Design and validation of Vehicle body fixture and process design for a welded assembly

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Abstract— **The objective of this thesis is to develop detailed process planning of a utility vehicle welded assembly and implement it for manufacturing. In body shop, process design plays a key role for setting up welded assembly stages to achieve the required cycle time and production capacity. Many difficulties are faced during process design such as spot welding gun selection and type of fixture selection to achieve the targeted cycle time. During Fixture design proper location, resting and clamping need to be designed based on size of the assembly and spot guns accessibility also need to be validated. For doing process design and fixture design AutoCAD, CATIA software's are used.**

Keywords: **Fixture design, process design, CAFD.**

I. INTRODUCTION

A fixture is a device for locating, holding and supporting a work piece during a manufacturing operation. Fixtures are essential elements of production processes as they are required in most of the automated manufacturing, inspection, and assembly operations.
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 devices must clamp and secure the work piece in that location for the particular processing operation.
Process design of a welded assembly depends upon size of the assembly and number of spot welding points, length of CO_2 welding, cycle time and production capacity.
Process design will study all the parameters to decide the number of stages of production to complete the welded assembly based on cycle time and production capacity.
A feasibility study evaluates the project's potential for success. Feasibility studies come before technical development and project implementation. Feasibility study includes the study of the size, material, cross-sections, etc. This activity helps us to define further capacity planning, process planning, layout, Standard operating procedure, sequence of operation. Process failure mode and effect analysis (PFMEA) is also carried out based on the feasibility study.
Fixture design work is also tedious and time-consuming. The increasingly intense global competition which pushes every manufacturer in industry to make the best effort to sharpen its competitiveness by enhancing the product's quality, squeezing the production costs and reducing the lead time to bring new products to the market, there is a need for the upgrading of fixture design methodology with the hope of making sound fixture design more efficiently and at a lower cost. The development of computer-aided fixture design (CAFD) technology over the past decades can be attributed to the fulfilling of this goal.
Earlier; process, research and design were totally dedicated to a single vehicle and single variant. The proposed design and process is defined and designed for the various variants of a single vehicle. Previous fixture was designed in a 2D modeling interface. There was no 3D design available. New fixture was a need to generalize the production process as per the demand of the vehicle variant. Generalizing the fixture to accommodate the various changes in the body parts helps in reducing the tools manufacturing requirement, cost reduction, time saving. Ultimately, it helps in increase productivity of the organization.

II. FIXTURE DESIGN

Various Design Change Notes are released from R&D to Production Engineering department for the purpose of Product improvement, cost savings, new products introduction, Customer complaints improvements, process improvements.
In the design of a fixture, a definite sequence of design stages is involved. They can be grouped into three broad stages of design development.
Stage One deal with information gathering and analysis. These include product analysis such as the study of design specifications, process planning, examining the processing equipment and considering operator safety and ease of use. In this stage, all the critical dimensions and feasible datum areas are examined in detail.
Stage Two involves the consideration of clamping and locating schemes. A clamping scheme is devised in such a way that it will not interfere with the tools or cutters and are fully compatible with proposed locating surfaces or areas. The locating scheme, using standard elements such as pins, pads, etc. is designed to be consistent with clamping and tool-guiding arrangements.

Stage Three is the design of the structure of the fixture body frame. This is usually built around the work piece as a single element which links all the other elements used for locating, clamping tool-guiding, etc. into an integral frame work.

2.1 Stage one

The size of various parts which will be assembled as a final assembly is noted from the drawing released from the Research and Development center. Also, quantity requirement of individual parts is noted. As the fixture design is done for a welded assembly the total number of spots is noted and the length of CO_2 welding is calculated for each individual mating part.`

A well-designed feasibility study should provide a historical data of project, a description of the product, accounting statements, details of the operations and management, financial data, legal requirements and tax obligations.

The data is further tabulated in the table below:

2.2 Stage Two

2.2.1 Locating procedure

To ensure precision in any machining operation, the work must be properly positioned with respect to the cutter or other tool. This is called referencing. To ensure the desired accuracy, the tool designer must make sure the part is precisely located and rigidly supported. They must also make the tool foolproof.

A tool designer must keep the following points in mind while designing the tool:

- Positioning the locators
- Tolerance
- Foul proofing

When designing a tool, the designer must keep the part tolerance in mind. As a general rule, the tool tolerance should be between 20 and 50 percent of the part tolerance. Specifying tool tolerances closer than 20 percent serves only to increase the cost of the tool and adds little to the quality of the part. Generally, tolerances greater than 50 percent do not guarantee the desired precision. Following are some of the locating tools used in fixture design:

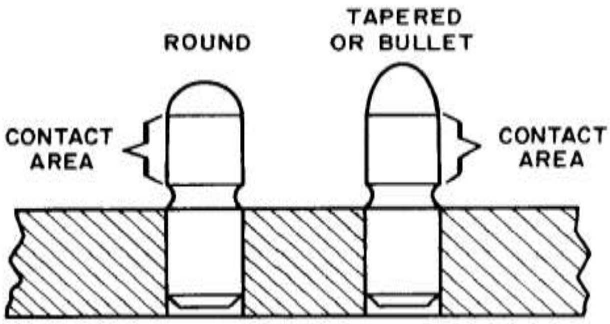

Fig.1 Round and tapered locators

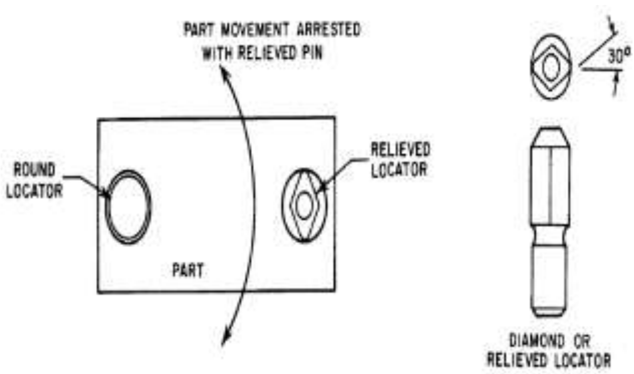

Fig.2 Diamond pin locator

Fig.3 Dowel pin locator

2.2.2 Clamping procedure

The main purpose of a clamping device is to securely hold the position of the part against the locators throughout the machining cycle. To do this, the clamp used must meet the following conditions:

- The clamp must be strong enough to hold the part and to resist movement.
- The clamp must not damage or deform the part.
- The clamp should be fast-acting and allow rapid loading and unloading of parts.

Following are some of the clamps used:

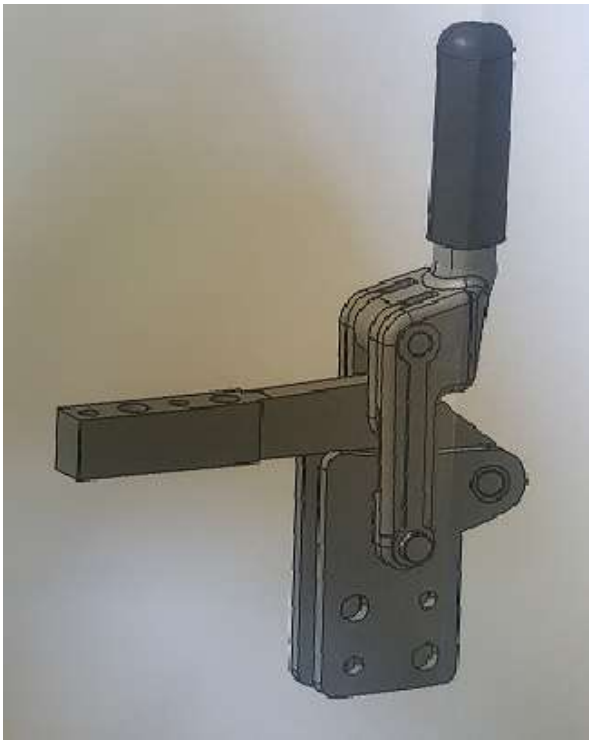

Fig.4 Vertical toggle clamp

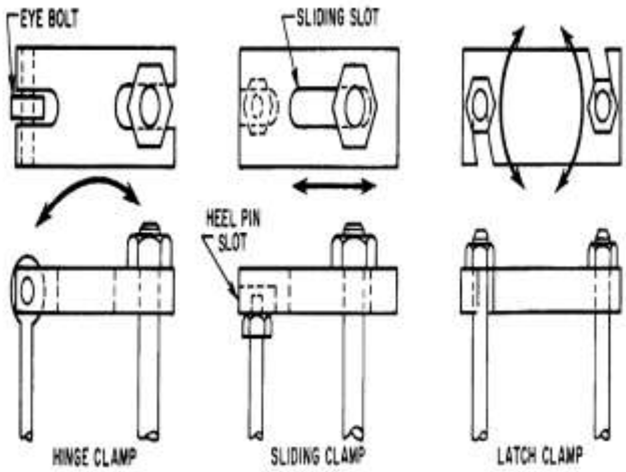

Fig.5 Strap clamps

2.3 Stage three

The structural body provides a rigid base for mounting the locators, supports, clamps, and other details needed to reference, locate, and hold the part while work is performed.

Structural bodies are made in three general forms: cast, welded, and built-up. The materials used for tool bodies are steel, cast iron, aluminum, magnesium, epoxy resins, and wood.

We have used various steel angles. tubes, base plate, random sized plates, shim, miller, etc. Following are some of the structural elements used:

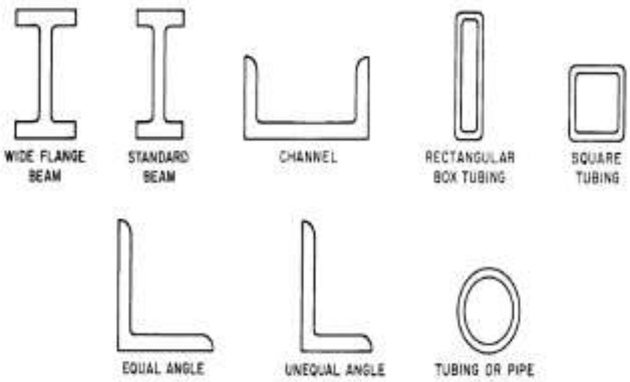

Fig.6 Structural steel

Fig.7 Shim set

III. FIXTURE VALIDATION

- Manufactured Fixture has to be checked for the accuracy and operation.
- First of all, visual inspection is carried out as per drawing.
- The number of clamps and work holding units are validated as per the drawing.
- While doing visual inspection, check the fixture structure is properly bolted and if necessary check the welding is done proper.
- Welding arc is properly coated with anti-rusting paint.
- Ensure for proper coat of primer and paint is applied.
- The nuts and bolts are tightened.
- Locating pin, dowel pins, set screw, etc have to be tightened properly.
- Further, smooth working of the clamps is ensured. Smooth working includes engaging and disengaging position of the clamp.
- The tool room manufacturing team will check if any of the clamp sub assembly is fouling with other components of the fixture.
- After ensuring the above entities, the fixture is set on Co-ordinate Measuring Machine (CMM).
- The fixture is checked on CMM. The CMM report will let us know the accuracy of manufacturing.
- If there is deviation in the CMM report and the desired dimensions, proper actions are taken by the tool room authorities.
- When the corrections are made, the fixture is again set on the CMM machine for validation as per design.
- Once the fixture is ready it is dispatched for mass production.

Following sketch shows the manufactured fixture for a welded assembly:

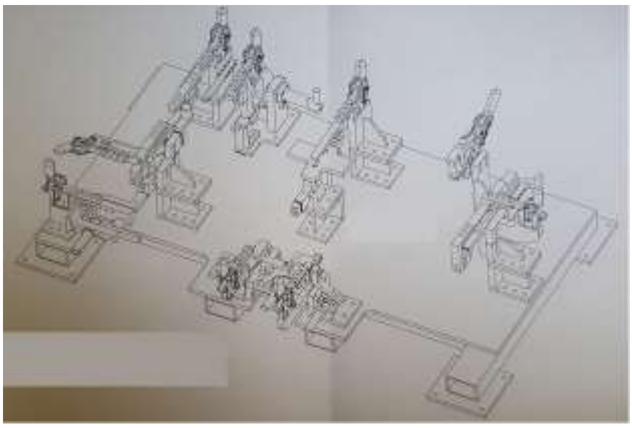

Fig.8 Welding Fixture

IV. PROCESS DESIGN FOR THE WELDED ASSEMBLY

PFMEA is potential failure mode effect analysis or process FMEA. It is an analytical technique utilized and a summary of the team's thoughts (including concerns) when a product or process is developed.
PFMEA is used:
1. To identify potential failure modes which may adversely affect safety or compliance with Govt. regulations.
2. To identify potential design deficiencies before releasing to production.
3. To identify potential process deficiencies before production begins.
4. To identify critical and/or Significant Characteristics.

Hence, it is "Before-the-event" action and not an "After-the-fact" exercise.

Process design includes capacity planning and process planning.

4.1 Capacity Planning

Capacity planning is the process of determining the production capacity needed by an organization to meet changing demands for its products.A discrepancy between the capacity of an organization and the demands of its customers results in inefficiency, either in under-utilized resources or unfulfilled customers. The goal of capacity planning is to minimize this discrepancy.

From a scheduling perspective it is very easy to determine how much capacity (or time) will be required to manufacture a quantity of parts.
Capacity is calculated as:
(Available time for 2 shifts)*(Efficiency)*(working days per month) / (total cycle time)
That is,

$$Capacity = \frac{Available\ Time * Efficiency\ * Working\ days\ per\ month}{Cycle\ \ Time}$$

Table 2 Cycle time calculation

Available time	8 Hrs	480 mins
Lunch Time	30 mins	
80% Man Efficiency	80%	
Available time with 80% Man Efficiency for single shift	360 mins	
Available time with 80% Man Efficiency for two shifts	720 mins	
Weld Parameters		**Cycle time**
Spot weld: 3mm combined thickness (Including gun repositioning)		5sec/spot
CO_2 welding of length upto 150mm	1 min	0.4sec/mm
Stud welding		3sec/stud
AVAILABLE TIME FOR SHIFT (2shiftx8hrsx60minx80 % eff)-(30min lunchx2)	**720** mins	

Capacity can be increased through introducing new techniques, equipment and materials, increasing the number of workers or machines, increasing the number of shifts, or acquiring additional production facilities.

4.2 Process planning

In process planning, the assembly is done in stages for ease of operation. For the selected assembly three stages are defined as per the feasibility study of the drawing. The stage wise operations are named as OPN-10, OPN-20 and OPN-30 (OPN stands for operation number) respectively for stage-1, stage-2 and stage-3.

SOP is known as sequence of operations. SOP is a detailed information about the loading sequence as well as it provides the direction of mounting and / or handling the tools.

The process sequence explained to Production supervisor and Production Engineering team.

V. CONCLUSIONS

By completing the fixture design and process design following major objectives are successfully achieved.

1. Carried out Feasibility study & PFMEA for the welded assembly
2. Process planning and capacity planning of the selected welded assembly done
3. Designed fixture with the help of CAD.
4. Fixture manufacturing & Validation done.
5. Handed over for regular production.

The table shows the comparison in planned cycle time and actual cycle time. We can conclude that the process designed has achieved the planned capacity.

Table 3 Cycle time Comparison

	Planned Cycle Time		**Actual Cycle Time (Stop Watch)**	
Part Name	**Total Cycle Time (Sec)**	**Total Cycle Time (Min)**	**Total Cycle Time (Sec)**	**Total Cycle Time (Min)**
Support angle front LH	161	**16.1**	157	**15.9**
Front wheel box LH	5		7	
Vertical panel reinf. LH	130		125	
Wheel box connecting panel LH/RH	80		80	
Wheel box support Bkt assly LH	106		105	
Second body Mtg support Bkt LH	54		55	
Bracket for front cover	54		57	
Interconnected Bkt LH	29		30	
Support angle middle LH	67		64	
Support angle rear LH	101		97	
Discharge pipe Mtg Bkt S/A	70		74	
Weld nut (M8)	42		40	
Weld Nut (M8)	8		10	
Stud for floor carpet holding	57		55	

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