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Design & Development of Work Holding Fixture for Cylinder Block

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Abstract –*Modeling the fixture design process is a particularly difficult activity because several types of knowledge are involved: design, process planning and manufacturing. The main aim is to design and develop the Work Holding Fixture for Machining of 5L Cylinder Block. In this paper, the literature survey is presented. Further it contains various concept design alternatives and one of the best design concept is selected which satisfies the evaluation criteria. Considering the selected design concept of the fixture, further designing and modeling of fixture on CATIA V5R25 software is done. Finally, manufacturing of fixture is done.*

***Key Words*: Work Holding Fixture, 5L Cylinder Block, concept selection.**

1. INTRODUCTION

The fixture designing and manufacturing is considered as complex process that demands the knowledge of different areas, such as geometry, tolerances, dimensions, procedures and manufacturing processes. A fixture is a work-holding or support device used in the manufacturing industry. The main purpose of a fixture is to locate, hold a work piece during either a machining operation or some other industrial process.
The primary purposes of fixtures are to:

- Reduce the cost of production
- Maintain consistent quality-precision/Accuracy
- Maximize efficiency-Productivity
- Enable a variety of parts to be made to correct specifications-Reliability/Repeatability
- Reduce operator errors- consistency
- Capacity enhancement

2. PROBLEM STATEMENT

To design and develop hydraulic fixture for machining of 5L cylinder block. The operations to be performed are machining operations of barrel bore, head face, sump face, fuel injection pump bore. Due to manual operated fixture, there is problem of high rejection rate. Hence for making loading and unloading simple, minimization of time and easier operations, it is required to design new fixture which will overcome the above difficulties.

3. LITERATURE REVIEW

Kubade C. A., et. al., [1] have presented a study on design and analysis of welding fixture for automotive component using FEA. The fixture designed for the cabs leg sub-assembly, which welded with companion for its application. Initially they investigated the study of basics of fixture and welding, need of fixture, location principle.

Li. K., et. al., [2] have developed an intelligent jig and fixture design system by applying artificial intelligence (AI) technology into the Computer aided fixture design (CAFD) system, using the theory of the expert system and technology of the 3D modeling. Finally, an example of virtual assembly designed by the CAFD system.

Pachbhai S. S., et. al., [3] have presented design and development of hydraulic fixture for machining hydraulic lift housing. They have done 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.

Barge K., et. al., [4] 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 too save time for loading and unloading of component.

3. COMPONENT DETAILS

Fig.-2: Actual component- 5L Cyl. block

The component is 5L Cylinder Block made up of Cast Iron and is one of the components of internal combustion engine. The casting of the 5L cylinder Block is done in foundry, which is followed by roughing operations of Barrel Bore, Head face, Sump face, Fuel Injection Pump Bore, Ac Bore, done to reduce the cycle timing.

4. DESIGN OF FIXTURE

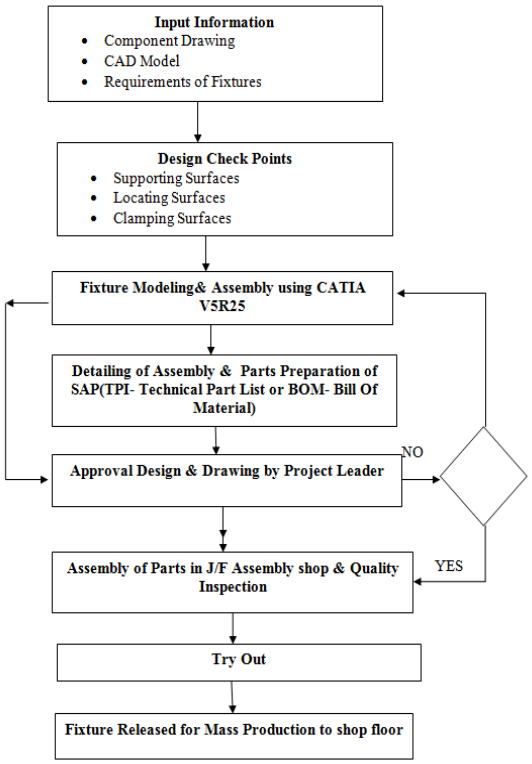

Fig.-3: Fixture Design methodology

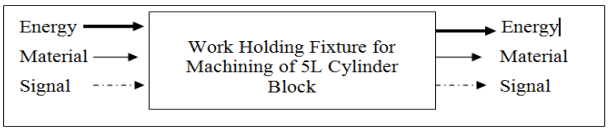

Fig.-4: Black Box representation of Work Holding Fixture

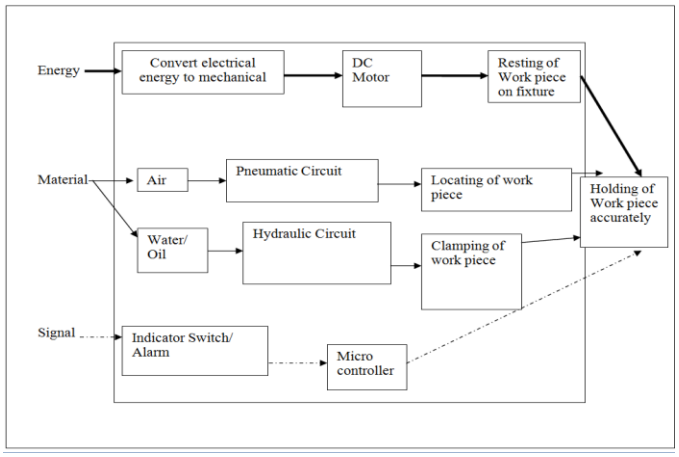

Fig.-5: Functional Decomposition of Work Holding Fixture

4.1 Concept Generation

As a first step to concept generation for Work Holding Fixture for Machining of 5L Cylinder Block, it is required to clarify the problem by any suitable functional decomposition. The functional decomposition is shown in Fig. 5.

Concept generation is a process of evaluating concepts with respect to internal customer needs and other criteria, comparing the relative strengths and weaknesses of the concepts and selection of one or more for further investigation, testing or development. [6]

The functional decomposition involved first representing the work holding mechanism as a single black box operating on energy, material and signal flows as shown in Fig 4. The black box was later subdivided into sub functions to create a more specific description of what the elements of the work holding fixture might do in order to implement the overall product function as shown in Fig 5.

Table -1: Internal Customer needs

Sr.No	Voice of Customer	Needs
01	The fixture should be light weight.	Provision of pockets within non-interfering areas.
02	The fixture should not contain intrinsic geometry.	Regularization of fixture geometry
03	The tedious task of accurate resting in short time span should be minimized.	Add Butting for smooth engagement and disengagement of the component
04	The difficulty in inspection of accurate resting of the component should be resolved	Provision of Rest pads with Air Setting
05	It should require minimum time for loading-unloading	Increase the number of rest pads
06	The possibility of fixture prone to failure due to fatigue should be minimized	Casting of the fixture components

Firstly, the conversion of voice of customer into customer needs are done followed by giving relative importance between 1 -5. Accordingly need matrics relationship is prepared which is helpful in designing fixture to satisfy customer needs as shown in table4.

Table -2: Relative Importance of Customer needs

Sr.No	Needs	IMPORTANCE
01	Provision of pockets within non-interfering areas.	1
02	Regularization of fixture geometry	5
03	Add Butting for smooth engagement and disengagement of the component	4
04	Increase the number of rest pads	2
05	Provision of Rest pads with Air Setting	2
06	Casting of the fixture components wherever required	3

Table -3: List of Metrices for Work Holding Fixture

Need No.	Metric No.	Metric	Units
5,3	1	Time to operate	Sec
1	2	No. of parts	No.
2	3	Dimension	Mm
1,2	4	Position Of machine	Subjective
4	5	Unit manufacturing cost	Rs
1,2	6	Compatability	List
1	7	Total mass	Kg
4,5	8	Access time	Sec
5	9	Loading and loading time	Sec
4	10	Special tools required for maintenance	List
4	11	Time to assemble/disassemble for maintenance	Sec
6	12	Force	N

Table -4: Need Metric Relationship

Need-Metric Relationship	Engineering Characteristics										
	Time to Operate	No. of Parts	Dimensions	Position of Machin	Unit Mfg. Cost	Compatibility	Total Mass	Access Time	Loading and Unloading time	Special tools reqd. for Maintenance	Time to assemble /disassemble for maintenance
Provision of Pockets within non-interfering areas		•	•			•	•				
Regularization of fixture geometry		•	•	•	•	•					•
Add butting pads for smooth engagement and disengagement of component	•	•				•	•	•	•	•	
Provision of rest pads with air setting	•	•				•	•	•	•	•	•
Increase the number of rest pads	•	•				•	•	•	•	•	•
Casting of the fixture components whenever required					•	•					

Relationship Matrix

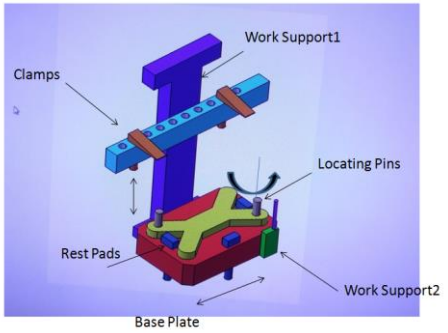

Fig.-6: Concept 1

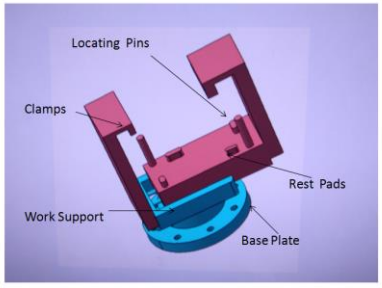

Fig.-7: Concept 2

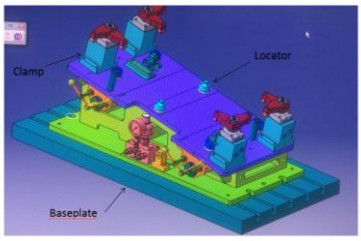

Fig.-8: Concept 3

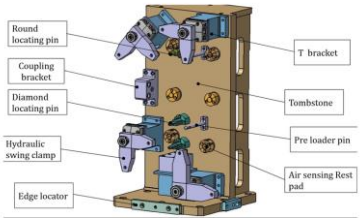

Fig.-9: Concept 4

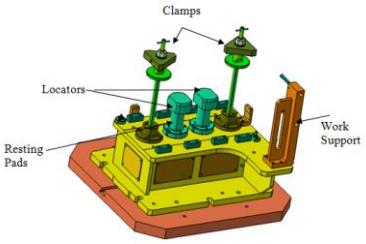

Fig.-10: Concept 5

4.2 Concept Selection

The concept selection method in this section is build around the use of decision matrix for evaluating each concept for Work Holding Fixture with respect to a set of selection criteria.

The generic steps involved in concept selection using concept scoring matrix are:

- Develop evaluation criteria
- Assign importance rate to each criterion
- Rate each concept with respect to each evaluation criterion, Rank the concepts

Table -5: Concept Scoring Matrix for concept 1,2,3

		Concepts					
		Concept 1		Concept 2		Concept 3	
Selection criteria	Weight	Rating	Weighted score	Rating	Weighted score	Rating	Weighted score
Accurate loading-unloading	80%	8	6.4	7	6.4	4	3.2
Ease of access	60%	8	4.8	6	4.8	8	4.8
Flexibility	75%	8	6	8	6	5	3.75
Load handling	40%	8	3.2	8	3.2	4	3.2
Versatility	70%	8	5.6	6	5.6	4	5.6
Compatability	30%	6	1.8	5	1.5	5	1.5
Certainty of success	80%	7	5.6	6	4.8	5	4
Total score		53		32.3		26.05	
Rank		1		2		3	
Continue		Yes		No		No	

- Select one or more concepts[6]

The following selection criterion for Work Holding Fixture was finalized by taking into consideration the customer needs:

- Accurate loading & unloading
- Ease of Access
- Flexibility
- Load Handling
- Versatality
- Compatability
- Short Cycle Time

Several different schemes can be used to weight the criteria such as assigning the importance value from 1 to 10. The concept scoring matrix for Work Holding Fixture is shown in Table 6,7. The method uses a weighted sum of the ratings to determine concept ranking.

Table -6: Concept Scoring Matrix for concept 4, 5

		Concept			
		Concept 4		Concept 5	
Selection criteria	Weight	Rating	Weighted score	Rating	Weighted score
Accurate loading-unloading	80%	4	3.2	8	6.4
Ease of access	60%	4	2.4	7	4.2
Flexibility	75%	3	2.25	6	4.5
Load handling	40%	4	1.6	6	2.4
Versatility	70%	6	4.2	6	4.2
Compatability	30	5	1.5	6	1.8
Certainty of success	80%	3	2.4	2	1.6
Total score		17.55		25.1	
Rank		5		4	
Continue		No		No	

The concept scoring matrix indicates that Concept 1 (Fig.6) satisfies all the evaluation criteria and has highest score 53. The design provides a simple and user friendly loading system. All other concepts remained below the score of concept no 1. Therefore, Concept 1 was finally chosen as the best design for Work Holding Fixture. Fig.6 shows a Catia model of the concept. Hence considering the selected concept, designing and modeling of fixture on CatiaV5 software is done.

4.3. Process Driven Design

The goal of the process driven design approach is to ensure the development of best possible part decomposition from a functional, manufacturing, support and business point of view.

For the design and development of Work Holding Fixture for machining of 5L Cylinder Block, the main focused area is on developing a product and process plan by conducted the following activities:

• Material and Process class for key component

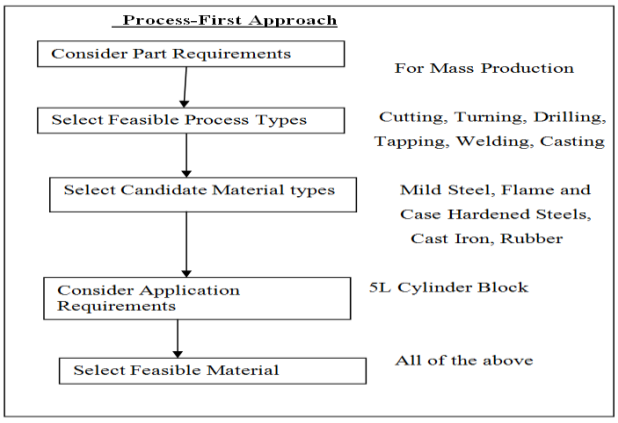

Fig.-11: Process first Appro

Table -7: Candidate Materials

Sr. No.	Material	Application(Heat Treatment)	Cost (Rs. /Kg)
01	Fe410Wa	For baseplates, brackets, structures, frames, odd shaped damps(stress relieved)Plates and locators where boring and tapping not involved(Case Hardened & Ground to 55-60HRC. Case Depth 0.4-0.6mm	18
02	40Cr4	For damps, studs, heel pins, flame hardened rest buttons, draw bas, dollies(toughened to 80-100kg/sq.mm Flame Hardened to 40-45HRC)	28
3	16Mn5Cr4	For locators, pins, dollies, mandrels, where core needs to be soft. Also for plates, rings etc.where bores or tapping need to be soft(Case Hardened& Ground to 55-60HRC, Case Depth 0.4-0.6mm)	28
4	20MnCr5	For plates, rings,where bores or tapping need to be soft(Case Hardened& Ground to 55-60HRC, Case Depth 0.4-0.6mm)	28
5	90MnCrV8	For rest pads, setting pieces, slip boshes, liner bushes, jig bushes, gauges and gauges for the hot bendings.(Hardened to 65±2HRC, Flame Hardened to 50-55HRC.Stabilized for gauges)	40
6	210Cr12	For bushes having inner diameter less than 6mm,small replacebale jig(Hardened to 60±2 HRC)	55
7	750 A50 BS970	For springs, collets etc(Hardened & tempered, 46-50 HRC)	
8	CAST IRON G-25-IS210	For bearing bushes, steady pieces	

Product architecture.

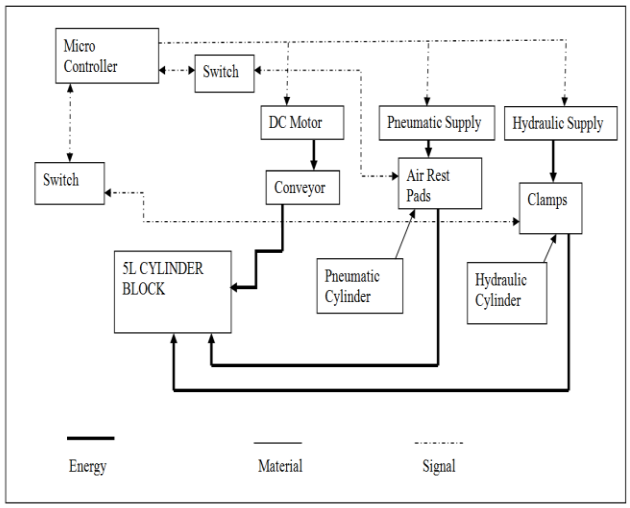

Fig.-12: Schematic of the product

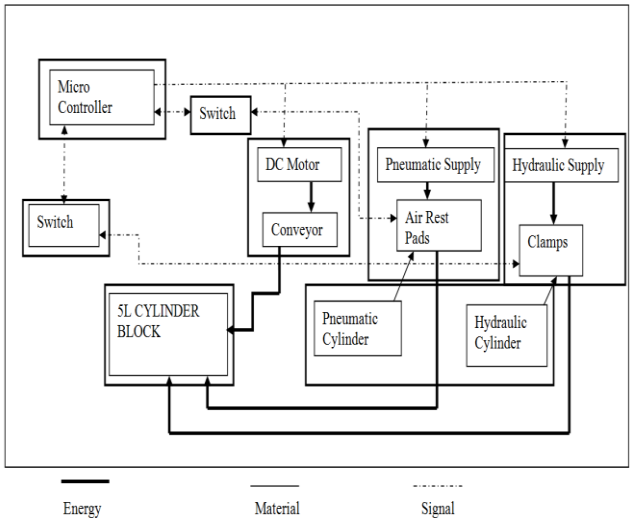

Fig.-13: Cluster of schematic diagram

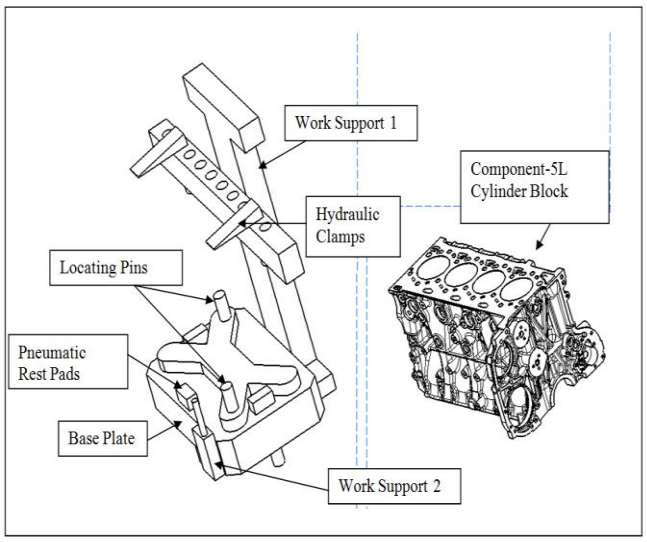

Fig.-14: Rough Geometric Layout

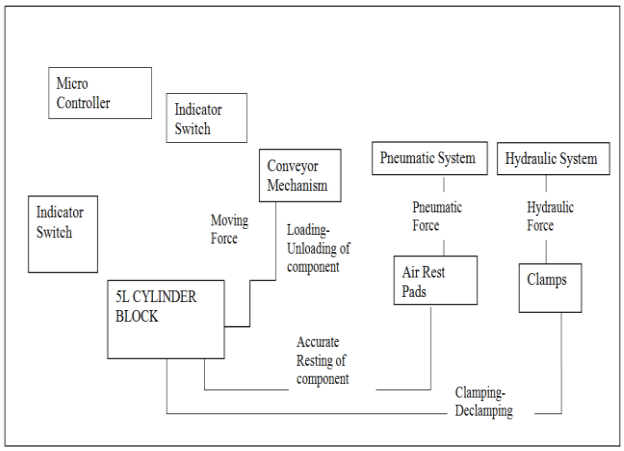

Fig.-15: Incidental Interactions Graph of fixture

5. ELEMENTS OF FIXTURE

A. Pallet: It connects the fixture to the machine.

B. Base Plate*:* A non-standard base plate of dimension is used for mounting the components of the fixture.. It was casted of Cast Iron because of its intrinsic construction. It is robust enough to damp the upcoming vibration in the machining process.

C. Support Fabrication*:* It is installed to provide the vertical support to the machining component

D. Locating pins*:* Precise location of the component on the baseplate is achieved by the use of one common round locating pin and one unique diamond-locating pin.

Butting pad*:* For butting, this pad is used against the component's vertical and horizontal face.. It is used for the easy resting of component thereby, directing the component for its easy entry.

F. Rest Pads*:* They are used for the proper resting of the component and to provide support against deformation..

G. Work Support: It is used to limit the movement of the component during resting and to support the component when the machining is done on the half crank bore.

H. Air sensing Rest pad: These are normal rest pads with the special provision of through air holes incorporated in them. Compressed air is passed into these rest pads and if the resting of the component is flawed, the air would escape from the unblocked outlets. Thus this mechanism is used to ensure proper resting for the component during the machining operations.

I. Hydraulic swing clamp: Hydraulic swing clamps are used for clamping the cylinder block during the machining operations. The levers, initially in the unclamped position, swivel by 90 degrees and then clamp down on the component sing hydraulics.

J. Block Cylinder : It is designed such that it can be used for direct clamping as well as positioning and support. It is Double Acting Cylinder.

K. Sequence Valve: It is used in circuits to operate multiple actuators in a particular Pressure dependent sequence. It is used for positioning and creating delays in actuation. Compact design allows for direct mounting on the fixture.

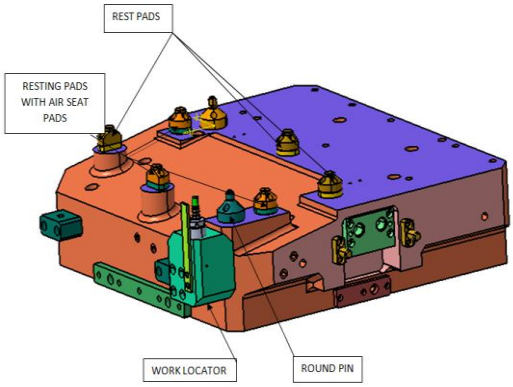

Fig.-16: Details of elements of fixture

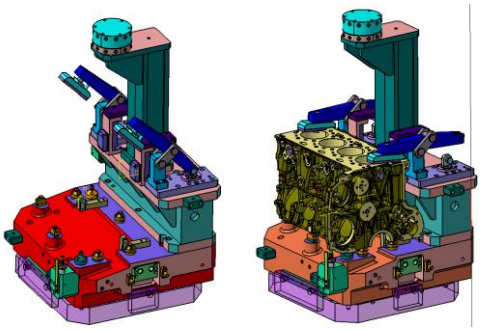

Fig.-17: Work Holding Fixture

Fig.-17: Manufactured Work Holding Fixture

- **Working of Fixture:** First the component's master dowel holes are located on round pin and diamond pin with the help of locators and butting pads. It is ensured that component is properly seated on Rest pads. By initiating the clamping of the circuit after the signal given by air seat pads, the engagement of the Fixture with pallet in the clamped condition is done. Machining of the component on the makino machine starts as the pallet along with the fixture
- moves inside. Disengagement of the machine pallet and the Fixture is done. After that unclamping and unloading is done.

- **Hydraulic Circuit:** The Hydraulic supply is provided externally to the Fixture.

1. Load the component on the rest pads R1,R2,R3,R4,R5,& R6 and locate & orient on cyl. Pin
2. Clamp cylinder actuates (LC-1&LC-2) against rest pads and clamp
3. Sequence valve 1 open, Work support1 actuates
4. Start machining

✓ **During Clamping:**

- Once accurate resting of the component is signalled, the operator then initiates the clamping operation.
- The hydraulic supply then flows through the pipes.
- As the hydraulic supply is not constant, the actuator is filled till 70 bar. It provides the hydraulic pressure
- when the fixture disengages from the supply line.
- The block cylinders then start filling.
- The flow control valve allows the cylinders to be filled simultaneously.
- The clamping action is thus done smoothly.
- As the cylinders get fully occupied the backpressure in the circuit starts rising.
- The back pressure rises to 40 bars and the work supports then actuates and clamps the cylinder.
- After the machining is done the operator the presses the unclamp switch.
- The fluid then flows out of the circuit.

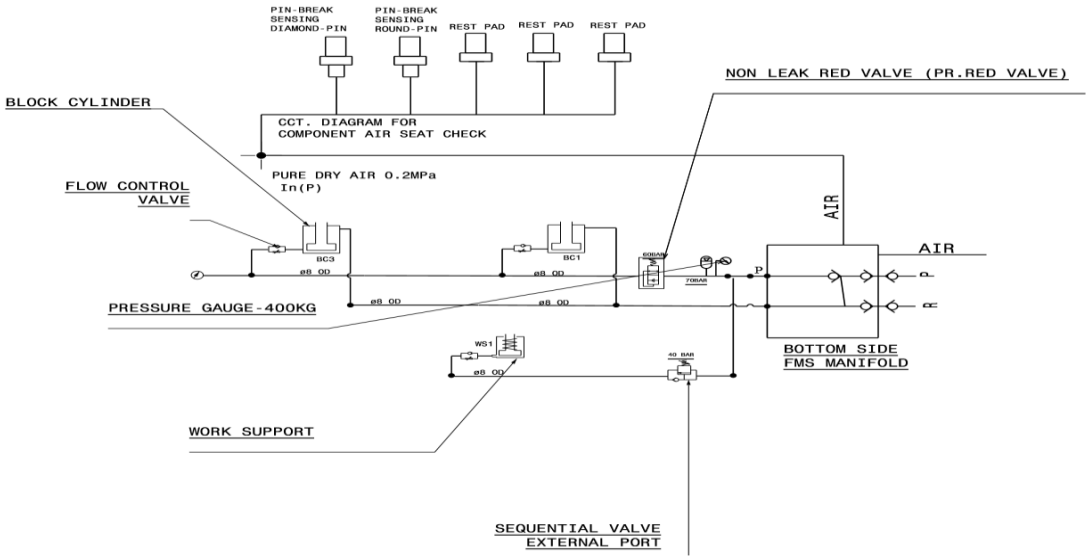

Fig.-19: Hydraulic Circuit

Table -8: Technical Part List

Technical Part List		
Sr.No	**Parameters**	**Unit**
01	Length of Base Plate (Max overall size)	740 mm
02	Width of base plate (Max overall size)	660
03	Weight of Fixture	820 Kg
04	No. of sub assembly	18
05	No. of Fab assembly	4
06	No. of Mfg Parts (Excluding Bushes)	117
07	No. of std parts(Screws and Dowels)	450
08	No. of dowels	10
09	No. of screws	150
10	No. of bushes	4
11	Hydraulic or Pneumatic Fixture	Yes

6. CONCLUSION

Fixture design has large impact on product quality, manufacturing lead time and cost. Designers have been working on various aspects of designing a better fixture to suit a specific application. In this work, the work holding hydraulic fixture for machining of 5L cylinder block has been designed. It is ensured in the design of work holding hydraulic fixture to have less units and work in minimum time. The fixture provides easy loading and unloading of the component.

Table -: 9: Customer Satisfaction Report

1	2	3	4	5	6	7	8	9	10
1. Ability of the fixture to machine auto component/ check auto component to the satisfied accuracy									
									●
2. Safety of the fixture									
									●
3. Ease of use of the fixture(User Friendliness)									
									●
4. Ability of the fixture to consistently produce correct component									
									●
5. General Outlook of the fixture (Deburring, Stamping, Painting, Necessary User Instructions, Lifting Provision)									
								●	
6.Fixture Rework(RW) Status									
Fixture Returned to Production Engg. Dept for RW Fixture reworked at user location ● No / Negligible RW at user location									

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