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Design & Development of Hydraulic Fixture for VMC

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Abstract— Fixtures play an important role within many manufacturing processes. They accurately locate and secure a workpiece during machining such that the part can be manufactured to design specifications. Thus fixtures have a direct effect upon machining quality, productivity, and the cost of products. This paper presents design and development of hydraulic fixture for real industrial component. The component is Exhaust manifold front which is engine part of mini truck. The operations to be performed are rough & finish milling of flange, drilling, reaming & spot facing on VMC. 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. The evaluated fixture uses hydraulic vertical swing clamps for holding the work piece driven by hydraulic power pack. Thus the new fixture achieves automatic and simultaneous clamping of parts.
Keywords— fixture, accuracy, clamping, productivity, VMC (Vertical machining centre)

I. INTRODUCTION

Now a days all manufacturing industries attempts to bring down the manufacturing time and resources. For that purpose they have in search of various types of specific manufacturing systems. Fixtures are one of the mean that it accomplishes this need effectively. Fixture is a special purpose tool which is used to facilitate production (machining, assembling and inspection operations) when workpieces are to be produced on a mass scale. Fixtures provide a means of manufacturing interchangeable parts since they establish a relation, with predetermined tolerances, between the work and the cutting tool. Once a fixture is properly set up, any number of duplicate parts may be readily produced without additional set up. The current system uses manual clamping of fixtures for holding the work piece in the proper position while machining operations is being done on the part due to which rejection rate is high. These operations have to be done hundreds of times per day this may cause considerable fatigue to the operator, thereby reducing his efficiency. Also the time spent in this activity can seriously affect the production. These problems can be overcome by making the performance of fixture automatic. Providing the proper work holding platform is an important issue in any kind of operations performed on the work component. In this way automation has played a vital role in providing a reliable and fast clamping system which will reduce the cycle time of clamping with the increase in accuracy thus decreasing the possible damages to the work piece [7].

A. *What is Hydraulic Fixture?*

Hydraulic Fixture is 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 [2].

1) The major benefit of hydraulic work holding is enormous time saved in clamping & unclamping the components. It reduces cycle time hence manufacturing capacity increases & cost reduces.
2) In hydraulic fixture clamping forces are constant resulting in very precise positioning & clamping. This ensures identical processing procedures & guaranteed quality.
3) For every cycle, parts are clamped with the same clamping force & in the same location eliminating the variability in part deflection from clamping forces and improving process stability.
4) More parts will fit within machine envelope due to the high clamp forces generated with small hydraulic components hence get more productivity.
5) Eliminates human error due to assurance that every clamp will be actuated with every cycle, eliminating human error and missed steps. Also allows operators to be consistently more productive with less effort hence increase ergonomic efficiency.

II. PROBLEM STATEMENT

To design & develop hydraulic fixture for machining Exhaust manifold front on Vertical Machining center.The operations to be performed are rough & finish milling of flange, drilling, reaming & spot facing. The main problem in such operation is high rejection with low productivity due to manually operated fixture. It is cumbersome process for the workers because present

method of machining makes use of Nut-bolts and clamps only which required long processing time. Maximum time of worker is used for setting of workpiece on the fixture. Also accuracy is not so precise. The main task for it is to make the loading and unloading process simple, the time required should be minimized and operation should be easier one. By observing industrial problem and studying previous process there is need of designing new fixture to increase the productivity and reduce the rejection rate with the loading and unloading process simple.

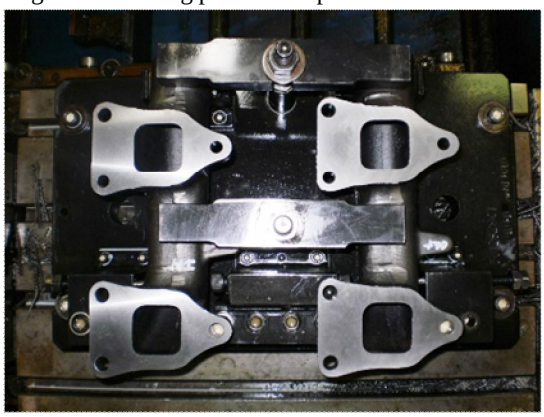

Fig. 1 Manually Operated Fixture

Fig. 2 Side view of manifold

III. LITERATURE REVIEW

Sridharakeshava K. B. et. al., [1] has discussed about the General Requirements of a Fixture which includes constraints of Deterministic location, contained deflection, geometric constraint in order to maintain the work piece stability during a machining process. They also discussed three broad stages of fixture design, Stage one deals with information gathering and analysis, Stage two involves product analysis, and Stage three involves design of fixture elements.

Shailesh S. Pachbhai et. al., [2] focuses on the advantages of Hydraulic Fixture. They also offer a solution of hydraulic fixture, which reduces workpiece distortion due to clamping and machining forces.

N. P. Maniar et. al., [3] reviews locating and clamping considerations, taxonomy of fixture planning & design, also shows an example of fixturing alternatives and characteristics for three types of fixtures i.e. Modular fixturing, General fixturing, Permanent fixturing. They provides a systems view of fixture planning and Design for data & information exchange also gives detailed discussion on CAFD- Computer Aided Fixture Design.

Navya K.R. et. al., [4] has discussed about basic concept of hydraulic circuit, hydraulic circuit designing. They suggested system which helps in achieving sophisticated, precise, reliable, safe as well as accurate production methods.

S.D.V.V.S.B.Reddy et. al. [5] has discussed about data required to design fixture, hydraulic fixture elements for transmission case, cutting force calculation and analysis of fixture body to check whether the fixture is withstanding the maximum cutting force during machining.

Vektec, hydraulic clamping information [6] describes Hydraulic Systems & Circuits which includes Power Supplies, Valves, System Types, Accumulators, Orifices, Filtration, Flow Requirements, Line Sizing, Circuit Design; General Description, information & Application Recommendations of Work Supports, Swing Clamps, Cylinders & Position Sensing.

IV. COMPONENT DETAILS

The component is Exhaust manifold front made up of S.G.Iron (spheroidal graphite) and is one of the components of internal combustion engine. Exhaust manifold is a pipe which connects the exhaust system to the exhaust valves of the engine. Through this manifold the products of combustion escape to the atmosphere. It is mounted on cylinder head of I.C.engine. The component is made by sand casting process. Operations to be performed on exhaust manifold are rough & finish milling of flange, drilling of 6 holes, reaming of 2 holes & spot facing on VMC.

V. DESIGN OF FIXTURE

Design of fixture whether it is manual or hydraulic is the same. Any work holding fixture must fulfil three basic functions.

1) Position the component accurately. 2) Support the component accurately. 3) Clamp the component accurately.

The structure of the fixture must be sufficiently rigid and heavy to avoid deformities and vibrations due to machine movements and clamping forces. For designing fixture it is necessary to study component details which include part geometry, machining process, design and interpretation rules for the machining fixture. Part drawing study is required to decide locating surface,

clamping surface and resting surface where process plan study is required to calculate cutting forces. As a part of first study, component geometry is discussed in above point. And the design considerations of fixture are discussed here.

A. Locating Principles

The location refers to the establishment of a desired relationship between the workpiece and the fixture. Correct location influences the accuracy of the finished products. The fixtures are so designed that all possible movements of the component must be restricted .The determination of the locating points and clamping of the workpiece serve to restrict the movements of the component in any direction, while setting it at the correct position relative to the fixture. The locating points are determined by first finding out the possible degrees of freedom of the workpiece, which are then restrained by suitable arrangements which serve as locators.

In order to study complete location of workpiece within a fixture, let us consider workpiece in space. In a state of freedom, it may move in either of two opposed directions along three mutually perpendicular axes XX, YY and ZZ. These six movements are called “movements of translation”. Also, the workpiece can rotate in either of two opposed directions around each axis, clockwise and anticlockwise. These six movements are called “rotational movements”. The sum of these two types of movements gives the twelve degrees of freedom of a workpiece in space.

1) *3-2-1 principle:* Three locating pins are inserted in the base of the fixed body which arrest five degrees of freedom 1,2,3,4 and 5.Two more pins are inserted in a vertical plane of fixed body which restrict three more degrees of freedom, namely 6, 7 and 8. Another pin in the second vertical face of fixed body, arrests degree of freedom 9.Thus six locating pins, three in the base of the fixed body, two in a vertical plane and one in another vertical plane, the three planes being perpendicular to one another, restrict nine degrees of freedom. And remaining three degrees of freedom may be arrested by means of a clamping device. This method of locating a workpiece in a fixture is called the “3-2-1” principle or “six point location” principle.

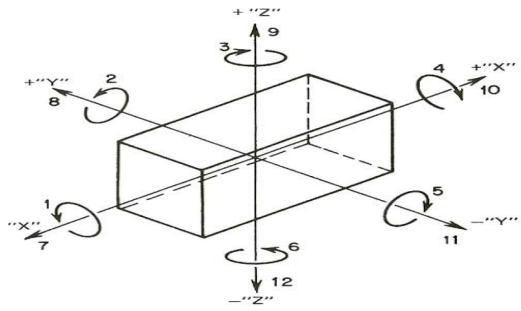

Fig. 3 Workpiece in space

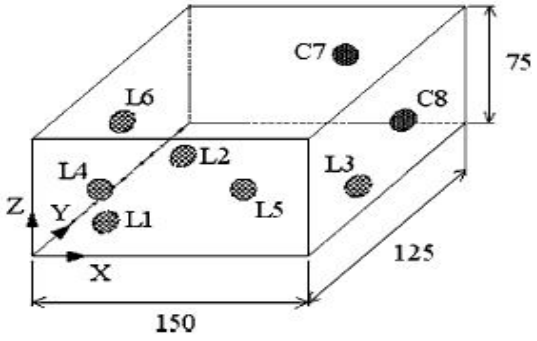

Fig. 4 Scheme of 3-2-1 fixture set-up

2) *Design principles for location purposes*

a) At least one datum or reference surface should be established at the first opportunity, from which subsequent machining will be measured. Also, the location must be done from the machined surface.

b) For ease of cleaning, locating surfaces should be small as possible consistent with adequate wearing qualities.

c) Sharp corners in the locating surfaces must be avoided.

d) Proper relief should be provided where burr or swarf get collected.

e) Adjustable type of locators should be used for the location on rough surfaces.

f) Locating pins should be easily accessible and visible to the operator.

B. Clamping Principles

If the workpiece cannot restrained by the locating elements, it becomes necessary to clamp the workpiece in fixture body. The purpose of clamping is to exert a pressure to press a workpiece against the locating surfaces and hold it there in opposition to the cutting forces. Since the proper and adequate clamping of a workpiece is very important, the principles of clamping described below

a) The clamping pressure applied against the workpiece must counteract the tool forces.

b) The clamping pressure must only hold the workpiece and should never be great enough so as to damage, deform or change any dimensions of the workpiece.

c) Clamping should be simple, quick and fool proof.

d) The movement of clamp should be strictly limited and if possible it should be positively guided.

e) The clamps should always be arranged directly above the points supporting the work; otherwise the distortion of the work can occur.

Since the total machining time for a workpiece includes work handling time, the methods of location and clamping should be such that the idle time is minimum. The design of fixture should allow easy and quick loading and unloading of the workpiece. The fixture should be as open as possible and clearance is provided in the fixture body.

VI. FIXTURE ELEMENTS

A. *Base Plate* (M.S; Qty-1)*:* It is made by mild steel. Structure of base plate is rectangular type having size 560 X 405 X 30mm.It is rigid and can withstand high vibrations. This base plate is machined on knee type milling machine. It has ten counter bored holes of dia. 25mm with height of 17mm.Also it has four counter bored holes of dia.17mm with height of 9mm. There are threaded holes for part fixing 2 numbers of M16, 2 numbers of holes of size M12 and 12 numbers of M6. Hydraulic piping holes are 4 numbers of size M10 and 32 numbers of M8 throughout. Front face will accommodate rest pads, locating V blocks, work supports and clamp cylinders. The bottom faces rest on the pallet.

B. *Locating Elements:*

1) V Block (M.S; Qty-2): Cylindrical part of manifold pipe is located by means of Vee block. V block is used so that variations in the workpiece size are not detrimental to location. It is made from Mild Steel. Angle between two slides of Vee is 90º.This is quick and effective method of locating the workpiece with desired level of accuracy.

2) Rear Resting Block (M.S; Qty-2): It is bolted to the base plate and is used to locate half part of the manifold. On this block adjustable rest rods are fitted which is used to rest the flange portion of manifold.

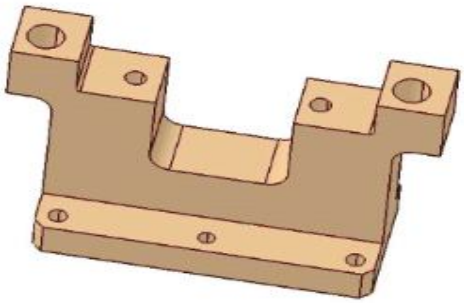

Fig. 5 Vee Block

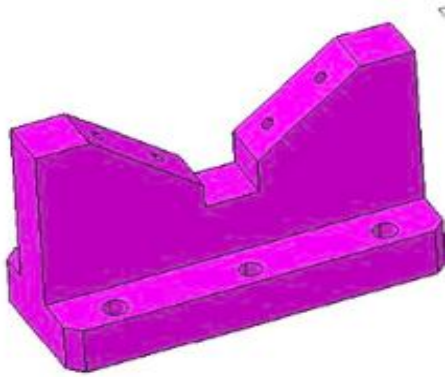

Fig. 6 Rear Resting Block

C. *Resting Elements:* Component shall be rested on suitable position and resting element shall be easily replaceable.

1) Rest Pad (EN24; Qty-4): It is made by En-24 material. It should be heat treated and hardness is 50 to 55 RC. These rest pads are mounted on the two slides of Vee block to rest the bottom part of the manifold. Also 2 back rest pads are used to support end portion of manifold pipe. These back rest pads are fixed to the back support plate.

2) Guide Rod (16MnCr5; Qty-4): Main purpose of the guide rod is to guide component while loading and unloading of the component. It is used to support the bottom side of the component while loading. Material used for guide rod is 16MncR5.It is case hardened with case hardness 55 to 58 HRC and case depth 0.8 to 1.2mm.

3) Front Pusher (EN8; Qty-2): manifold pipe's starting end is rested by front pusher which is attached to the front pusher block. This front pusher is toughened with 30 to 35 RC. Two compact cylinders are used to provide hydraulic pressure to lock the manifold's starting end by front pusher.

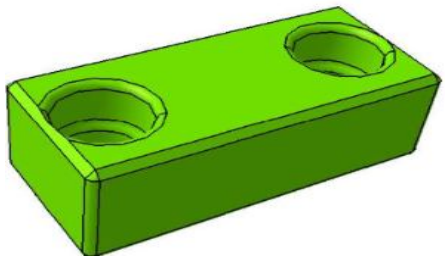

Fig. 7 Rest Pad

Fig. 8 Guide rod

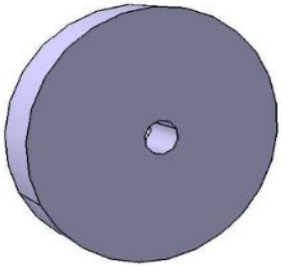

Fig. 9 Front Pusher

D. *Clamping Elements:* Component shall be clamp above the resting face. Clamping face should have sufficient wall thickness. Three hydraulic swing clamp cylinders are used to clamp front side of manifold in which two swing clamps are used to clamp middle part of the manifold separately for each manifold and clamp 2 as shown in fig. below is used to clamp ended part of both manifolds. These three clamps are toughened with 30 to 35 RC.Material used for clamp lever is En8 and cylinder mounting block is mild steel. The cylinders are double acting and works on 120 bar pressure. It gives 10.3KN force at maximum pressure rating i.e. 150 bar. To support these swing clamp cylinders a frame i.e. base for cylinders is designed such that all three swing clamp cylinders are maintained at same height and also a work support is provided to support the component. The Hydraulic connections are given by internal holes in the frame and standard hydraulic fittings. Clamp lever with swivel pad is fitted to this hydraulic cylinder. The job gets clamped in the piston push direction. The clamping strap is connected to the piston by a linkage mechanism.

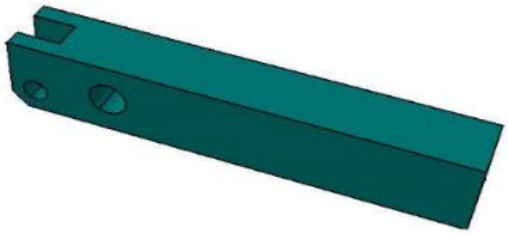

Fig. 10 Clamp 1.

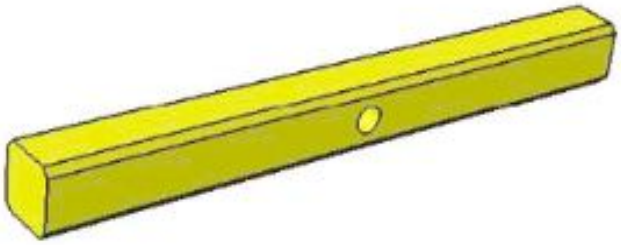

Fig. 11 Clamp 2.

E. *Supporting Elements:* Before power clamping the component a support for the Component needed.

1) Spring Loaded Vee (EN24; Qty-2): Spring loaded Vee is provided to support the manifold at the middle to position accurately. This is fastened to the base plate by a guide rod at its two ends. Spring is placed on the periphery of guide rod. This guide rod is also used for resting purpose.
2) Front pusher block (M.S; Qty-2): Front pusher block is used to support front pusher which is used to rest manifold's starting end.
3) Back support plate (M.S; Qty-2): It is used to support back rest pad which is to support end portion of manifold pipe.
4) Base for cylinders (M.S; Qty-3): It is designed to support vertical swing clamp cylinders such that all three swing clamp cylinders are maintained at same height.
5) Work Support (16MnCr5; Qty-2): Work supports are supplementary support devices to be used in a fixture. They also supports reduce the effects of vibration and deflection, helping to maintain work-piece accuracy during machining operations. Work support uses hydraulic pressure to push plunger to contact the work-piece. In this work support, work support plunger is placed on which bottom part of the manifold is placed where upper portion of the manifold is clamped by clamp 2.

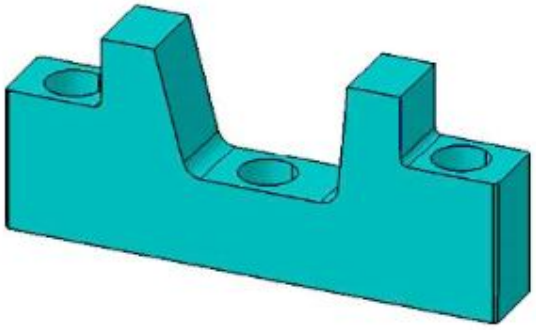

Fig. 12 Spring Loaded Vee

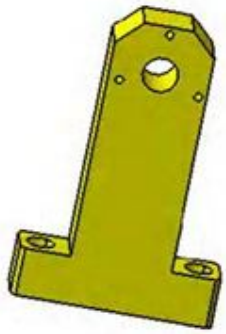

Fig. 13 Front Pusher block

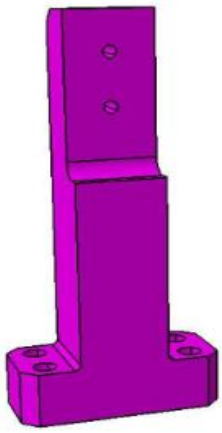

Fig.14 Back support plate

F. *Hydraulic Elements:*

1) Hydraulic Coupling Unit: This fully equipped coupling unit has been developed for manual coupling and uncoupling for the purpose of clamping and unclamping. It is used whenever the fixture is separated from pressure generator. This unit includes two quick disconnected coupling to connect or disconnect "Hydraulic Power Unit", Pilot operated check valve to hold pressure in clamping line, Accumulator to compensate leakage (if any) in clamp line, pressure relief valve to avoid excessive pressure. Minimum operating pressure for this coupling unit is 50 bar and maximum operating pressure is 250 bar.
2) Vertical Swing Clamp Cylinders: 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 a linkage mechanism. In the unclamped position, the work piece area is free from the strap. Due to the vertical swing action, loading and unloading of the job is very easy. It is a compact design with higher clamping force. Three vertical swing clamp cylinders are used in this fixture which is fitted on the base for cylinders.
3) Compact Cylinder: Compact cylinders are solid piston, double acting and with single rod end. Cylinders are very compact in the axial direction. These cylinders are used where height is a constraint. Mounting of the cylinder is very easy. Two compact cylinders are used in this fixture to lock the manifold's starting end by front pusher.
4) Piping: Pipes which are used to transmit hydraulic oil having diameter of 8mm and 10mm.Pipes are made of copper.

Fig.15 Hydraulic Coupling Unit

Fig. 16 Vertical Swing Clamp Cylinder

Fig. 17 Compact Cylinder

VII. HYDRAULIC CIRCUIT

A hydraulic circuit is a system comprising an interconnected set of discrete components that transport liquid. Circuit is the routing and control of a confined liquid to apply power. This power is used to achieve a specific function resulting in work being performed. Before the hydraulic circuit can be designed, the following things must be defined

1) The type and number of each type of hydraulic actuator to be used on fixture.
2) The operating pressures required.
3) The cycle time required to clamp and unclamp.
4) The sequence of operation.
5) Type of control required.
6) Coupled or de-coupled system.

The circuit comprises the following components:
Active components-Hydraulic power pack
Transmission lines- Hydraulic pipes
Passive components- Hydraulic cylinders
Hydraulic power pack used is of tank capacity 30 Litres. The hydraulic fluid reservoir holds excess hydraulic fluid to accommodate volume changes from cylinder extension and contraction, temperature driven expansion and contraction, and leaks. Hydraulic pump is used of output 1.8 LPM. Hydraulic Pump is a device used to impart motion and pressure to the fluid in a hydraulic circuit. Pump is driven by 3 phase, 1hp electric motor to create flow. Pump that creates flow pushes against the

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piston of a hydraulic cylinder. The motor is controlled by a pressure switch, which will close when a pre-set pressure has been reached in the system, and shut it off. If pressure in the system should fall below the reset point of the pressure switch, it will re-open and re-start the electric motor to replenish system pressure. Directional control valve is one of the most fundamental parts in hydraulic circuit. They allow fluid flow into different paths from one or more sources. Here double solenoid, spring centred and centre open type D.C. valve is used. The valve is controlled by an electric current through a solenoid. At centre position pressure line is connected to tank line and motor is unloaded. Due to this one can connect or disconnect quick disconnect coupling at centre position. Cylinders are linear actuation devices that are typically used to keep a work piece stationary or move work piece into position. They provide axial clamping force proportional to the hydraulic pressure applied. Hydraulic clamp used is of 10.3KN force @ 150Bar, piston diameter is of 32 mm, Stroke is 30 & Reserve stroke is 3 mm. Oil volume push in CC is 24 and Oil volume pull is 16cc.

It is important when designing a circuit that all devices including fittings, hoses, valves, tubing have a working pressure compatible with circuit pressure. Never exceed the maximum operating pressure of any device. When considering required clamp time it is important to keep in mind that some devices have minimum actuation time requirements in order to protect the integrity of individual components. If the system flow requirement for clamp time is established with in the restrictions of the largest device, the addition of a flow control will be required to prevent over driving the smaller devices. Representative hydraulic circuit diagram is shown below.

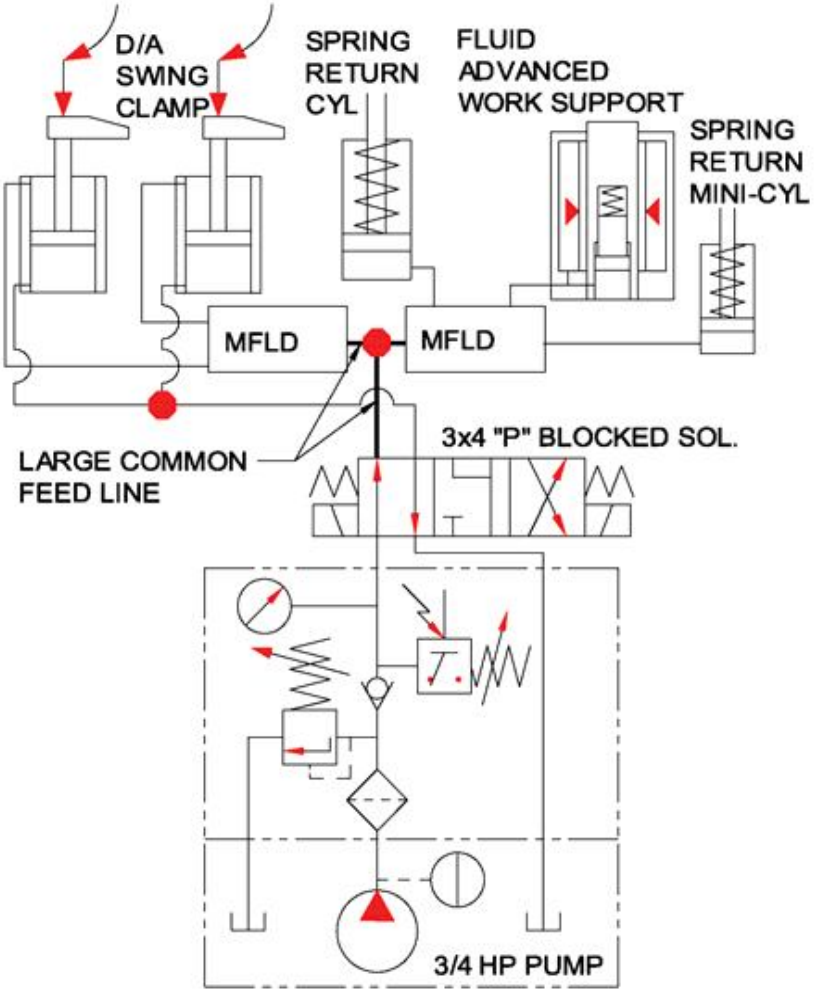

Fig. 18 Hydraulic Circuit Diagram

VIII. CLAMPING FORCE CALCULATIONS

A. *Manually Operated Fixture:*

Clamping Force = [Machine spindle power x Machine efficiency x 60 x factor of safety] / [cutting speed x coefficient of friction]

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= [1.5 x 0.8 x 60 x 1.5] / [100 x 0.12]
= 9 KN ≈ 10.3KN

B. *Hydraulic Fixture:*

Clamping pressure = Clamping Force / clamping area
Diameter of cylinder bore = 32mm = 3.2 cm
Area of cylinder = 0.785 d^2 = 0.785 x (Piston dia.)^2 = 0.785 x 3.2^2 = 8.0384 cm^2
Clamping pressure = 1030 / 8.04 = 130.58 kgf/cm^2 = 120 bar.

Cylinder Force = Oil pressure x Plunger effective area x 9.81
Pressure generated in clamping line is 120 bar = 130.58 kgf/cm^2
Cylinder bore size = 32 mm = 3.2 cm
Plunger effective area = 0.785 d^2 = 0.785 x (Piston dia.)^2 = 0.785 x 3.2^2 = 8.0384 cm^2
Clamping Force =8.0384 x 120 x 9.81 = 9462.80 N = 9.47 KN ≈ 10.3KN.

IX. RESULTS AND DISCUSSIONS

A. *Construction:* This fixture is made by Fabrication method in which body is made up from separate parts. In a fabricated construction, all the component parts can be completely machined before assembly. The construction is held together by screws and dowels. The screws serve only to hold the parts together with the dowels assuring accurate alignment. Fabrication has following advantages:

1) Standard parts can be used to build up the body.
2) Fixture can be built up quickly by using standard parts.
3) A fabricated construction is easy to repair because disassembly is comparatively easy.

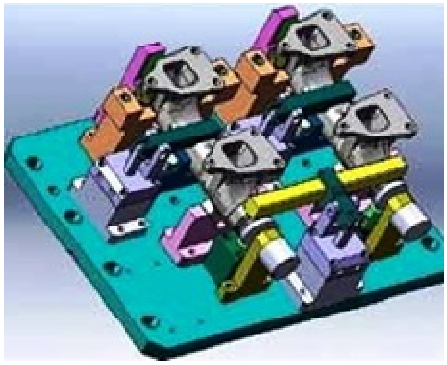

Fig. 19 Hydraulic Fixture Assembly

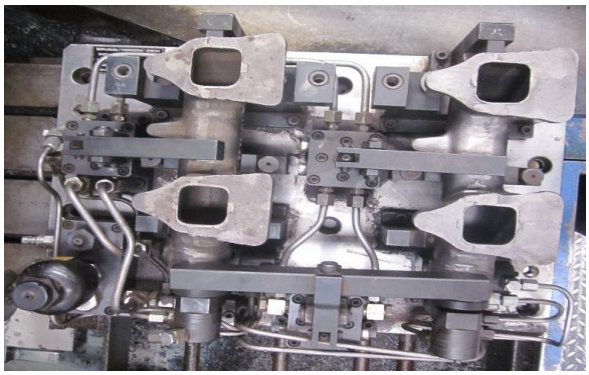

Fig. 20 Hydraulic Fixture

B. *Results:* Results of using hydraulic fixture instead of manual fixture is shown in table given below.

TABLE I
COST JUSTIFICATION TABLE

Sr.No.	Parameters	Manual Fixture	Hydraulic Fixture
1	Loading/Unloading time	1 min 30 sec	30 sec
2	Cycle time/job	5 min.30 sec.	3 min 30 sec.
3	Jobs/shift	60	85
4	Rejection % of 1product	3%	1%
5	Productivity	Less Productivity	Productivity increased

Major benefits of this project to company

1) By using this fixture cycle time reduces by 2 minute. Cycle time on manual fixture was 5 min 10 sec and on hydraulic fixture is 3 min 30 sec because loading and unloading time is reduced by 1 min.
2) Rejection of product is minimized by 2%.
3) 60 products are produced per shift on manually operated fixture and 85 products are produced on hydraulic fixture. With the help of this fixture extra 25 parts per shift are produced.

4) By using this fixture □80,000 saved in one month.

X. CONCLUSION

Implementation of this project eliminates the need of human operator for clamping of manifolds. It reduces the cycle time. It gives an economically feasible design. Also ensures accurate & efficient clamping of parts. The suggested system helps in achieving sophisticated, precise, reliable, safe as well as accurate production methods. The clamping systems are designed such that they withstand the huge retention forces applied from the machining operations onto the workpiece. By using manual fixture production of manifold is insufficient in industries. Hence, hydraulic fixture is a good option to increase the production of manifold.

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