DESIGN & DEVELOPMENT OF MIDDLE BLOCK ASSEMBLY JIG FOR MRS-1 PROJECT

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Abstract BEML Limited (formerly Bharat Earth Movers Limited) was established in May 1964 as a Public Sector Undertaking for manufacture of Rail Coaches & Spare Parts and Mining Equipment at its Bangalore Complex. Metro car body consists of four main modules such as Underframe

structure, Sidewall structure LH/RH, End & Cab structure and Roof structure and it is of 21 metre length. The main assembly roof structure consists of sub-assemblies like ceiling block assembly, curved roof assembly(middle block, end block and cab block) and flat roof assembly (4 meters & 8 meters length).Manufacturing or fabrication of roof structure will be carried out individually sub assembly wise keeping in view of length and material handling difficulty and will be integrated at one stage, i.e. at roof final integration stage. The fabrication techniques used in roof structure are mainly GTAW (Gas Tungsten Arc Welding), GMAW (Gas Metal Arc Welding), Resistance Spot and Seam Welding processes.

Index Terms—Assembly, Design, Jig, Manufacture, Part-modelling, Production. Productivity,

1.INTRODUCTION

JIGS and fixtures are essential to working holding and tool holding devices in industries. These devices facilitate clamping of the workpiece on the machine tool in correct relationship with the cutting tool. Jigs and fixtures are often used in interchangeably and sometimes in pairs, but there is a difference between two terms jigs and fixtures. A jig is usually made of metal which locates and holds the work-piece(s) in a positive manner and also guides the cutting tool(s) such that it is in the correct relationship to the work when machining commences. It is usually necessary for the work to be held in the jig by clamping. The jig is not fixed to the machine table by clamping but is held by hand. Jigs are used for quantity drilling, reaming and tapping for example.

1.1 The purpose of using jigs:

- To reduce the cost of production, by using them, they eliminate the laying out of work and setting up of the tools.
- To increase the production rate.
- To ensure high accuracy of parts produced without any manufacturing defects.
- To provide for interchangeability.
- To ensure heavy and complicated shaped parts are to be machined easily.
- Reduce quality control expenses.
- Increased versatility of the machine tool.
- To provide safety at the work point.

1.2. Types of jigs:

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

Template Jig:

This is the simplest type of jig. It is simply a plate made to the shape and size of the work piece; with the require number of holes made it. It is placed on the work piece and the hole will be made by the drill; which will be guided through the holes in the template plate should be hardened to avoid its frequent replacement. This type of jig is shown in figure 1.

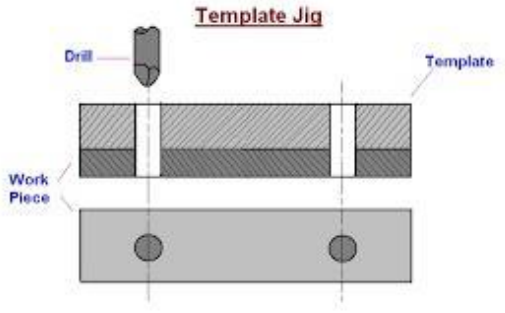

Figure 1

Plate Type Jig:

This is an improvement of the template type of jig. In place of simple holes, drill bushes are provided in the plate to guide the drill. The work piece can be clamped to the plate and holes can be drilled. The plate jig is shown in figure 2.

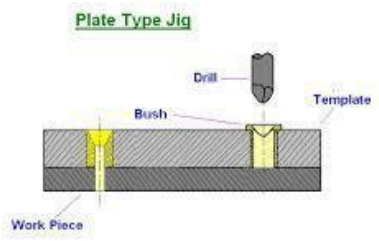

Figure 2

Channel jig:

The channel jig is a simple type of jig having channel like cross section. The component is fitted within the channel is located and clamped by locating the knob. The tool is guided through the drill bush. It is shown in figure 3.

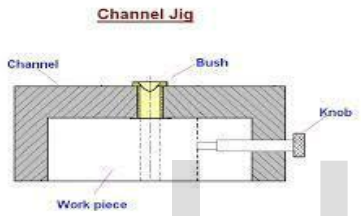

Figure 3

Leaf Jig:

It is also a sort of open type jig, in which the top plate is arrange to swing about a fulcrum point, so that it is completely clears the jig for easy loading and unloading of the work piece. The drill bushes are fitted into the plates, which is also known as leaf. The leaf jig is shown in figure 4.

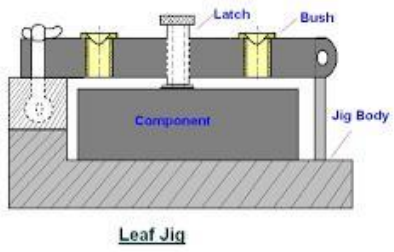

Figure 4

1.3. Advantages of Jigs:

- Productivity: Jigs increase the productivity by eliminating the individual marking, positioning and frequent checking. The operation time is also reduced due to increase in speed, feed and depth of cut because of high clamping rigidity.
- Interchangeability and quality:

  Jigs and fixtures facilitate the production of articles in large quantities with high degree of accuracy, uniform quality and interchangeability at a competitive cost.
- Skill reduction:

  There is no need for skillful setting of work on tool. Jigs make possible to employ unskilled or semi-skilled machine operator to make savings in labour cost.
- Cost reduction:

  Higher production, reduction in scrap, easy assembly and savings in labour cost results in ultimate reduction in unit cost.

1.4. Applications for jigs and fixtures:

Typically, the jigs and fixtures found in a machine shop are for machining operations. Other operations, however, such as assembly, inspection, testing, and layout, are also areas where work holding devices are well suited. There are many distinct variations within each general classification, and many work holders are actually combinations of two or more of the classifications shown.

2.Review Stage

The design and development of the jig is done in various different stages. The process begins with thoroughly understanding the complete manufacturing process of the roof section. The manufacturing processes are taken into consideration while designing the jigs. The part for which the jig is to be built is then designed on a modelling software. Catia V5, Solid Edge 2020, Autodesk student are some of the softwares used in obtaining the 2D and 3D models. We first produce a model of the roof section and then design the jig based on the roof section designs.

2.1. Study of manufacturing process of middle block of roof section

The manufacturing process of the middle block of the roof section generally comprises of 8 different parts which serve a unique purpose in the design of the roof in order to hold all the additional components rigidly. These components are obtained based on the designs obtained from the R and D department according to the customers' demands, which in this case, is the Mumbai Metro Rail Corporation. These parts are manufactured individually on different work stations and assembled together using the most common, spot welding for enhances strength and toughness. During these processes, usually there are errors which vary the overall structure from the design drawings. These errors and corrections are studied deeply in order to obtain an economical and sustainable "error free" production.

2.2. Design and analysis

The R&D department uses CATIA in order to obtain the virtual image or a 3D image of the part to be manufactured. These parts can be later assembled virtually on CATIA. The behavior and compatibility with the other components can be checked and desired corrections can be made before actually manufacturing the components. Hence, we produce a virtual 3D image of the components which are being manufactured in the company based on the dimensions obtained during the study mentioned above. It helps us obtain a clear picture of how the middle block responds when it is processed after placing it on a jig during the assembly. These parts created in the CATIA software are then assembled. The errors are then identified and necessary rectification is done. The above created middle block of the roof section is then analysed on a suitable platform for any deformations on the assembly which is under stress beyond the permissible limits. The component is also subjected to a lot of heat during various welding operations further in the line of manufacturing. This creates heat affected zones which affects these components and are most likely to cause deformation in the component which can affect the shape and dimensional accuracy of the manufactured component which could potentially harm the overall strength of the component. These deformations can be reduced if an appropriate and a precise jig is used. The jig needs to arrest the motion of the component placed on it in all possible directions.

2.3. Final Stage

Design of jigs for the suitable requirements

Jigs are mechanical devices that are used to hold the component in its place by restricting all the degrees of freedom in order to fix the component rigidly so that the welding and other manufacturing processes can be performed smoothly. As per the data collected from the existing jigs used for manufacturing; it has been identified that after the clamps used for the welding processes are removed there is a change in the dimensions beyond the tolerance limits due to a phenomenon of SPRINGBACK EFFECT. Also, we can see a considerable amount of weld distortions in several places because of the heat produced by welding. Keeping all these parameters in mind, we have designed a jig structure which can significantly reduce the distortions and the spring back effect.

Components of New Design

Several parts/components were used in producing 3D model of the middle block of the roof section. The parts used and their details have been mentioned below:

Sl NO.	Quantity	Part no.	Description
1	8	46335	PURLINE
2	8	46327	PURLINE
3	4	46162	CARLINE ASSEMBLY
4	4	46138	PURLINE
5	12	46132	PURLINE
6	2	46131	PURLINE
7	2	46202	CANTRAIL
8	2	46028	CAR LINE ASSEMBLY
9	8	46027	CAR LINE ASSEMBLY

Table 1

CANTRAIL

It is a piece of metal supporting the roof of a metro carriage. The objective is to optimise resistance to shocks, the cantrail/chassis is carried out by both bolting and adhesive bonding. The old cantrail on the fitting side of the coach has been cut in two places to create three shorter sections. The reinforcement part is a forged aluminium component which is bolted to the cantrail. A 3D model of a cantrail is shown in figure 5.

Figure 5

PURLINE

In steel construction, the term purline typically refers to roof framing members that support the roof decking or sheeting Purlines are most commonly used in Metal Building Systems, where Z-shapes are utilized in a manner that allows flexural continuity between spans. (model shown in figure 6)

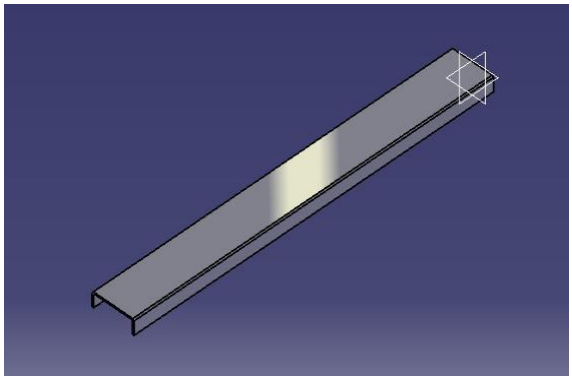

Figure 6

CARLINE

The Carline is an arc shaped structure that supports the roof structure of the middle block. The carline is welded to the cantrail. There are two types of carlines. one is the carline on the two ends of the middle block. The carlines on either side of the middle block are mirror images of each other. The other type of carline is placed between the 2 ends. The part model of the cantrail is shown in figure 7.

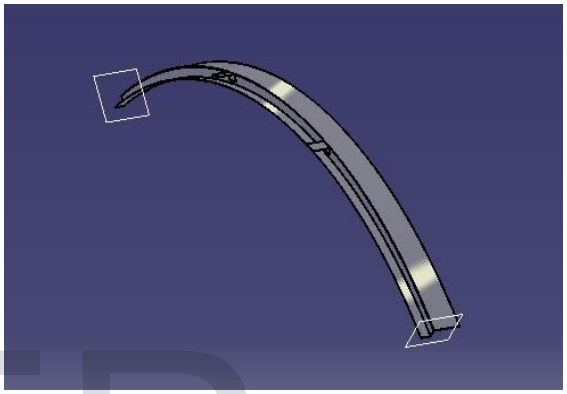

Figure 7

These parts are then assembled. The assembly is obtained on Solid Edge 2020/CATIA.

3.DESIGN OF THE JIG DEVELOPED

Left and Right purline locators

Purline Locators can be found on both the sides of the middle block which essentially hold the purline components in place on either side of the middle block based on the dimensions obtained in the drawing, just before welding the purline to the carline structure. Purline locators also hold an additional purpose by providing an ac exit vent structure on the roof section. This structure of the locator is also an angled cut out measuring 60mm height and 60mm breadth with a cut out of 50mm with a depth of 15mm from the top end at an angle of 99 degrees, as shown in figure 8 and 9.

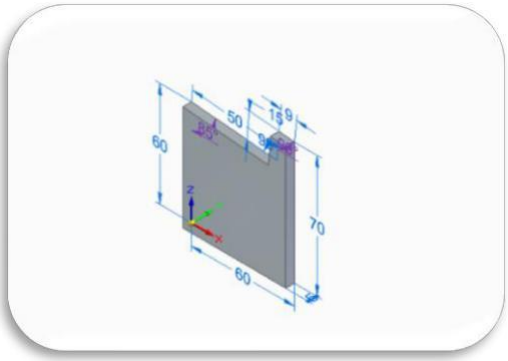

Figure 8

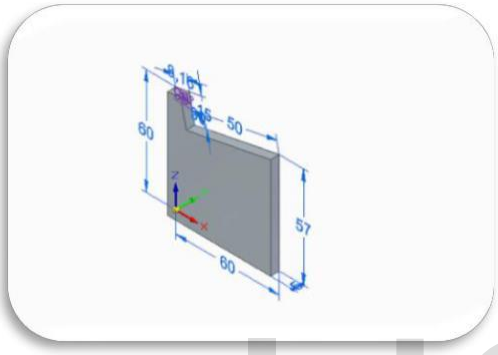

Figure 9

Carline section

The carline middle section is the one which comes right next to the carline end jig. It acts as a guide way to place the carline component accurately as per the dimensions. It does not support the component while welding but only acts as a channel to place the carline and making sure it connects to both the cantrails.(part model shown in figure 10)

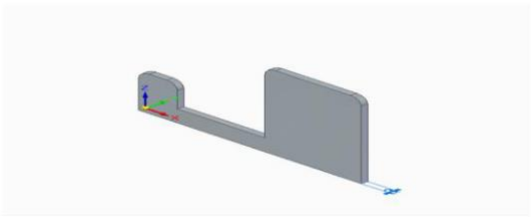

Figure 10

Carline end Locator (clamping)

The carline end jig or the clamper is one of the primary components of the entire middle block jig. This component holds the carline rail with the help of mechanical clamps and is used to hold the entire assembly rigidly by securing and constraining all the degrees of freedom so that the welding process can be done efficiently, based on the required dimensions. One V shaped metal welded to a semi triangular structure, which in turn acts as a guide way for the cantrail and to clamp the carline to the cantrail respectively. The model of this is as shown in figure 11.

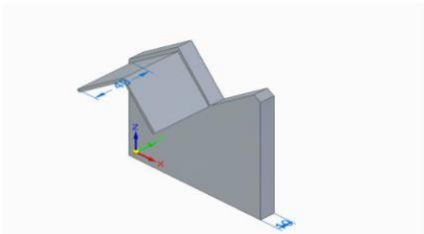

Figure 11

The above part models are then assembled on a workbench/table. On placing these locators in the predetermined positions, we obtain the following Jig Design. (as shown in figure 12)

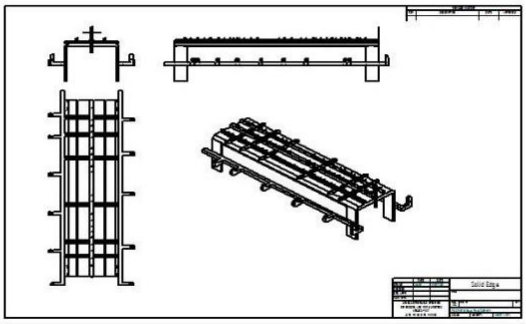

Figure 12

3.1. Evaluating the effect of the newly designed jig on the middle block of the roof section

A new design cannot be approved by the industry for any further operations unless it is tested and validated by the firm that it serves the purpose rightly. Hence, this new designed jig structure is to be tested in the manufacturing process of the middle block of the roof section, by reducing or eliminating the heat distortions which occur when the component is subjected to high temperatures during welding. The new jig is able to reduce the distortions and the Spring back effect, the effective usage of the new jig structure can take place in order to provide a comparatively accurate and precise middle block section after the operations performed during the assembly.

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Results

The jig was tested in the assembly of 5 middle blocks. By incorporating the new dedicated jig for fabrication of roof middle block assembly the followings are the main achievements of this project are summarised as below:

- The Length of the Middle Block Achieved= 5562 mm
- Width of the Middle Block Achieved = 2534.6 mm
- Height of the Middle Block Achieved = 415 mm
- Diagonal of the Middle Block Achieved = 6112 mm
- No. Of Spot welding's missing = Zero

Conclusion

As a result of the above work, by developing a jig in accordance to the drawings, a higher dimensional accuracy is obtained. Important factors like spring back effect during the fabrication process, minimisation of welding distortions, achieving good dimensional accuracy are obtained by providing locators and supports very precisely as per the drawing dimensions. Productivity is improved due to reduction in cycle time and improvement in quality of the middle block. The welding distortion is also found to have significantly lowered. There is a reduction in dimensional error due to Springback. The values obtained for the dimensions of the middle block were closer to the desired value.

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