor car (M-Car) & Trailer car (T-Car) is shown in Figure below.

![General External layout of DT, M & T-car](image.png)
The car body of the vehicle is made of high tensile cold rolled stainless steel (SUS301L, SUS304L-JIS 4305) and hot rolled atmospheric corrosion resisting steels (SMA 490B- JIS 3114). The car body shell is designed according to car body profile, which meets the specified requirements for kinematic envelope, ride quality, structural strength, styling considerations and maintainability.

The car body is constructed of a welded structure consisting of the under frame, side, end, roof and cab structure.

Side wall structure consists of posts, panels, vertical and horizontal frames, cantrails, etc, made up of pressed and rolled stainless steel sections.

The frames incorporate attachment points for the external skin and prevent buckling. The posts and frames transmit loads between side sills and cantrails. The panels from the external shell and transmit longitudinal and vertical forces between the under frame and the roof.

The cantrails take up longitudinal forces that are transmitted from the sidewalls. The side posts and frames transmit vertical loading between side sills and cantrails. The side panels from the external shell and transmit longitudinal and vertical forces between the under frame and the roof.

The side wall structure is made of stainless steel and includes the external sheathing, vertical posts and horizontal frames. The side external sheathing consists of flat panel. Rain gutters are installed on both the sides below cantrails which is constructed of stainless steel. They shall prevent rain water to drip onto passenger at the door positions. The drainpipes are fitted on the cab and end part in the recess roof.

The vertical side post and the horizontal frames are formed of Hat section – pressings.

The side panel is composed of flat steel sheet, with cut-outs for the windows.

The side inner frames are formed if angle-section for fixing of the interior panels.

Both side cantrails are longitudinal, pressings with a vertical reinforcing strip welded at each side post.

Material: Panel – SUS3011-DLT (Dull Finish)
Frame – SUS3011-ST

The side wall structure is spot welded on a jig. A jig is a type of tool used to control the location or motion of another tool. On the other hand, a fixture is a support or work holding device used to hold work in place.

Depending upon method of operation and construction, drill jigs can be broadly classified as follows:

(a) Plate Jig
(b) Leaf Jig
(c) Box jig
(d) Indexing Jig
(e) Pump jig

**Plate Jig**

This is the simplest type of jig. Plate jig consists of single bush plate. This plate has a provision of loading and unloading of work piece, clamping and chip removal. Figure 3.26 shows the construction of plate jig. The work piece profile is located by six location pins and clamp by two knurled screws against location pins. In any drill jig the work piece should be supported adequately against bending due to the downward thrust of drill. The disadvantage of plate jig is that only one surface can be drilled at one loading and drilling forces are generally directed toward the clamping element. Hence, clamps should be rigid enough to withstand drilling forces.
Information in detail regarding jigs and fixtures is available in workshop Technology Volume I and II by Hazra Choudry, production Technology volume I by O.P. Khanna & M. Lal & Introduction to jig and tool design by Kempster and M.H.A.

**Aim of the study**

The main objective of the project is to improve the productivity and quality, where these can be expressed in terms of cycle time, no. Of components produced and distortion.

The possible reasons for distortion are Vibrations, Heavy loads, Heat dissipation, Clamping, Positioning, Welding defects.

Primarily I studied the effect of above mentioned factors on the frame. From all the above mentioned consequent factors the distortion parameters were observed to be less significant. In spot welding as there is maximum heat dissipation to the frame. This led us to assume that maximum spring back action in terms of quality is due to thermal distortion so the project has been carried out in this sense.

In the side wall assembly of stainless steel AC Electric multiple unit (SS AC EMU) Car, the middle block is a critical part of side wall assembly. While doing spot welding for the frame, as the frame is too large many distortions occur in the frame. Moreover it requires 4 persons to work on a single assembly for a period of 8 hours to finish it. Hence if the entire large jig is divided into 3 parts viz., window upper, window lower and Left Hand & Right Hand, it becomes much easier to handle the jigs. Besides as the size of each part is less, the adopting this method, 4 persons by working for 8 hours can produce 2 assemblies i.e., the cycle time can be reduced by almost half and the productivity can be increased by two times.

**DESIGN INPUTS**

The design is carried out accordingly and finally involved with manufacturing and fabrication

**Frame Assembly Window Lower (Part Drawing)**
Frame Assembly Window Upper (Part Drawing)

Drafting of window lower and upper jigs in Auto CAD
Window Lower Frame Assembly

Window Upper Frame Assembly
Window Upper Jig Table

Window Lower Jig Table

NOTE: The numbers in the above two figures represents the item number in table 1

Cost and Estimation

Estimation is an art of finding the material requirement, cost of the component or product and the time which is likely to be incurred in the manufacturing. Cost and estimation is one of the most important steps in project management. A cost estimate establishes the base line of the project cost at different stages of development of the project. A cost estimate at a given stage of project development represents a prediction provided by the cost engineer or estimator on the basis of available data. According to American Association of Cost Engineers, cost engineering is defined as that area of engineering practice where engineering judgement and experience are utilized in the application of scientific principles and techniques to the problem of cost estimation, cost control and profitability.
Advantages

- Estimation helps in deciding the manufacturing and selling policies.
- Estimation helps in filling up the tender enquiries.
- It helps in deciding about the amount of overheads which helps in comparing and checking the actual overheads of the factory.
- It helps to decide about the wage rates of the work.

Cost of materials used in fabrication

- Density of the material used = 7810 kg/m³.
- Cost of the plate material (mild steel) = 52 Rs./kg.

The cost estimation of various parts used for window lower and upper jigs is given in table 1

Table 1

<table>
<thead>
<tr>
<th>ITEM NO</th>
<th>DESCRIPTION</th>
<th>SIZE(mm)</th>
<th>QTY</th>
<th>VOLUME (m³)</th>
<th>WEIGHT (Kg)</th>
<th>COST(Rs.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Upper Base plate</td>
<td>2050×600×16</td>
<td>1</td>
<td>0.01968</td>
<td>153.70</td>
<td>7992.4</td>
</tr>
<tr>
<td>2</td>
<td>Square Tube1</td>
<td>1790×45×45</td>
<td>8</td>
<td>0.003625</td>
<td>28.3093</td>
<td>11776.66</td>
</tr>
<tr>
<td>3</td>
<td>Square Tube2</td>
<td>790×45×45</td>
<td>4</td>
<td>0.00160</td>
<td>12.494</td>
<td>2598.752</td>
</tr>
<tr>
<td>4</td>
<td>Square Tube3</td>
<td>340×45×45</td>
<td>4</td>
<td>0.00069</td>
<td>5.377</td>
<td>1118.416</td>
</tr>
<tr>
<td>5</td>
<td>Leg</td>
<td></td>
<td></td>
<td>0.005312</td>
<td>41.487</td>
<td>17258.592</td>
</tr>
<tr>
<td>6</td>
<td>Lower Base Plate</td>
<td>2050×1050×16</td>
<td>1</td>
<td>0.03444</td>
<td>268.97</td>
<td>13986.44</td>
</tr>
<tr>
<td>7</td>
<td>Strap clamp</td>
<td></td>
<td></td>
<td></td>
<td>200</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Toggle clamp</td>
<td></td>
<td></td>
<td></td>
<td>350</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Locator Pad</td>
<td>25×046.5</td>
<td>25</td>
<td>0.00004243</td>
<td>0.3316</td>
<td>431.08</td>
</tr>
<tr>
<td>10</td>
<td>Supporting plate 1</td>
<td>125×100×5</td>
<td>8</td>
<td>0.0000625</td>
<td>0.4881</td>
<td>203.049</td>
</tr>
<tr>
<td>11</td>
<td>Stopper1</td>
<td>16×16×110</td>
<td>14</td>
<td></td>
<td>70</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Stopper2</td>
<td>16×30×30</td>
<td>12</td>
<td>0.000135</td>
<td>0.1054</td>
<td>65.76</td>
</tr>
<tr>
<td>13</td>
<td>Plate-2</td>
<td>16×100×108</td>
<td>1</td>
<td></td>
<td>512.402</td>
<td>55900</td>
</tr>
</tbody>
</table>

The cost estimation of fabrication of Window upper and lower jig are given below

FABRICATION COST'S:

WINDOW UPPER JIG

<table>
<thead>
<tr>
<th>ITEM NO</th>
<th>DESCRIPTION</th>
<th>SETUP TIME IN MIN (AVG)</th>
<th>MILLING TIME IN MIN (AVG)</th>
<th>TOTAL TIME IN MIN (AVG)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Plate-1</td>
<td>5</td>
<td>15</td>
<td>20</td>
</tr>
<tr>
<td>2</td>
<td>Square Tube-1</td>
<td>10</td>
<td>35</td>
<td>45</td>
</tr>
<tr>
<td>4</td>
<td>Square Tube-3</td>
<td>10</td>
<td>35</td>
<td>45</td>
</tr>
<tr>
<td>11 &amp; 12</td>
<td>Stopper-1 &amp;2</td>
<td>5</td>
<td>15</td>
<td>20</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td></td>
<td></td>
<td>130</td>
</tr>
</tbody>
</table>

Flame Cutting Cost = Rs.250/hour
Total time spent on flame cutting = 2.1 hours
Total cost incurred due to flame cutting (Rs.250/hour) = 2.1×250 = Rs. 525/-
Milling Cost = Rs. 350/hour
Total time spent on milling = 120 min = 2 hours (approx)
Total cost incurred due to flame cutting (Rs. 350/hour) = 2 × 350 = Rs. 700

**WINDOW LOWER JIG**

<table>
<thead>
<tr>
<th>ITEM NO</th>
<th>DESCRIPTION</th>
<th>DIMENSIONS IN (mm)</th>
<th>QUANTITY</th>
<th>TIME IN MIN</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Base Plate</td>
<td>16 × 2050 × 600</td>
<td>1</td>
<td>40</td>
</tr>
<tr>
<td>10</td>
<td>Plate-1</td>
<td>16 × 150 × 150</td>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>2</td>
<td>Square Tube-1</td>
<td>45 × 45 × 1790</td>
<td>4</td>
<td>30</td>
</tr>
<tr>
<td>4</td>
<td>Square Tube-3</td>
<td>45 × 45 × 340</td>
<td>4</td>
<td>20</td>
</tr>
<tr>
<td>11</td>
<td>Stopper-1</td>
<td>16 × 16 × 110</td>
<td>6</td>
<td>10</td>
</tr>
<tr>
<td>12</td>
<td>Stopper-2</td>
<td>16 × 30 × 30</td>
<td>12</td>
<td>10</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>120</strong></td>
</tr>
</tbody>
</table>

Milling Cost = Rs. 350/hour
Total time spent on flame cutting = 2.6 hrs (approx) = 160 min
Total cost incurred due to flame cutting (Rs. 250/hour) = 16 × 250 = Rs. 650

**FLAME CUTTING COST = Rs. 250/HOUR**
Total time spent on flame cutting = 2.6 hrs (approx) = 160 min
Total cost incurred due to flame cutting (Rs. 250/hour) = 2.6 × 250 = Rs. 650

<table>
<thead>
<tr>
<th>ITEM NO</th>
<th>DESCRIPTION</th>
<th>SETUP TIME IN MIN (AVG)</th>
<th>MILLING TIME IN MIN (AVG)</th>
<th>TOTAL TIME IN MIN (AVG)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10, 13</td>
<td>Plate-1 &amp; 2</td>
<td>15</td>
<td>30</td>
<td>45</td>
</tr>
<tr>
<td>2</td>
<td>Square Tube-1</td>
<td>15</td>
<td>35</td>
<td>50</td>
</tr>
<tr>
<td>3</td>
<td>Square Tube-2</td>
<td>10</td>
<td>25</td>
<td>35</td>
</tr>
<tr>
<td>11</td>
<td>Stopper-1</td>
<td>10</td>
<td>30</td>
<td>40</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>170</strong></td>
</tr>
</tbody>
</table>

Milling Cost = Rs. 350/HOUR
Total time spent on milling = 2.8 hours (approx) = 170 min
Total cost of milling (Rs. 350/hr) = 2.8 × 350 = Rs. 980
Welding cost = Rs. 200/hour.
Total time spent for welding = 16 hours.
Total cost incurred due to welding = 16 × 200 = Rs. 3200

**Extra cost**
Painting cost = Rs. 250
Miscellaneous costs = Rs. 250
COST ANALYSIS

Cost comparison between work done on main jig and sub assembly jig is given below

<table>
<thead>
<tr>
<th>SL.NO</th>
<th>FACTOR CONSIDERED</th>
<th>WITHOUT SUB-ASSEMBLY</th>
<th>WITH SUB-ASSEMBLY</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Number of labours needed</td>
<td>4-5</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>Labour cost</td>
<td>Rs.250/-</td>
<td>Rs.250/-</td>
</tr>
<tr>
<td>3</td>
<td>Working hours required per frame (including skinning,</td>
<td>8 hours</td>
<td>4 hours</td>
</tr>
<tr>
<td></td>
<td>loading, spot welding times)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>No. of components per shift</td>
<td>1</td>
<td>4 (three sub components and all three integrated to one component)</td>
</tr>
<tr>
<td>5</td>
<td>Production planned per year</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>6</td>
<td>Labour cost per component</td>
<td>Rs.1600/-</td>
<td>Rs.800/-</td>
</tr>
<tr>
<td>7</td>
<td>Total cost of labour per year</td>
<td>Rs.1,60,000</td>
<td>Rs.80,000</td>
</tr>
<tr>
<td>8</td>
<td>Manufacturing Cost of each component</td>
<td>8x1x250x5+62000=72000</td>
<td>66000 (similar calculation as done)</td>
</tr>
</tbody>
</table>

Life of Jig = 15 years (approx)
Rate of interest = 15%
Salvage value after 15 years = Rs. 18/kg
Salvage value = 512.402x18 = Rs. 9,223.346/-
Equivalent annual cost of jig
From Westermann table:
More information related to the Westermann tables is available on Westermann tables by Herman Jutz4.

\[ A = (P-S) \times i \times (1+i)^n/[(1+i)^n-1] \]

Where A = equivalent annual cost of the jig
P = total cost of jig (All fabrication costs included)
= 1000+650+3200+980+805=6100+55900=62000
S = salvage value = Rs. 9,223.346/-
I = rate of interest = 15%
n = life of jig = 15 years.
A = (62000 – 9223.346) \times 0.15 \times (1+0.15)^{15}/ (1+0.15)^{15}-1 = Rs. 9, 025.785 -
Annual maintenance cost = Rs. 750/year [assumed to be constant for all years]
Labour cost = 1, 00,000 Rs (obtained from the company as fixed pay)
Total cost/year of sub assembly jig = labour cost + annual cost + maintenance cost
=1, 00,000+9,025.785+750
= Rs. 1, 09,775.785/-

Total cost incurred for main jig = 2, 00,000 Rs (Information given by the company as fixed expenses)

Annual savings = total cost incurred for main jig - total cost incurred for sub Assembly

= 2, 00,000 - 1, 09,775.785 = Rs. 90, 224.215/-

**ESTIMATION OF RECOVERY PERIOD**

Payback period in capital budgeting refers to the period of time required to recoup the funds expended in an investment, or to reach the break-even point. For example, a $1000 investment which returned $500 per year would have a two-year payback period. The time value of money is not taken into account. Payback period intuitively measures how long something takes to "pay for itself." All else being equal, shorter payback periods are preferable to longer payback periods.

Amount to be recovered = cost of jig = Rs. 62, 000 /-

Annual savings = Rs. 90, 224.215

Considering the equal payment series method, payback period is calculated as

\[ P = A \left[ \frac{(1+i)^n - 1}{i(1+i)^n} \right] \]

Solving for \( n \)

\[ 62000 = 90,224.215\left[ (1+0.05)^n - 1 \right] / 0.05 (1+0.05)^n \]

\[ n = 0.25 \text{ years} \]

\[ n = 91 \text{ days.} \]

**RESULTS AND CONCLUSIONS**

Jigs are the most modern manufacturing and mass production process. It is an economical means to produce respective work.

The project “**Design and Development of Spot welding Jig for Window Lower and Upper of Middle Block in SSACEMU**” was carried out in the company premises of BEML, Bangalore. After going through a detailed procedure of designing, fabrication, cost and estimation I came to a conclusion that by implementing this sub assembly welding jigs for Window Upper and Lower:

- The production time has been reduced approximately by 50 percentage.
- The production cost per year has been reduced from Rs.200000/- to Rs.100000/-.
- The work of labours has been reduced and their job was made is easier.
- The designed jig can be effectively used for production with reduced production time, production cost, increases the product accuracy in terms of quality and labour work becomes more convenient.
- There was an additional improvement i.e. there was betterment in the quality in terms of distortion due to heating during spot welding.
Hence I conclude that the project aim of reducing the production time along with increasing the accuracy and reducing the production cost has been achieved successfully.

ACKNOWLEDGEMENTS

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