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Research Paper

DESIGN AND DEVELOPMENT OF HYDRAULIC FIXTURE FOR MACHINING HYDRAULIC LIFT HOUSING

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In machining fixtures, minimizing workpiece deformation due to clamping and cutting forces is essential to maintain the machining accuracy. The recent trends in industry are towards adopting the hydraulic techniques, because it save time generates accuracy and it is having some flexibility. Hydraulic Fixture is major application in the field of designing, where in several software's are available for the purpose of design. Hydraulic lift housing is engine part of an agricultural tractor which plays an important role in application of lifting trolley of tractor and machining of hydraulic lift housing is a important task. Loading and unloading of workpiece in manual clamping is time consuming process, so reducing machining time, set up time etc is a main aim of process. The job having cylindrical shape, this is a challenging task for design engineer, hence hydraulic fixture design is incorporated in manufacturing industry. Except toggle clamp, no other option is available to hold cylindrical object, hence special type of fixture is design for this case, which can be used for machining of hydraulic lift housing, Fixture reduces operation time, increases productivity, and best quality of operation is possible. The project deals with the designing of different parts of fixture assembly, 3D modeling by using Pro-E WILDFIRE 5.0, finite element analysis of hydraulic lift housing by using ANSYS software.

Keywords: Fixture, Accuracy, Clamping, Toggle clamp

INTRODUCTION

Background and Context

A fixture is a device used to locate, clamp and support a workpiece during machining, assembly or inspection. The most important criteria's for fixturing are workpiece stability, position accuracy and workpiece deformation. A good fixture design is one that minimizes workpiece geometric error. Workpiece location principles are defined in terms of 3-2-1 fixturing which is widely used workpiece location method for prismatic parts. Force analysis is concerned with checking whether the forces applied by the fixture and clamping are sufficient to maintain static equilibrium (E Caillaudli D *et al*., 1995).

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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 workpiece in that location for the particular processing operation. There are many standard work holding devices such as jaw chucks, machine vises, drill chucks, collets, etc. which are widely used in workshops and are usually kept in stock for general applications. Fixtures are normally designed for a definite operation to process a specific workpiece and are designed and manufactured individually (Kailing LI, *et al*., 2006).

Importance of Fixtures in Manufacturing

The use of fixtures has two fold 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 cost which also translates into enhanced production rate. Furthermore, the use of well-structured fixtures with higher locating and clamping rigidity would allow for increase in cutting speeds and feeds, thereby reducing ***tm***, 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:

Increases 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, Either fully or partly automates the machine tool (Yun-Hui Liu, 2004).

What is Hydraulic Fixture?

A clamping system that uses high-pressure liquids to power clamps and hold a work piece in place. Hydraulically clamped fixtures have many advantages over manually clamped fixtures. In most cases, these benefits reduce costs for manufacturers allowing them to justify the initial investment for a hydraulic clamping system. Hydraulic clamping enables manufacturers to put more intelligence into the fixture eliminating human error and producing a more stable, predictable processes no matter who the operator is or what production shift your machine runs.

Advantages of Hydraulic Fixture

1) **More Productivity:** More parts will fit within machine envelope due to the high clamp forces generated with small hydraulic components.

2) **Consistent Clamping Forces**: Every cycle, parts are clamped with the same clamping force, eliminating variables and improving process stability.

3) **Repeatable Clamp Location**: Every cycle, parts are clamped in the same location eliminating the variability in part deflection from clamping forces.

4) **Eliminates Human Error:** Assurance that every clamp will be actuated with every cycle, eliminating human error and missed steps.

5) **Faster:** Load and unload times and more productivity when cycle times are operator dependant.

6) **Ergonomic Efficiency:** Allows operators to be consistently more productive with less effort.

7) **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.

8) **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.

Problem Identification

With the advent of VMC machining technology and the capability of multi axis machines to perform several operations and reduce the number of set-ups, the fixture design task has been somewhat simplified in terms of the number of fixtures which would need to be designed. However, there is a need to address the faster response and shorter lead-time required in designing and constructing new fixtures (Jose F Hurtado and Shreyes N Melkote, 2001).

Problems Occurring in Existing Fixture are

- Fixture setup is done manually due to this cycle time is more.
- Overtightning or loosening of screw leads to machining defects.
- Product quality is not obtained as per specification.
- Sometimes rejection rate is observed.
- Manual clamping leads to accidents.
- More hectic to operator to load and unload.

As solution to this problem greatly helps the industries to increase their productivity, this problem is needed to be solved to meet the current trends of designing and manufacturing. Solution to this problem requires hydraulic fixture in modelling software's which are now a day's back bone of all design and manufacturing industries (Dan Ding Guoliang *et al*., 2002).

REVIEW OF LITERATURE

The main purpose of literature reviews that discussion on important point regarding matter of fixture which is represented by different researcher:

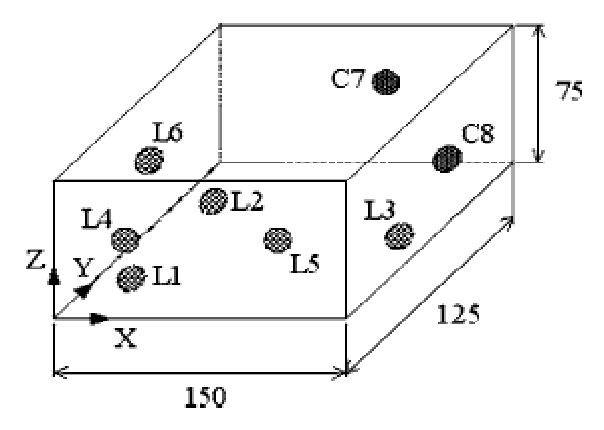
Principles of Locations

Guohua Qin *et al*., (2006), focuses on the fixture clamping sequence. It consists of two parts:

a. For the first time he evaluated varying contact forces and workpiece position errors in each clamping step by solving a nonlinear mathematical programming problem. This is done by minimizing the total complementary energy of the workpiece-fixture system. The prediction proves to be rigorous and reasonable after comparing with experimental data and referenced results.

b. The optimal clamping sequence is identified based on the deflections of the workpiece and minimum position error. Finally, to predict the contact forces and to optimize the clamping sequence three examples are discussed.

Figure 1: Scheme of 3-2-1 Fixture Setup (Guohua Qin, Weihong, Zhang Min Wan, 2006)

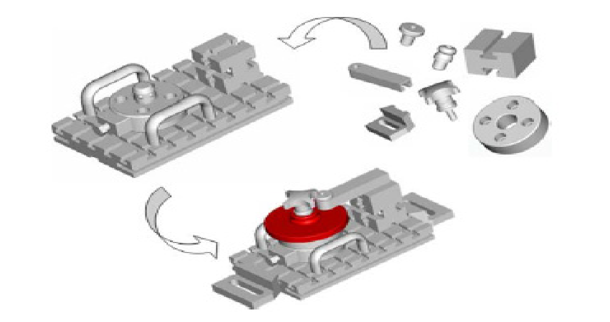


First mathematical modeling for clamping sequence is done then he determined the contact forces in clamping sequence as shown in Figure 1. After that he optimized of clamping sequence for higher stiffness workpiece and low stiffness workpiece. He found that with the use of optimal clamping sequence, good agreements are achieved between predicted results and experimental data and the workpiece machining quality can be improved.

Design Consideration in Fixtures

The importance of fixture design automation is emphasized by Djordje Vukelic (Michael Stampfer, 2008). General structure of the automated design system shown in Figure 2 with a highlight on the fixture design systems and their main characteristics.

Figure 2: Layout of Working (Michael Stampfer, 2008)



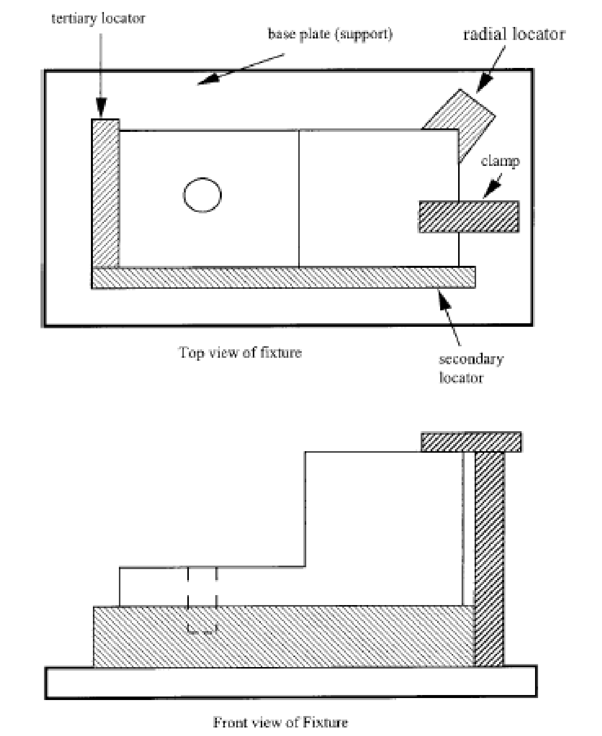
It also shows a structure and a part of output results of the automated modular fixture design system. The expert systems have been mostly used for the generation of partial fixture solutions, i.e. for the selection of locating and clamping elements.

Shrikant *et al*., (2013), discussed various design and analysis methods in the context of to improve the life of fixture; different fixture geometries are compared experimentally and are selected. The proposed eccentric shaft fixture will fulfilled researcher Production target and enhanced the efficiency, fixture reduces operation time and increases productivity, high quality of operation.

Clamping Approach

J Cecil proposed an innovative clamping design approach is described in the context of fixture design activities. The clamping design approach involves identification of clamping surfaces and clamp points on a given workpiece. This approach can be applied in conjunction with a locator design approach to hold and support the workpiece during machining and to position the workpiece correctly with respect to the cutting tool. Detailed steps are given for automated clamp design. Geometric reasoning techniques are used to determine feasible clamp faces and positions. The required inputs include CAD model specifications, features identified on the finished workpiece, locator points and elements.

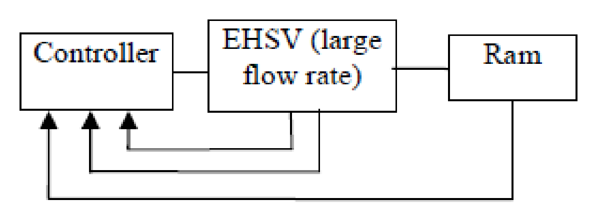
Figure 3: Fixture Design for the Sample Part (J Cecil, 2008)



Hydraulic System

This paper proposes a polynomial fit based simulation method to build nonlinear model in hydraulic actuator control system. This method is used to simulate two kinds of typical hydraulic actuator control system. Contrastively, a simulation with traditional linear model is also executed. Through comparison among the result of two kinds of simulation and the test data, it is proved that this polynomial fit based method is more accurate than the traditional method and it can perform more effectively for fault detection in hydraulic actuator control system.

Figure 4: Configuration of Hydraulic Actuator Control System (Wang Jinyong, 2012)



Shop air is just used for boosting .In addition electric booster and hydraulic pump are used to air- operated booster system. Hydraulic pump is used for larger applications. Accumulator is installed between clamps and power source which maintain the necessary pressure when power is disconnected.

DEVELOPMENT OF FIXTURE FOR HYDRAULIC LIFT HOUSING

Fixtures accurately locate and secure a part during machining operations such that the part can be manufactured to design specifications. To reduce design costs associated with fixturing, various clamping methods have been developed through the years to assist the fixture designer (E Caillaudli D *et al*., 1995).

For making a fixture following steps involved are

- Analytical design for fixture.
- 3-D modeling in PRO - ENGINEER Wildfire 5.0

- Assembly
- Analysis by using ANSYS.

Existing Fixture

Figure 5 shows the existing CAD model of fixture which is used for machining of hydraulic lift housing.

Figure 5: CAD Model of Complete Fixture Assembly

In this fixture clamping is done manually so there is extra time loss for loading and unloading operation. To avoid this problem there is necessity to develop new design to improve the productivity.

Type of Machine

Vertical machining centre is used to perform operation on hydraulic lift housing. The machining is to done on the upper surface of the workpiece. VMC provides the features and performance needed making it the best investment we've ever considered, and providing more utility, flexibility, and productivity. Basically operations such as drilling, reaming and chamfering takes place on workpiece. Drilling is a cutting process that uses a drill bit to cut or enlarge a hole of circular cross-section in solid materials. In drilling operation, hole created from 18mm to 26 mm from upper surface of workpiece. Following are the machining parameters for drilling:

- Spindle speed 500 rpmo Feed 0.15 mm/rev
- Radial depth 18 mm
- Projection length 90 mm

The process of using a multi-point tool to smooth the interior surface of a hole is called as reaming. Following are the machining parameters for reaming:

- Reamer diameter 26 mm
- Number of flute 4
- Spindle speed 120 rpm
- Feed 0.25 mm/rev
- Radial depth 26 mm
- Projection length 90 mm

DESIGN OF PARTS OF FIXTURE

The design of fixture parts includes consideration of material of fixture and after that analytical design of parts such as design of base plate, locating pins and clamp is carried out.

Criteria for Material Selection of Fixture

Mechanical Properties

The material must possess a certain strength and stiffness. Selected materials are examined for strength and stiffness values, and then potential materials are further inspected for other desired properties.

Wear of Materials

Wear is a problem when the materials are contacting each other in a product. So it must be ensured that the selected materials have sufficient wear resistance.

Corrosion

The importance of material selection in engineering is clearly visible in corrosive environments. Also it is an important engineering design criterion for designs open to the environment for a longer period of time. Some materials are very likely to be corroded in the service depending on the service environment. Metals like iron are heavily prone to corrosion if it not prepared to resist *corrosion*. Therefore it must be assured that the material is capable of being employed for the particular design before selecting it. Painting or any other surface coating method, cathodic protection, etc. are possible ways to minimize the effect and increase the service life.

Ability to Manufacture

The material is well capable of using for the design, it may be difficult to manufacture. This is particularly applicable in mechanical engineering design. If this selection criteria is neglected the manufacture process might be very costly making it unprofitable as a commercial product. So before selecting the materials this fact also must be considered.

Cost

Cost is a critical fact to consider when selecting materials for a certain design for most products because they are facing a severe competition in the market. So you may see that most of the metal or other valuable materials are replaced by plastics in most of the designs which they are applicable such as mechanical engineering designs. The cost factor can be neglected when performance is given the top priority. When estimating costs, all the associated cost factors must be considered to get a more reasonable value. It may involve the transportation, processing, etc. costs.

Design of Base Plate

While designing base plate total length should be considered.

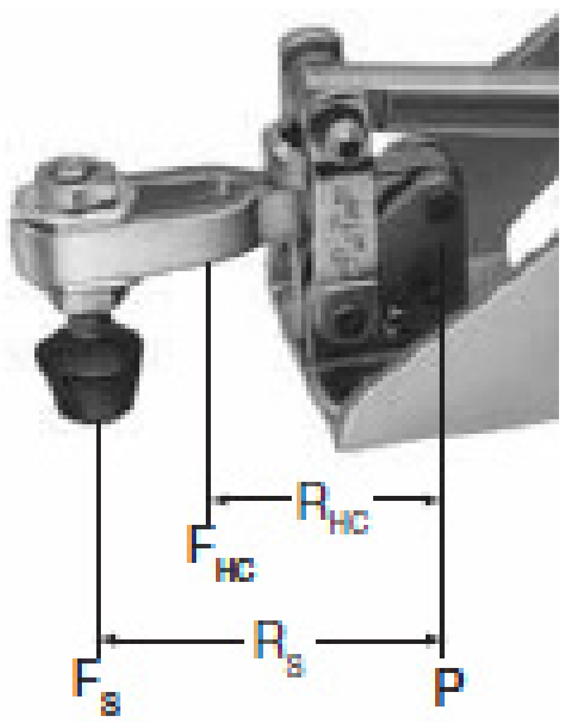
Base plate length (l) = 300 mm
Base plate width (b) = 300 mm
Base plate height (h) = 30 mm

Design of Clamp

Clamping mostly depends on cutting forces

$$\text{Clamping force} = \frac{\text{FHC X RHC}}{\text{RS}} = 200 \text{ N}$$

Figure 6: Clamp of Fixture



Where, FHC- holding force

Cylinder bore size = 25 mm

Piston area = 0.785 d^2

= 506.4506 sq. mm

Cylinder force= 111.20 N

Therefore, the required cylinder output force is 12 bar.

Calculations for Existing Fixture

Followings are the data available from the company

1) Time Required

Total number of shifts = 3

There are 3 Shift of 8 hours each.

Total working time in a shift is 7 hr 30 min i.e 450 min (30 minutes utilized in lunch break).

Total number of finished part in each shift = 32

Processing time = machining time + loading/ unloading time + part travel time (from pallet to fixture or vice versa)

Machining time = 11.36 min

Loading time = 1.20 min

Unloading time = 1 min

Part travel time = 10 sec

Therefore, Processing time = 14.06 min

2) Cost of Operation

Cost of finished product = Rs. 345/- part

Cost of finished product/shift = Rs. 11040/-

Cost of finished product /day = Rs. 33120/-

There are 26 days of working in one month

Therefore,

Annual production cost of finished product = Rs. 10333440/-

3) Machine Utilization

A measure (usually expressed as a percentage) of how intensively a resources is being used to produce a good or service (J Cecil, 2008).

Capacity = 3*8*1*6

= 144 machine hours

$$\text{Machine Utilization} = \frac{\text{Hours available - hours down}}{\text{Hours available}} \times 100$$

= 91.66%

Calculations for New Proposed Fixture

1) Time Required

Total processing time includes machining time, clamp actuation/de-actuation time and part travel time.

According to standard specification of cylinder, clamping will actuate in 5 sec.

Therefore,

Processing time = machining time + clamp acting time + part travel time

v machining time = 11.36 min

clamp acting time = 0.10 min

part travel time = 0.10 min

Total number of finished parts per shift = 39

2) Cost of Operation

Cost of finished product per day = Rs.40365/-

Annual cost of finished part = Rs.1,25,93880/-

Annual increase in production cost of finished part = Rs.22,60,440/-

3) Machine Utilization

$$\text{Machine Utilization} = \frac{\text{Hours available - hours down}}{\text{Hours available}} \times 100$$

Machine hours = 144

Hours down = 9.5

Analysis of Fixture

Figure 7: Minimum and Maximum Von Misses Stress or (Equivalent Tensile Stress)

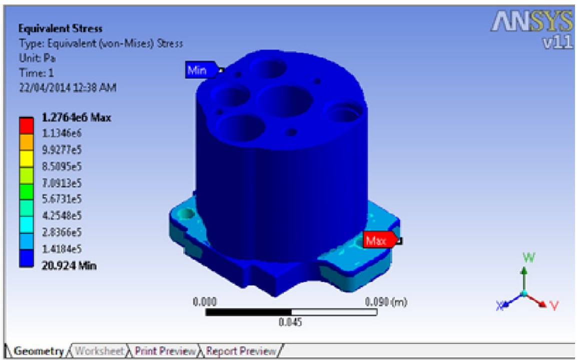


Figure 7 shows a stress distribution across the fixture A force of 200N is applied on three points where clamping force acting on it. After analysis it is observe that, von misses stresses is comparatively lower than standard values and hence, we can conclude that design is safe.

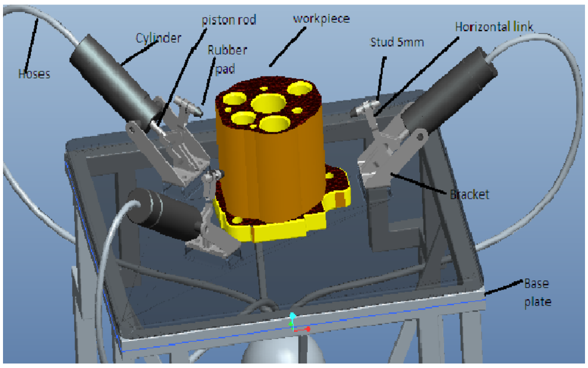
RESULTS

Table 1: Comparative Analysis

Parameter	Existing Fixture	Proposed Fixture
Finished part/shift	32 parts	39 parts
Production cost of finished part	Rs.1,03,33440/-	Rs.1,25,93880/-
Machine utilization	91.66%	93.40%
Processing time	14.06 min	11.56 min

Figure 8 shows the fixture with hydraulic attachments it includes a component such as base plate, cylinder, hoses, rubber pad etc.

Figure 8: Hydraulic Fixture Assembly



Hydraulic clampings are actuated by cylinders, clamping fixtures is clamping nut attached to cylinder ram. When pressurized fluid pulls ram and clamps against workpiece, toggle clamps operate through a linkage system of levers and pivots. The fixed-length levers, connected by pivoting pins, apply the action and clamping force. The toggle action has a lock point which fixes and stops linkage. Once in the lock position, the clamp does not unlock unless the linkage is moved/released.

CONCLUSION

- The proposed fixture will not only provides the repeatability and high productivity, but also offers a solution, which reduces workpiece distortion due to clamping and machining forces.
- All the values of deformation and von misses stress calculated with ANSYS software is comparatively lower than standard values and hence, we can conclude that design is safe.
- As per calculations, the proposed fixtures have a direct impact on product quality, productivity and cost.

- The person from industry will definately satisfied with the performance of fixture for machining hydraulic lift housing because of more benefits compared to conventional process with accuracy and repeatability on vertical machining center (VMC).

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