A Review on Design of a Fixture for Rear Cover

Satyapal Vaghela[1] Abhishek Singh[2]
[1]PG Student, [2]Assistant Professor
[1,2]Department of Mechanical Engineering
[1,2]Atmiya Institute of Technology & Science, India

Abstract— In fixtures which are used for machining process, minimizing work piece deformation due to clamping and cutting forces is necessary due to which machining accuracy can be maintained. The different methodologies used for clamping operation in different application by various authors are discussed in this paper. Fixtures are required in different industries according to specific application. Rear Cover is important part in agriculture tractor. The fixture set up for Rear Cover is done manually, which leads to machining defects, poor quality, increase in rejection rate, more cycle time and more hectic to operator. So, there is need to develop system which can help in achieve quality, increase productivity, elimination of human error, reduction in cycle time.

Key words: fixture, accuracy, clamping, productivity

I. Introduction

The fixture is a special designed tool which holds a work piece in proper position during manufacturing operation. Fixtures are used for supporting and clamping the work piece. Frequent checking, positioning, individual marking and non-uniform quality in manufacturing process can be eliminated by use of fixture. Fixtures help to increase productivity and reduce operation time. Fixture is widely used in the industry because of feature and advantages.

To locate and immobilize work pieces for machining, inspection, assembly and other operations fixtures are used. A fixture consists of a set of locators and clamps. Locators are used to determine the position and orientation of a work piece, whereas clamps exert clamping forces so that the work piece is pressed firmly against locators. Clamping has to be appropriately planned at the stage of machining fixture design. The design of a fixture is a highly complex and intuitive process, which require knowledge. Fixture design plays an important role at the setup planning phase. Proper fixture design is crucial for developing product quality in different terms of accuracy, surface finish and precision of the machined parts In existing design the fixture set up is done manually, so the aim of this project is to replace with hydraulic fixture to save time for loading and unloading of component. Hydraulic fixture provides the manufacturer for flexibility in holding forces and to optimize design for machine operation as well as process function ability [1]

A. Steps of Fixture Design:

Successful fixture design starts with a logical and systematic plan. With a complete analysis of the fixture's functional requirements, very few design problems occur. When they do, chances are some design requirements were forgotten or underestimated. The work piece, processing, tooling and available machine tools may affect the extent of planning needed. Preliminary analysis may take from a few hours up to several days for more complicated fixture designs. Fixture design is a five step problem-solving process. The following is a detailed analysis of each step.

1) *Step 1: Define Requirements:*

To initiate the fixture-design process, clearly state the problem to be solved or needs to be met. State these requirements as broadly as possible, but specifically enough to define the scope of the design project. The designer should ask some basic questions: Is the new tooling required for first-time production or to improve existing production

2) *Step 2: Gather/Analyze Information:*

Collect all relevant data and assemble it for evaluation. The main sources of information are the part print, process sheets, and machine specifications. Make sure that part documents and records are current. For example, verify that the shop print is the current revision, and the processing information is up-to-date. Check with the design department for pending part revisions. An important part of the evaluation process is note taking. Complete, accurate notes allow designers to record important information. With these notes, they should be able to fill in all items on the "Checklist for Design Considerations." All ideas, thoughts, observations, and any other data about the part or fixture are then available for later reference. It is always better to have too many ideas about a particular design than too few. Four categories of design considerations need to be taken into account at this time: work piece specifications, operation variables, availability of equipment, and personnel. These categories, while separately covered here, are actually interdependent. Each is an integral part of the evaluation phase and must be thoroughly thought out before beginning the fixture design.

3) *Step 3: Develop Several Options:*

This phase of the fixture-design process requires the most creativity. A typical workpiece can be located and clamped several different ways. The natural tendency is to think of one solution, then develop and refine it while blocking out other, perhaps better solutions. A designer should brainstorm for several good tooling alternatives, not just choose one path right away. During this phase, the designer's goal should be adding options, not discarding them. In the interest of economy, alternative designs should be developed only far enough to make sure they are feasible and to do a cost estimate. The designer usually starts with at least three options: permanent, modular, and general-purpose workholding. Each of these options has many clamping and locating options of its own. The more standard locating and clamping devices that a designer is familiar with, the more creative he can be. Areas for locating a part include flat exterior surfaces (machined and unmachined), cylindrical and curved exterior surfaces. The exact procedure used to construct the preliminary design sketches is not as important as the items sketched. Generally, the preliminary sketch should start should start with the part to be fixtured. The required locating and supporting elements, including a base, should be the next items added. Then sketch the clamping devices. Finally, add the machine tool and cutting tools. Sketching these items together helps identify any problem areas in the design of the complete fixture.

4) Step 4: Choose the Best Option:

The total cost to manufacture a part is the sum of per-piece run cost, setup cost, and tooling cost. Expressed as a formula:

$$\text{Cost per Part} = \text{Run Cost} + \frac{\text{Setup Cost}}{\text{Lot Size}} + \frac{\text{Tooling Cost}}{\text{Total Quanity Over Tooling Lifetime}}$$

These variables are described below with sample values from three tooling options: a modular fixture, a permanent fixture, and a hydraulically powered permanent fixture.

5) Step 5: Implement the Design:

The final phase of the fixture-design process consists of turning the chosen design approach into reality. Final Details are decided, final drawings are made, and the tooling is built and tested. The following guidelines should be considered during the final-design process to make the fixture less costly while improving its efficiency. These rules are a mix of practical considerations, sound design practices, and common sense [7].

II. IMPORTANT CONSIDERATIONS WHILE DESIGNING FIXTURES

Designing of fixtures depends upon so many factors. These factors are analyzed to get design inputs for jigs and fixtures. The list of such factors is mentioned below:

- Study of work piece, finished component size and geometry
- Type and capacity of the machine, its extent of automation
- Provision of locating devices in the machine
- Available clamping arrangements in the machine
- Available indexing devices, their accuracy
- Evaluation of variability in the performance results of the machine
- Rigidity and of the machine tool under consideration
- Study of ejecting devices, safety devices, etc.

Required level of the accuracy in the work and quality to be produced[1]

III. MEANING OF LOCATION

The location refers to the establishment of a desired relationship between the work piece and the jigs or fixture. Correctness of location directly influences the accuracy of the finished product. The jigs and fixtures are desired so that all undesirable movements of the work piece can be restricted. Determination of the locating points and clamping of the work piece 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 the all possible degrees of freedom of the work piece. Then some of the degrees of freedom or all of them are restrained by making suitable arrangements. These arrangements are called locators. These are described in details below[8]:

A. Principle of Locations:

The principle of location which is discussed here is available in any of the book covering jigs and fixtures. It is important to understand the problem first. Any rectangular part may have three axis: x-axis, y-axis and z-axis. Part can move along any of these axes. At the same time the part can also rotate about these three axis. So total degree of freedom of the part along which it can move is six. For processing the part it is required to fix all the degree of freedom (DOF) by applying suitable locating points. Then clamping of the part is to be done in a fixed and required position. The basic principle which is used to locate the points is described below. Rectangular block is shown in fig. 1. It is made to rest on several points on the jig body. Provide a rest to this work piece 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. Three points supporting is considered as better support then on one point or two points support. Now, Rest the work piece on two points of side surface (x-z). Due to which movement of work piece along y-axis and rotation with respect to z-axis will be fixed. Then provide a support at one point of the adjacent surface (y-z). It will fix other remaining free movements. This principle of location of fixing points on the work piece is also termed as 3-2-1 principle of fixture design. Because in this method numbers of points selected at different faces of the work piece are 3, 2 and 1 respectively. If the operation to be carried out on the cylindrical surface, it requires restriction of the above mentioned free movements also and some more locating provisions must also be provided in addition to use of the Vee block. Guohua Qin[2] discussed fixture clamping sequence. It consists of two parts:

- For the first time he evaluated varying contact forces and work piece position errors in each clamping step by solving a nonlinear mathematical programming problem. This is done by minimizing the total complementary energy of the work piece-fixture system. The prediction proves to be accurate and acceptable after comparing with experimental data and referenced results.
- The optimal clamping sequence is identified based on the deflections of the work piece and minimum position error. Finally, to predict the contact forces and to optimize the clamping sequence three examples are discussed.

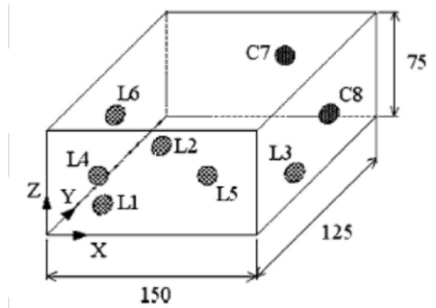

Fig 1: Scheme of 3-2-1 fixture setup [2]

Firstly he prepared mathematical modeling for clamping sequence then the contact forces in clamping sequence is determined as shown in fig. 1. After that he optimized clamping sequence for higher stiffness work piece and then for low stiffness work piece.

He found that using optimal clamping sequence better agreements are achieved between predicted results and experimental data. Work piece machining quality can also be improved.

For a fixture designing, it is very important how to locate the work piece in the fixture. It is described previously that any free body has a total of twelve degrees of freedom as below:

6 translational degrees of freedom: +X, -X, +Y, -Y, +Z, -Z

- And 6 rotational degrees of freedom:
- Clockwise around X axis (CROT-X)
- Anticlockwise around X axis (ACROT-X)
- Clockwise around Y axis (CROT-Y)
- Anticlockwise around Y axis (ACROT-Y)
- Clockwise around Z axis (CROT-Z)
- Anticlockwise around Z axis (ACROT-Z)

It is required to fix all the degrees of freedom except the three transitional degrees of freedom (-X, -Y and -Z) in order to locate the work piece in the fixture. So, 9 degrees of freedom of the work piece needed to be fixed. It can be done by using the 3-2-1 method as shown below in fig. 2.

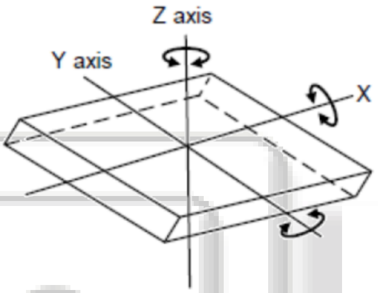

Fig 2 : Available Degree of Freedom of Rectangular Block[8]

Rest the work piece at two points of side surface (XZ), by this way the +Y and ACROT-Z degrees of freedom can be fixed. Now, by resting the work piece at one point of the adjacent surface (YZ), the +X and CROT-Z degrees of freedom can be fixed. So, 9 required degrees of freedom can be fixed by using the 3-2-1 principle of fixture design.

B. Different Methods Used for Location:

There are several methods used for location of a work. The locating arrangement should be decided after studying the type of work, type of operation, degree of accuracy required and volume of mass production to be done. Different locating methods are described below:

1) Flat Locator:

Flat locators are used when flat machined surfaces of the component are to be located. The examples which can be served as a general principle of location for flat locaters is described here in fig. 3.

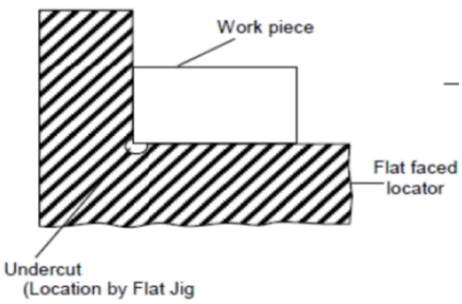

Fig 3: Flat Locator[8]

2) Jack Pin Locator:

Jack pin locator is used for supporting work pieces having rough surfaces by using the button as shown in Fig. 4. Height of the jack pin is adjustable to accommodate the work pieces having variation in their surface texture.

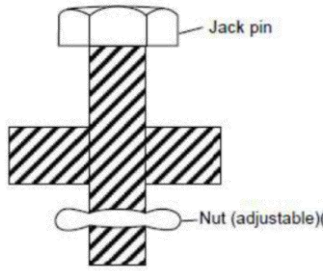

Fig 4: Jack Pin Locator [8]

3) Drill Bush Locator:

The drill bush locator is used for holding and locating the cylindrical shaped work pieces. For locating purpose the bush has conical opening and it is sometimes screwed on the fixture body for the adjustment of height of the work.

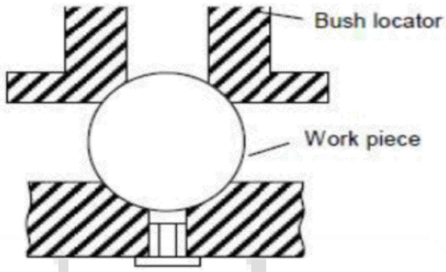

Fig 5: Drill Bush Locator [8]

4) Vee Locators:

This is fast and effective method of locating the work piece with desired level of accuracy. This is used for locating the circular and semi-circular shaped work piece. The main part of locater is 'V' shaped block which is fixed to the fixtures. The locator can be of two types: fixed Vee locator and adjustable Vee locator. The fixed type locator is fixed on the fixture and the adjustable locator can be moved axially to provide proper grip of Vee band to the work piece.

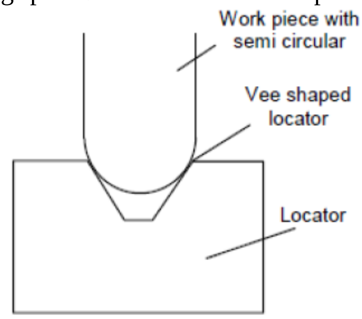

Fig 6: Vee Locator[8]

Y. Wang[3] discussed about identification of locating error and machining error. These errors can be studied by systematic method of error identification and calculation, using finite element analysis (FEA). The machining error, the surface error shown in fig. 7 generated from machining operations by Y. Wang [3].

A methodology of machined surface error calculation and error decomposition was presented in this paper. The research has discussed about (a) surface error including both locating error and machining error, also machining error generated during multi machining operations was analyzed; (b) the sensitivity of individual errors was investigated, and the resultant surface error of locating and machining was evaluated against tolerance; and (c) the method is suitable for both components with complex geometry as well as simple geometry.

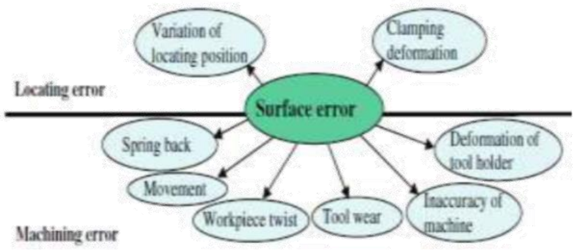

Fig 7: Surface error sources [3]

IV. CLAMPING

To fix the work piece completely a clamping device is required in addition to locating device. Function of a clamping device is to hold the work piece securely in a jig or fixture against the forces applied over it during any operation. Proper clamp in a fixture directly affects the accuracy, quality and production cycle time. Basic requirement of a good clamping device are listed below:

– It should rigidly hold the work piece.
– The work piece which is clamped should not be damaged due to clamping pressure.
– The clamping pressure should be enough to overcome the operating pressure applied on the work piece.
– Clamping device should be capable to be unaffected by the vibrations generated during an operation.
– It should also be user friendly, like clamping and releasing of work piece should be easy and less time consuming. Maintenance should also be easy.
– Clamping pressure should be applied towards the support surfaces or support points so undesired lifting of work piece can be prevented from its supports.
– Clamping faces should be hardened by proper treatments to minimize their wearing out.
– The work pieces made of fragile material the faces of clamping unit should be applied with fiber pads to avoid any damage to work piece.

J. Cecil[4] suggested innovative clamping design approach. The clamping design approach includes identification of clamping surfaces and clamp points on a work piece. This approach can be applied in association with a locator design approach to hold and support the work piece during machining and to position the work piece correctly with respect to the cutting tool. Detailed steps are given in the paper for automated clamp design. The required inputs include CAD model specifications, features identification on the finished work piece, locator points and elements.

A. Different Types of Clamps:

Different types of clamps used with jigs and fixtures are classified into different categories are discussed here:

– Strap Clamp: it is also termed as an edge clamp. In this type clamping device clamping is done with the help of a lever pressure which is acting as a strap on the work piece. Different types of strap clamps are discussed below.
– Heel Clamp: In this type of devices rotation of the clamp in clockwise direction is prevented but it is allowed in anticlockwise direction. For releasing work piece the clamping nut is unscrewed. The free movements in anticlockwise direction takes place before un-securing the nut to release the work piece.

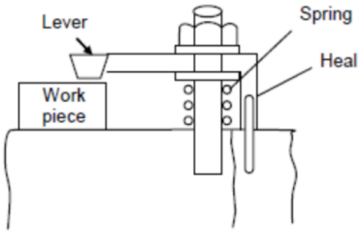

Fig 8: Heel Clamp [8]

– Bridge Clamp: These types of clamps apply more clamping pressure as compared to heel clamp. The clamping pressure on the work piece depends upon the distances ‘x’ and ‘y’ marked. To release the work piece the clamping nut is unscrewed.

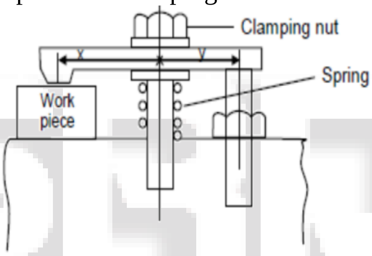

Fig 9: Bridge Clamp[8]

– Edge Clamp or Side Clamp: It is also known as edge clamp. In this type of clamping, the surface to be machined is always clamped above the clamping device. This clamping device used for fixed length work piece. Releasing and clamping of the work piece can be done by unscrewing and screwing of the clamping nut.

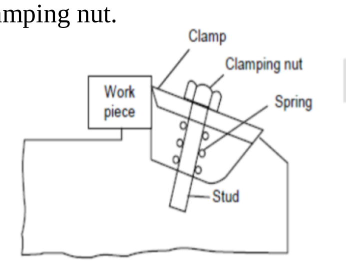

Fig 10: Edge Clamp or Side Clamp[8]

– Screw Clamp: It is also known as clamp screw. This clamping device applies pressure directly on the side faces of the work piece.

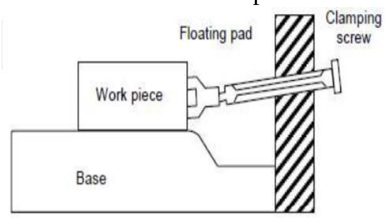

Fig 11: Screw Clamp [8]

This type of clamp includes floating pad at their end which serves the following purposes:

- To prevent displacement of work piece and slip
- To prevent denting of clamping area of work piece
- To prevent deflection of screw

In addition to the above there are some disadvantages associated with this method. The clamping pressure mostly depends on the work piece; it varies from one work piece to other. It is more time consuming and more efforts are required.

Latch Clamp: In this type of clamping the clamping system is normally locked with the help of a latch provided. To unload the work piece the tail end of the latch is pushed which causes the leaf to swing open. In this type of clamping, time consumed in loading and unloading is very less as no screw is tightened but clamping pressure is less than other clamping devices. Life of this type of clamping device is short.

Equalizing Clamp: These types of clamps are used to apply equal pressure on both sides of the work piece The applied pressure can be changed by tightened or loosening the screw

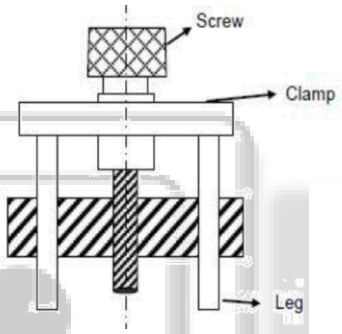

Fig 12: Equalizing Clamps [8]

Power Driven Clamping: Power clamps are operated by the hydraulic or pneumatic power. Power clamps are high pressure clamping, quick acting, easily controllable, reliable and less time consuming. Light duty clamps are used manually when small power is required to operate. Hand clamping leads to variable pressure, operator's fatigue and more cycle time. The power driven clamping over comes problems of hand clamping.

V. CAD FOR FIXTURE DESIGNING

Michael Stampfer[5] presented a paper which describe the problem of setup and fixture planning for the machining of box-shaped parts on the horizontal machining centers. The setup and fixture planning is shown in fig.13. The main topic of this research is the automation of the conceptual design of fixtures shown in fig.13. This topic is deal with the setup planning.

The main aim of the author is integrated handling of tasks of setup and fixture planning and the finding of solution in an integrated system. Based upon the work piece model the setup sequence, the conceptual solution of fixture for each setup is determined automatically by the developed system.

A. *Fixturing Functional Requirements:*

From a layout point of view, fixtures have six basic functional requirements: (1) Stable Resting (2) Accurate Localization (3) Support Reinforcement (4) stable clamping (5) Foreclosure (or total restraint) (6) quality performance

These functions stated above have strong precedence conditions. The first five functions are required at the fixture designing stage in sequential order. When a work piece is placed into a fixture, firstly, it must be assumed a stable resting against the gravity. Then, the locators are located as it should provide accurate localization. Next, supports are provided in place, and in last clamps are activated for the part immobilization. The part location must be maintained in the process of instantiating clamps without work piece lift-off. The performance of the fixture is defined as work piece geometric error during the manufacturing stage. The geometric error is mainly determined by the fixture localization accuracy and the work piece static and elastic deformation during manufacturing. The additional constraints should also to be satisfied such as interference-free and easy loading and unloading.

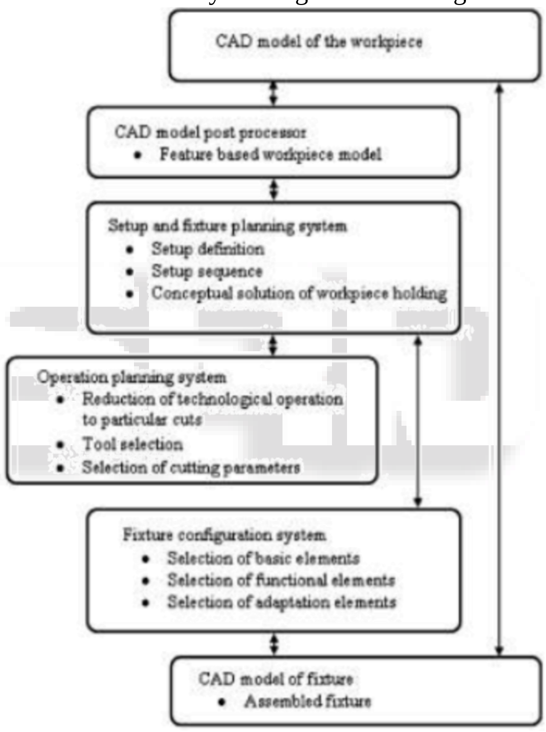

Fig 13: Integrated process planning and fixture planning system [5]

B. *Design Consideration in Fixtures:*

- The main frame of fixture must be strong enough and deflection of the fixture should be kept as minimum as possible. This deflection of fixture is due to forces of cutting, clamping of the work piece or clamping to the machine table. The main frame of the fixture should have enough mass to prevent vibration and chatter.
- Frames should be built from simple sections so that frames can be fastened with screws or welded whenever necessary. The parts of the frame that remain permanently with the fixture may be welded. The parts that need frequent changing may be held with the screws.
- Clamping action should be fast enough and require least amount of effort.

- Clamps should be arranged such that they are readily available and should be easily removed.
- Clamps should be supported with springs so that clamps can be held against the bolt head whenever it's possible.
- If the clamp is to swing off the work piece, it should be permitted to swing as far as it is necessary for removal of the work piece.
- All locator's clamps should be easily visible to the operator and easily accessible for cleaning, positioning or tightening.
- Provision should be made for easy disposal of chip.
- All clamps that need to be adjusted with a wrench should be of same size.
- Work piece should remain stable when it is placed in fixture. If the work piece is rough, three fixed support points should be used. If work piece is smooth, more than three fixed support points can be used.
- The three support points should circumscribe the centre of gravity of the work piece.

The surface area of contact of support should be kept as small as possible without causing damage to the work piece. The damage is due to the clamping or work forces.

VI. REAR COVER

Fig. 14 shows the CAD model of Rear Cover. Rear cover is very important part of the agricultural tractor. Facing and drilling operation is carried out on the Rear cover in Vertical machining centre. For machining process conventional fixture is used. In which clamping is done manually by operator. So it is observed that clamping force will be different every time in manual method as it depends upon operator and applied force will be varied from operator to operator. In manual method, overtightning or loosening of screw leads to machining defects. Due to which the flatness of the rectangular surface which is highlighted in fig.14 is not maintained. Center distance of dowel holes is also not maintained due to surface deformation. Another drawback of manual clamping is extra time loss for loading and unloading operation. This leads to increase in cycle time. To avoid these problems it is required to design new fixture to improve the quality and productivity.

Fig. 14: CAD model of Rear Cover

VII. HYDRAULIC CLAMPING

Hydraulic clamping system uses high-pressure liquids to operate clamps and fix a work piece. In these types of clamping, clamp is actuated by cylinders. Clamping fixtures includes clamping nut which is attached to cylinder ram. A Pressurized fluid pulls ram and clamps against work piece. For unclamping, port connected to unpressurized discharge line. For clamping and unclamping, three way direction control valve, lever and pedal are used. Hydraulically clamped fixtures have many advantages over manually clamped fixtures. Hydraulic clamping is used to eliminate human error and to produce more stable and predictable processes no matter who the operator is or what production shift the machine runs[6].

A. *Advantages of Hydraulic Clamping:*

- More Productivity: More parts will fit within machine envelope due to the high clamp forces generated with small hydraulic components.
- Consistent Clamping Forces: Every cycle, parts are clamped with the same clamping force, eliminating variables and improving process stability.
- Repeatable Clamp Location: Every cycle, parts are clamped in the same location eliminating the variability in part deflection from clamping forces.
- Eliminates Human Error: Assurance that every clamp will be actuated with every cycle, eliminating human error and missed steps.
- Faster: Load and unload times and more productivity when cycle times are operator dependant.
- Ergonomic Efficiency: Allows operators to be consistently more productive with less effort.
- Improved Part Stability: Hydraulic work supports can be used to support the part and/or dampen machining forces without distorting the work piece. Manual work supports are easily ignored, distort the part and cause miss-loads.
- Flexibility: Sophisticated clamping sequences can be developed with 'live' hydraulic systems. Clamping can be sequenced automatically during the machining cycle to provide clearance for cutting tools, to remove forces for finish cuts of close tolerance features, retain parts for robotic loading, reduce cycle times and improve productivity[9]

VIII. CONCLUSION

Proper clamping in a fixture directly affects the accuracy, quality and production cycle time. In manual clamping of the work piece, the clamping force cannot be maintained same every time. Variation in clamping force leads to machining defects. Sometimes excessive clamping force leads to surface deformation of work piece. Manual clamping of work piece also increase cycle time of production. While in hydraulic clamping these all problems can be avoided. Hydraulic fixtures provide constant clamping force, reduce operation time, increase productivity, give high quality of operation, and reduce accidents. So, the hydraulic fixture can be considered as a good option for machining of Rear Cover. The problems due to manual clamping can be avoided if hydraulic fixtures will be used. The proposed fixture will give high quality of operation, enhance the efficiency and fulfill researcher production target. If modern CAD, CAE are used in designing the systems then significant improvement can be assured.

REFERENCES

[1] Shailesh S Pachbhai and Laukik P Raut (2014), "A Review on Design of Fixtures", International Journal of Engineering Research and General Science, Vol. 2, No. 2, ISSN, pp. 2091-2730.
[2] Guohua Qin, Weihong, Zhang Min Wan (2006) "Analysis and Optimal Design of Fixture Clamping Sequence" ASME for publication in the Journal of Manufacturing Science and Engineering.
[3] Y. Wang, X. Chen. N. Gindy (2007) "Surface error decomposition for fixture development" Int J Adv Manuf Technol DOI 10.1007/s00170-005-0270-z.
[4] J. Cecil (2008) "A Clamping Design Approach for Automated Fixture Design" Int J Adv Manuf Technol 18:784–789.
[5] Michael Stampfer (2008) "Automated setup and fixture planning system for box-shaped Parts" International Journal of Advance Manufacturing Technology 45:540–552 DOI 10.1007/s00170-009-1983-1.
[6] Shailesh S Pachbhai and Laukik P Raut (2014), "Design and Development of Hydraulic Fixture for Machining Hydraulic Lift Housing" International Journal of Mechanical Engineering and Robotics Research, Vol.3, No.3, ISSN 2278 – 0149.
[7] http://www.carrlane.com/Articles/StPartCL.cfm
[8] http://www.ignou.ac.in/upload/jig.pdf
[9] http://www.dmtworkholding.com/

