Design and Development of Hydraulic Fixture on VMC

Rushikesh R Patil[1], Rushikesh G Patil[2], Vinayak N Patel[3], Sejal M Kotecha[4]

[1234 5]*Department of Mechanical Engineering, Sinhgad College of Engineering, Pune, India*

Abstract— **Main aim of this paper is to reduce the cost of fixture by modifying clamp design and thereby number of cylinders. Fixture is a device for locating, holding and supporting a workpiece during machining process. It uses high pressure liquid to operate clamps and hold workpiece in position. To increase production and reduce the time it is required to maintain positional accuracy of fixture because fixtures directly affect on machining quality, productivity and cost. The recent trends in industry are towards adopting the hydraulic and pneumatic techniques because it save time generates accuracy and it is having some flexibility. This paper presents design and development of hydraulic fixture for cylinder block to perform drilling and boring operations using vertical machining centers. By using computer aided fixture design techniques the model of hydraulic fixture is created in NX11 software.**

***Keywords*— Hydraulic, Fixture, Clamp, VMC, Cylinder block**

I. INTRODUCTION

Fixture is a vital tool which holds a work piece in a proper position during manufacturing process. For clamping and supporting the work piece on its position, device called fixture is used. The most important criteria's for fixturing are workpiece stability, position accuracy and workpiece deformation. Workpiece location principles are defined in terms of 3-2-1 fixturing which is widely used workpiece location method for prismatic parts. Fixture must correctly locate a workpiece. Fixture consists a set of locators and clamps. Locators are used to determine the orientation and position of workpiece, whereas clamp exerts clamping forces on the workpiece so that the workpiece is pressed firmly against locators. Thus use of fixture helps mass production of component and also it is having direct impact upon product quality, productivity and cost. The design of fixture is highly complex and intuitive process, which requires knowledge. Proper fixture design is crucial for developing product quality in different terms of accuracy, surface finish and precision of the machined part.

A. Elements of Hydraulic Fixture

1. Base plate (M.S; Qty-1): It is made of mild steel. Structure of base plate is rectangular type and can withstand high vibrations. This base plate is machined on Vertical Milling Machine.
2. Resting Elements: Component shall be rested on suitable position and resting element shall be easily replaceable. Resting Pad (Qty-3): It is made of WPS material. It is case hardened and heated up to 50 to 60 HRC.
3. Clamping elements: Component shall be clamp above the resting face. Clamping face should have sufficient wall thickness. Two hydraulic swing clamp cylinders are used to clamp cylinder head of IC engine.
4. Vertical Swing Clamp Cylinder: It is a flange mounting, double acting cylinder. The job gets clamped in the piston push direction. The clamping strap is connected to the piston by linkage mechanism. In the unclamped position, the work piece area is free from the strap. Due to the vertical wing action, loading and unloading of the job is very easy. It is compact design with higher clamping force. Two vertical swing clamp cylinders are used in this fixture which is fitted on the base for cylinders.
5. Locating Elements: Locators are used to determine the orientation and position of workpiece. Spring loaded diamond pin: It is made of 20MnCr5 which is case hardened and tempered to 58 to 60 HRC. It is mounted on base plate to hold the cylinder block and prevent its misalignment.

E Base plate Clamp Locators Rest Pads

Fig 1. Elements of Hydraulic Fixture

Effective force and less time for machining of parts has leads to the need of hydraulic fixture. Also main problem of existing fixture is high rejection with low productivity of work piece, loosening and tightening of nuts and bolts. The main task which stands in front of industry is to make loading and unloading simple and to minimize time required for operation. Thus design and development of hydraulic fixture is required.

Objective is to design, develop and analysis of hydraulic fixture for machining engine cylinder block on VMC. Minimizing fixture and work piece deflections due to clamping forces in machining for maintaining given machining accuracy and tolerances.

II. Literature Review

The content of this paper is on overview of the available literature and information on hydraulic fixture that was used as foundation of this case study.

1. Barge K., et. al., [1] have presented design and development of hydraulic fixture for VMC. They have used hydraulic vertical swing clamps for holding the work piece driven by hydraulic power pack by replacing existing hydraulic fixture. The existing fixture replaced with hydraulic fixture to save time for loading and unloading of component
2. Raghu and Melkote., et. al., [2] have presented research paper on design, development and analysis of clamping force in fixture assembly in which workpiece location error is done by consideration of the fixture and workpiece due to fixturing forces. For modelling of workpiece, location error.
3. Sridharakeshava K. B. et. al., [3] has discussed about the general requirements of a fixture which includes constraints of deterministic location, contained deflection, geometry constraint in order to maintain the work piece stability during a machining process. They discussed 3 stages of fixture design, one deals with information gathering and analysis, second deals with product analysis and third involves design of fixture elements.

III. Design of fixture

It is a systematic approach for the realization of total task. It comprises the theoretical analysis of the body, methods and principles associated with a branch of knowledge. Typically, it encompasses concepts such as paradigm, theoretical model, phases and quantitative or qualitative techniques.

A. Basic requirements

Study of part: The part study is most essential and initial step for the planer. The segment drawings are examined in order to find clamping zones of fixture parts.

Geometric Model: For this it is required to have all the basic measurement tolerance and result required.

Calculation: It includes calculation of different forces and direction going to act on Part while performing operation on it

Selection of tooling material: The material should be selected according to force required and also considering properties of part.

Cost estimation: Tool cost estimation is important particularly for little and medium clump of generation runs, where the expense of an instrument proclaims to a critical rate of the item cost advancing.

B. Component Details

The component is cylinder block of 4 stroke single cylinder SI engine made up of aluminum alloy AlSi 132, weighing 1.985 kg and component is produced by pressure die casting process. The operations to be performed on the component, using desinged fixture setup, are drilling and boring.

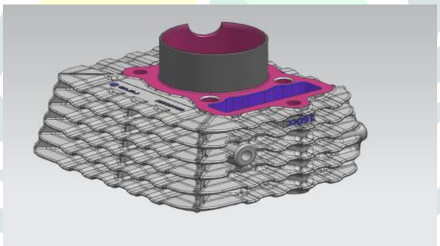

Fig 2. 3D CAD model of Cylinder Block

C. Computer Aided Fixture Designs

The clamping forces applied are caused to deform the workpiece, so therefore it is important to minimize such effects by using optimal design of the hydraulic fixture layout. In machining, work holding is a main concept and hydraulic fixture is the element responsible to satisfy this. Locating, orienting, centering, supporting and clamping can be considered as basic function requirements of fixtures.

For this engine cylinder block hydraulic fixture is designed in NX 11 software by considering all locating and clamping principles. The fixture is having two locating pins, three resting pads and two vertical hydraulic clamps.

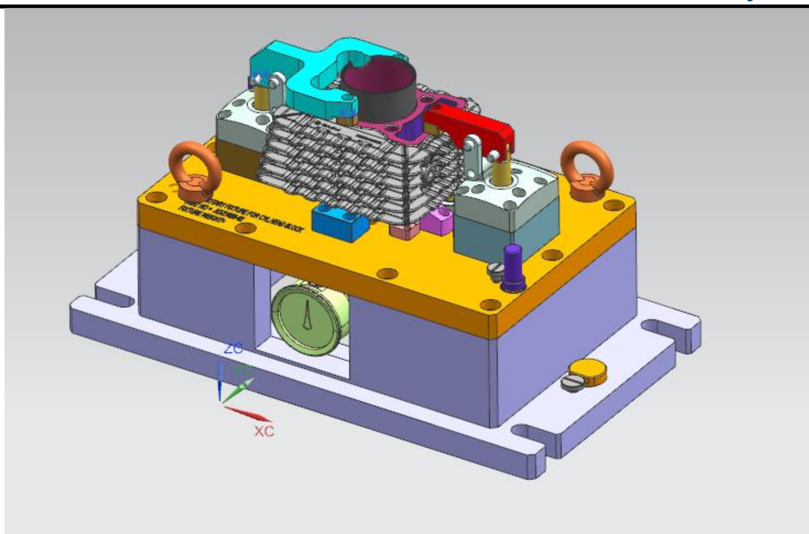

Fig 3. 3D CAD model of Fixture assembly with cylinder block

D. Clamping forces calculations by analytical method

The clamping forces by numerical and analytical method are to be calculated at given hydraulic pressures of 40, 50 and 60 bar.

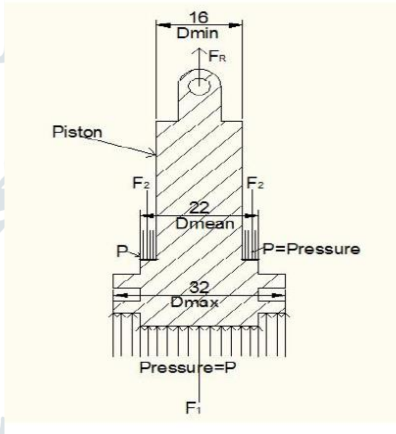

Fig 4. Boundary conditions applied on piston

By considering free body diagram as shown in fig with clamping force and hydraulic pressure

Hydraulic pressure= 4MPa

D_{min}= 32mm

D_{min}=16mm

D_{mean}=22mm

Force acing on piston by hydraulic pressure

$F_1 = \pi/4 \times D_{max}^2 \times P$

$= 3.126$ KN

Force acting on piston head by cylinder head

$F_2 = \pi/4 \times (D_{mean}^2 - D_{min}^2) \times P$

$= \pi/4 \times (22^2 - 16^2) \times 4$

$= 0.715$ KN

Net force acting

$= F_1 - F_2$

$= 3.126 - 0.715$

$= 2.5$ KN

By considering clamp lever a rigid element with negligible mass forces acting on beam will be

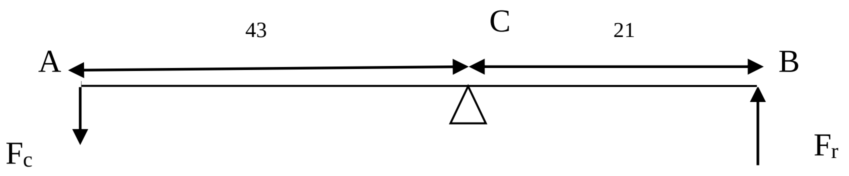

Fig 5. Free body diagram of single clamp lever

C= point where lever is hinged
F_H= reaction force at hinge
B= point where net piston force is applied F_R
A= point where clamping force is applied

From free body diagram taking moment about C
$\sum M_C = 0$
$F_c \times 43 = F_r \times 21$
$F_c = 2.5 \times 21/43$
$F_c = 1.22$ KN
Total reaction force
$F_H = F_C + F_R$
$= 3.72$ KN
Similarly clamping forces for 5 and 6 MPa hydraulic pressure are calculated and those are 1.526 KN and 1.831 KN respectively
For clamp 2
C = point where lever is hinged
F_H= reaction force at hinge
B= point where net piston force is applied FR
A= point where clamping force is applied

$F_{C1}$and $F_{C2}$are individual clamping force given by both sides of C- clamp
For calculation it is required to transfer both F_{C1} and F_{C2} along the center line of the clamp
In order to transfer these forces, transferring angular moments of these forces at center line is required, angular moments are equal and opposite because of symmetry so they are cancelled. Now C-clamp is converted into simple beam clamp with clamping force $F_C = F_{C1} + F_{C2}$.

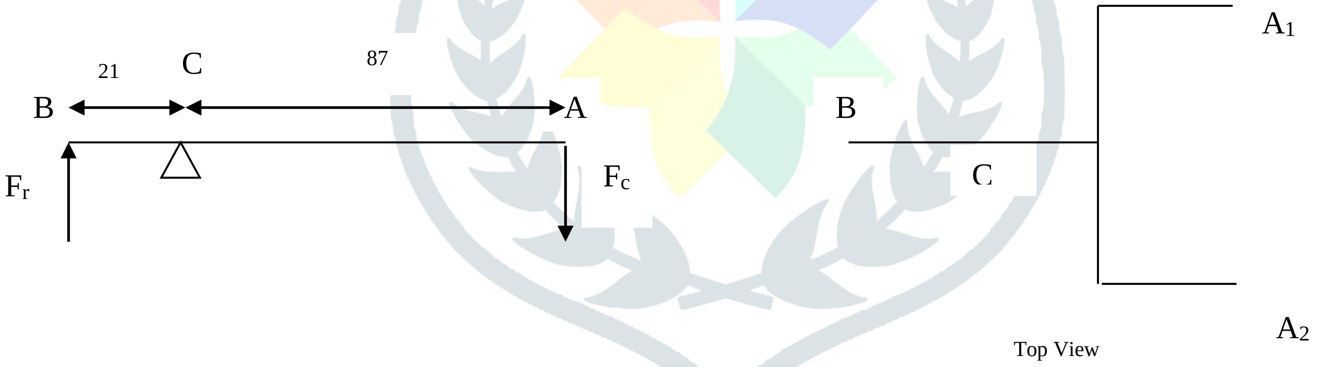

Fig 6. Free body diagram of C-clamp lever

From free body diagram
Taking moment about C
$\sum M_C = 0$
$F_c \times 87 = F_R \times 21$
$F_c = 2.5 \times 21/87$
$F_c = 0.6037$ KN
$F_{C1} = F_{C2} = F_C /2 = 0.301$ KN
Similarly clamping forces for 5 and 6 MPa hydraulic pressure are calculated and those are 0.377 KN and 0.452 KN respectively.

E. Development and Experimentation of manufactured fixture

E.1 Development

Here in final CAD model of complete fixture assembly the two single clamps are converted into C-clamp and hence by using one C-clamp and one single hydraulic vertical clamp,total required hydraulic cylinders are reduced to two and thus cost of entire fixture assembly is reduced.

After manufacturing of all parts used in fixture and by assembling it total weight of fixture is 25.74 kg. It is manufactured according to given requirement within given tolerance limits.

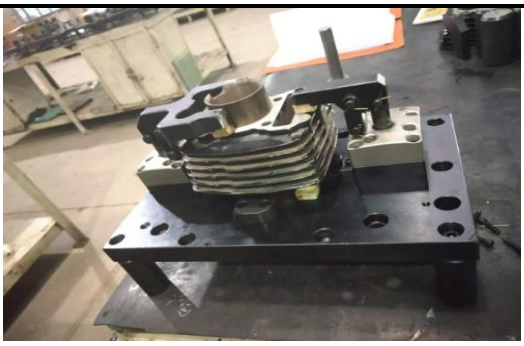

Fig. 7 Hydraulic fixture Assembly

E.2 Experimentation of Manufactured Fixture

For testing deformations in cylinder block at different clamping forces for different hydraulic pressures used a dial gauge indicator for deflection measurement is used.

Least count of dial indicator is 0.01mm. For upward movement of lever ball pointer on dial scale deflects towards clockwise direction and for downward movement of lever ball pointer deflects on anticlockwise direction.

Fig. 8 Dial gauge indicator mounted on fixture

F. *Results and Discussions*

From experimental testing by using dial indicator following results of total deformation at different clamping loads for hydraulic pressures of 40, 50 and 60 bars are found

Table I- Deformation table

Hydraulic Pressure (bar)	Clamping Force (KN)	Deformation (Micron)
40	0.301	15.18
50	0.377	21.89
60	0.452	26.54

Table II- Benefits of using hydraulic fixture

Sr. No	Parameters	Manual fixture	Hydraulic Fixture
1	Loading/Unloading time	1min 25 sec	25 sec
2	Cycle time/job	5 min	2 min
3	Jobs/shift	70	90
4	Rejection % of 1 product	3%	1%

Major benefits of this research work

As three hydraulic clamps get reduce to two clamps that are one C-clamp and one single vertical clamp, cost of one hydraulic cylinder is reduced saving 11000/- in total manufacturing of fixture.

IV. Conclusions

In this paper design requirements of hydraulic fixture were studied and accordingly fixture was design in NX11 software and deformation of component is calculated by Dial gauge indicator. Clamping forces are calculated at required optimum hydraulic pressure using numerical and analytical methods.

At 40 bar hydraulic pressure cylinder block is perfectly clamped and maintained its position as well as stability against cutting forces with minimum deformation of 15.18 micron. Hence for clamping 40 bar hydraulic pressure is selected over 50 and 60 bar.Thus suggested fixture helps in achieving precise, reliable and accurate production methods.

ACKNOWLEDGMENT

We thank our colleagues from Department of Mechanical Engineering, Sinhgad College ofEngineering who provided insight and expertise that greatly assisted the research. We thank Prof.G.E.Patil for guiding us throughout the research work and Mr R.B.Patil CEO of Jyotirling Industries, Aurangabadfor sponsoring our research work.

REFERENCES

[1] Sridharakeshava K B, Ramesh Babu, An Advanced Treatise on Jigs and Fixture Design", International Journal of Engineering Research & Technology", (IJERT), Vol. 2 Issue 8, August – 2013, pp. 1076 – 1080.

[2] Raghu. A., Melkote, S.N.: Analysis of the effects of fixture clamping sequence on part location errors. Int. J. Mach. Tools Manuf. 44 (2004) 373-382, 2004..

[3] Komal Barge, S.M. Bhise, Design & Development of hydraulic fixture for VMC, IJRASET 6, 2015, pp.174-182

[4] Ms.Padmashree Barge , Prof.[Dr.]V.D.Shinde , Mr.L.J.GadsingM.tech student, DKTE societies Textile and Engineering Institute Ichalkaranji India-416116 Prof. Mechanical Department DKTE societies Textile and Engineering Institute Ichalkaranji India. Assistant General Manager, Central Jigs and Fixtures Designing Department , TATA Motors Ltd., Pune, India Design and Development of work holding fixture for cylinder block , International Research Journal of Engineering and Technology (IRJET) July-2018

[5] AbhijeetSwami, Prof.G.E.Kondhalkar :"Design, Development and Analysis of Hydraulic Fixture for machining Engine cylinder block on VMC" , International Research Journal of Engineering and Technology (IRJET), Issue 8 August 2016.