Design &Development of Semiautomatic Averaging Fixture for Engine Cylinder Block for Enhancement of Productivity & Quality

Pravin Gudale [1], Dr.Vinayak Naik [2]

[1]P.G. Student, [2]Professor & Head,

Department of Mechanical Engineering, D.K.T.E. Textile & Engineering Institute.

Ichalkaranji (Kolhapur), Maharashtra, India

Pravingudale999@gmail.com

Abstract— **in an important field of manufacturing engine cylinder block, averaging fixture is key tool used for generation of averaging dowel holes on casting produced for creating initial machining references on it. Current paper deals with design & development of semiautomatic averaging fixture for enhancement of productivity & quality. Main emphasis is given on need of averaging fixture with problem definition & methodology used to solve problem. Problems incurred with old type averaging fixture are totally eliminated with use of newly manufactured averaging fixture along with increase in production rate & quality of component produced.**

Keywords- Engine cylinder block; conceptual designs of fixture, Semiautomatic averaging fixture; pneumatic circuits for clamping& loading system.

I. INTRODUCTION

The purpose of automotive engines is to deliver power needed to move vehicle. These engines contain cylinder blocks as a main component, which is the foundation of the engine. Most blocks are cast from gray cast iron [1] & send to machine shop for doing further machining operations. A fixture is a mechanism used in manufacturing to hold a work piece, position it correctly with respect to a machine tool, and support it during machining. Widely used in manufacturing, fixtures have a direct impact upon product quality, productivity and cost. Generally, the costs associated with fixture design and manufacture can account for 10%–20% of the total cost of a manufacturing system. Approximately 40% of rejected parts are due to dimensioning errors that are attributed to poor fixturing design. [2]. Thus in an important field of manufacturing of engine cylinder blocks, it is necessary to create machining references on engine block casting before sending it to machine shop. Therefore, for creating these references we require fixture which is known as averaging fixture. Generally, this averaging operation is carried out on radial drilling machine in foundry area itself.

II. IMPORATANCE & NEED OF SEMIAUTOMATIC AVERAGING FIXTURE FOR ENGINE CYLINDER BLOCK.

After the casting is made, it is send to machine shop for machining as required by customer. It is necessary to ensure that minimum machining allowance is available on all the machined faces before machining the first references in all 3 axes. Subsequent machining is done with respect to the first machined references. This activity of ensuring availability machining allowances is done by marking the casting on a layout marking machine for small quantity of casting .Since this is time consuming activity for mass produced castings, averaging fixtures are used in such cases. Hence averaging fixtures should logically have features to ensure minimum machining allowance and facility to conduct first machining references in 3 axes. [3]

Normally 3 small machined pads in one axis and 2 dowel holes on these pads are sufficient to locate the casting, constraining all the three degrees of freedom for subsequent machining either on transfer line or gang of SPM's. This operation of averaging is mainly done on radial drilling machine.

By taking into consideration point of averaging fixture for engine cylinder block, old type design of averaging fixture is very complicated .This practice of creating averaging references on casting in 3 axes is very skilled ,very time consuming and tedious process.

Also in order to meet customer requirement for supply of castings, manual averaging fixture is not found much suitable because doing machining operation with such type of fixture contains problems such as more cycle time for operation with less productivity , Averaging dowel holes centre distance variation due to hinge type design , Fatigue to operators while loading of job inside fixture ,Manual clamping , Visualization of template profiles while setting of job, Fatigue to operator for template pushing & pulling, Any mistake proofing's or poka yokes is not existing , Not easy to inspect fixture for calibration to quality persons, Setting of fixture on machine at time of setup change over is not easy, Maintenance of screw jacks & other parts is time consuming, heavy type of alignment gauge to inspect centre distance of averaging dowel holes. Hence is in needed to overcome above mentioned drawbacks in manual averaging Fixture.

This generates Need of Semiautomatic Averaging Fixture for improvement of productivity, reducing rejection with quality improvement & customer satisfaction, reducing fatigue to operators.

Present engine cylinder block:-

It is made up of gray cast iron. Grade=FG 200,Tensile Strength = 200 N/mm2 (depends on wall thickness),Wall thickness (In mm) = 5.5-7.5,Hardness Range=160-220 BHN,Chemical Composition- C= 3.2 -3.5 %,Si = 1.8-2.3 %,Mn= 0.6 -0.9%,P= 0.2 %(Max.),S= 0.1 % (Max.),Iron =Remainder

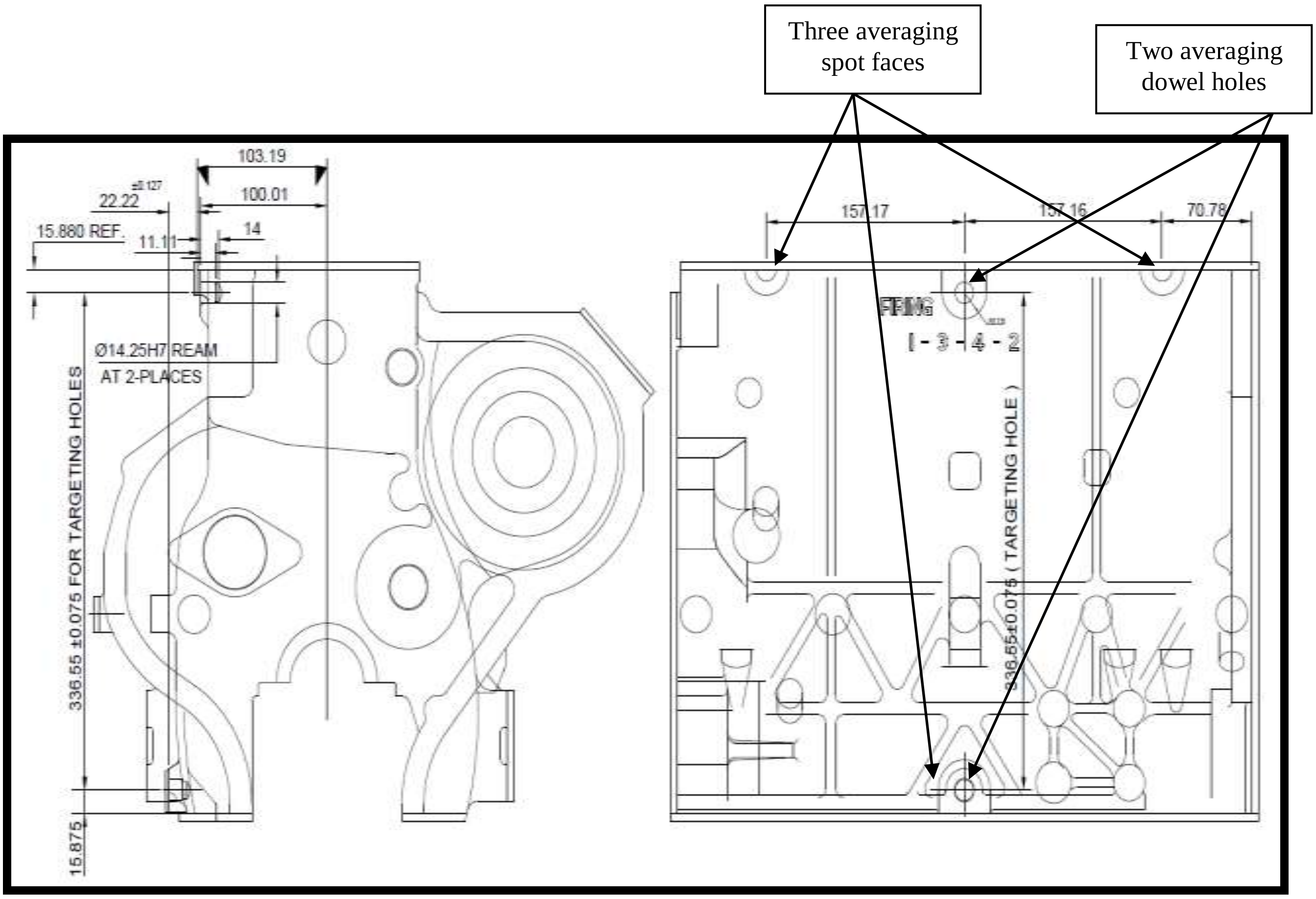

Figure No.1.Present engine cylinder block

Thus when we get this engine cylinder block casting, it is required to create averaging references on this casting before sending it to machine shop for producing further machining operations.

This block contain averaging dowel holes & spot faces operations shown in figure no.1& which are listed below-

Ø14.25 H7 dowel holes = 2 nos., Ø35 mm spot faces = 3 nos.

Centre distance of averaging dowel holes:-336.55±0.075mm, Spot face height difference:-22.22±0.127mm. This project concerns design & development of semi-automatic averaging fixture , on which this averaging operation is generated on product.

III. PROBLEM DEFINITION & METHODOLOGY USED FOR DESIGN & DEVELOPMENT OF FIXTURE

By considering needs of customers problem statement will be developed as,

"DESIGN AND DEVELOPMENT OF SEMI-AUTOMATIC AVERAGING FIXTURE FOR ENGINE CYLINDER BLOCK FOR ENHANCEMENT OF PRODUCTIVITY & QUALITY".

Main objectives of project are as:-

- To design a new semiautomatic averaging fixture by considering specifications of component by using AUTOCAD or any suitable software.
- To establish & set a process on new averaging fixture.
- To improve productivity by identifying scope of improvement & to improve quality by achieving co-ordinates of averaging operation within required specifications.

Proposed Flow of Work:-

Design & Development of new semiautomatic averaging fixture which includes following steps:-

Preparation of Conceptual designs of fixture & finalizing suitable concept.

↓

Calculation of Cutting forces coming during averaging operation.

↓

Design of pneumatic loading system of job inside fixture

↓

Design of Pneumatic system for clamping & loading of job, by using FLUIDSIM or any suitable software.

↓

Design of different fixture elements such as jig plate, main base, templates, guide bars, flush pin gauge, bushes & liners etc.

↓

Performing Design Failure Mode &Effects Analysis FMEA for semiautomatic averaging Fixture

↓

To Develop Manufactured & Assembled Model of semiautomatic averaging Fixture

↓

To set & establish averaging operation on newly manufactured semi automatic averaging fixture using Radial Drilling Machine .

IV. LITRATURE REVIEW

Some of the present theories and practices in the area of fixture designing, Machining process improvement are as explained below as very less literature is available on averaging fixtures. Following is a brief review of the available literature for design, development & manufacturing of semiautomatic averaging fixture.

The authors Hui wang, et.al. [2] have explained regarding Computer aided fixture design(CAFD) and automation over past decades. first introduction is given on fixture applications in industry ,then significant work done in CAFD field, including their approaches, requirements and working principles. This mainly reports how fixtures have direct impact on product manufacturing quality, productivity and cost.

In literature review based on reference course material by foundry & forge training Centre [3] principles of jigs & fixture designing are explained .Also it explains different types of fixtures used in foundries & how averaging fixtures are used for creating initial machining references on castings for further subsequent machining.

Xiumei Kang and Qingjin peng . [4] have explained information regarding recent research on computer aided fixture planning(CAFP).How CAFP is used to improve fixture design. CAFP mainly contributes to verification of fixture quality and integration of fixture design with CAD/CAM systems. This paper mainly summarizes constraints of fixture planning & its four phases.

Central Machine Tool Institute (CMTI) [5] ,Machine Tool Design Handbook explains detailed information regarding details of cutting operations like Drilling, Milling etc. FESTO Key Product Catalogue[6] explains regarding selection of different types of pneumatic cylinders which will be used for fixture manufacturing.

As very less study is done in the field of developing averaging fixtures for engine cylinder blocks which will result in higher productivity along with desired quality & less fatigue, present dissertation deals with design & development of semiautomatic fixture

V. FLOW CHART FOR CONCEPTUAL DESIGN BY USING DIFFERENT APPROCHES.

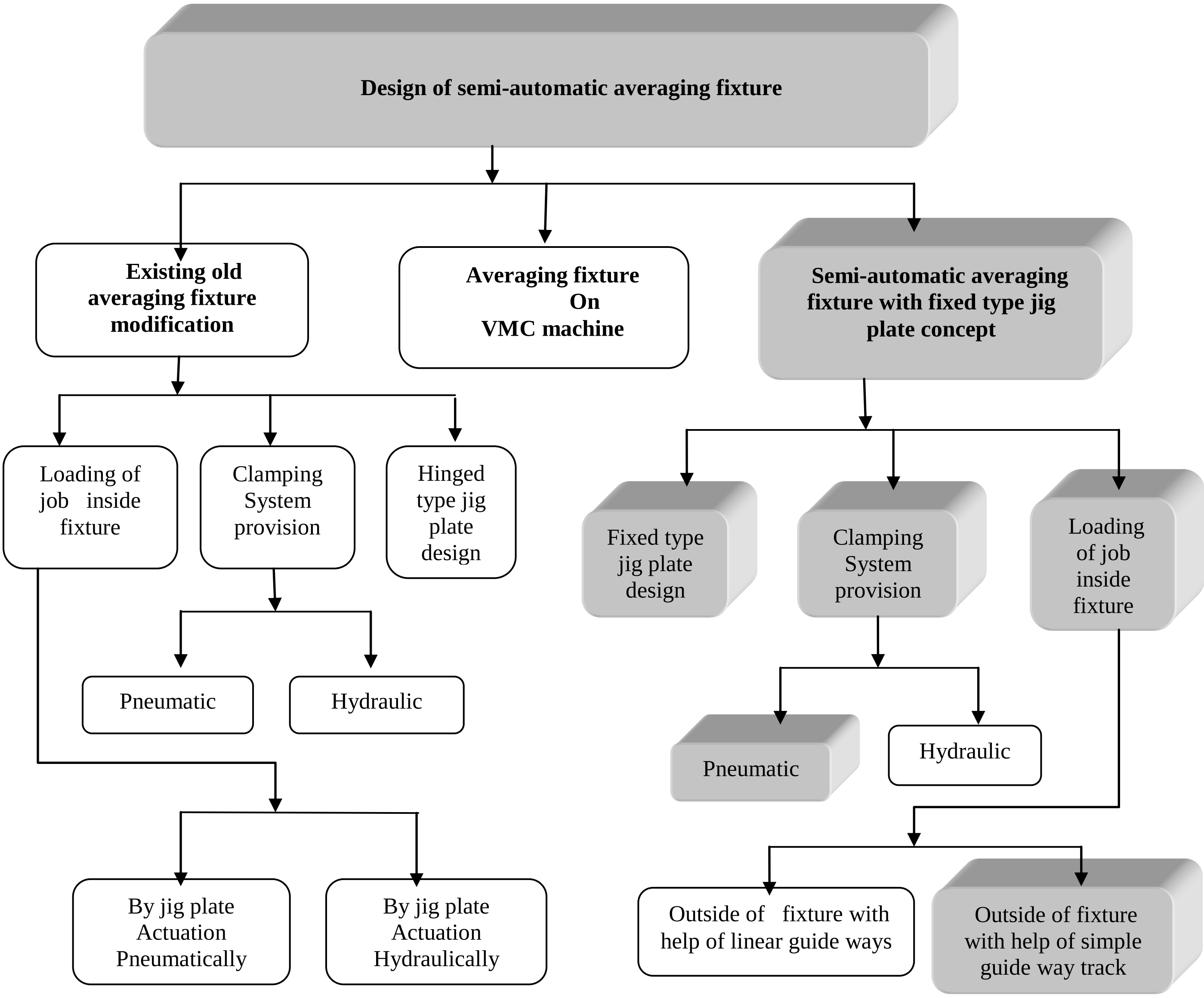

Figure no.2.Flow chart for conceptual design by using different approaches

After performing concept study, by consideration of different advantages & limitations, Design of averaging fixture with concept having fixed type jig plate design with pneumatic clamping & job loading outside fixture finds better option. Flow chart for different approaches used for conceptualization phase is shown in fig. No2. We go for concept with bold marked blocks.

VI. CALCULATIONS OF CUTTING FORCES COMING DURING AVERAGING OPERATION.

A. For drilling operation:-[5]

1] Cutting speed (V) - a) For Ø 13 mm drill-

$$V = \frac{\pi \times D \times N}{1000} = (3.14*13*490)/1000 = 20 \text{ m/min}$$

2] Select the suitable feed (S)- which is depends upon the type of the material of the Work piece (C.I.). S-feed per revolution (mm/rev) , For the cast iron it is S= **0.15 mm/rev**

3] Select material factor (k) - It depends upon the type of the material of the work piece hence it is calculated as follows, K for C.I. is 1, 1.5, and 2. but for CI with BHN (160-220) & UTS (200N/mm2) Taking the material factor as **k = 1.5**

4] calculate the thrust force coming on the spindle,

a) Axial thrust on spindle of Ø 13 mm drill,

$$Th = 1.16 \times k \times D \times (100 \times 0.15)^{0.85}$$

Th = 1.16 x 1.5 x 13 x (100 x 0.15)$^{0.85}$ =226.032 Kgf = **2217 N**

B. For reaming operation:-[5]

1] Cutting speed (V) - a) For Ø 14.25 mm reamer :-

$$V = \frac{\pi \times D \times N}{1000} = (3.14*14.25*268)/1000 = 12 \text{ m/min}$$

2] Select the suitable feed (S)- which is depends upon the type of the material of the Work piece (C.I.). S-feed per revolution (mm/rev) , For the cast iron it is S= **0.41 mm/rev.**

3] Select material factor (k) - It depends upon the type of the material of the work piece hence it is calculated as follows, K for C.I. is 1, 1.5, and 2. but for CI with BHN (160-220) & UTS (200N/mm2) Taking the material factor as **k = 1.5**

4] calculate the thrust force coming on the spindle,

a) Axial thrust on spindle of Ø14.25 mm reamer ,

$$Th = 1.16 \times k \times D \times (100 \times 0.15)^{0.85}$$

Th = 1.16 x 1.5 x 14.25 x (100x0.15)$^{0.85}$ =247.76 Kgf = **2430 N**

C. For spot facing operation:- [5]

1] Cutting speed (V)- a) For Ø 42 mm Spot face cutter:-

$$V = \frac{\pi \times D \times N}{1000} = (3.14*42*758)/1000 = 100 \text{ m/min}$$

2] Select the suitable feed (S)- which is depends upon the type of the material of the Work piece (C.I.). S-feed per revolution (mm/rev),For the cast iron it is S= **0.41 mm/rev.**

3] Select material factor (k) - It depends upon the type of the material of the work piece hence it is calculated as follows, K for C.I. is 1, 1.5, and 2.but for CI with BHN (160-220) & UTS (200N/mm2)

Taking the material factor as **k = 1.5**

4] calculate the thrust force coming on the spindle,

a) Axial thrust on spindle of Ø 42 mm Spot face cutter,

$$Th = 1.16 \times k \times D \times (100 \times 0.15)^{0.85}$$

Th = 1.16 x 1.5 x 42 x (100x0.15)$^{0.85}$ =730 Kgf = **7163 N**

VII. DESIGN OF PNEUMATIC LOADING SYSTEM OF JOB INSIDE FIXTURE

Loading of job inside fixture is very tedious task, as operator has to pull Crane to lift the job, lift the job by using tackles, then to lift hinge typed jig plate& then has to load job inside fixture. Thus in order to load job inside fixture it is decided to use crane only for lifting job & then to put job on newly designed sliding base. Below sliding base four M.S. brackets are bolted. Each M.S. bracket comprising of three case hardened resting flats inside it. This whole assembly of sliding base, four brackets & (3 X4 =12) rest flats is allowed to slide on resting flat track on main base with the help of pneumatic cylinder

Design of pneumatic cylinder used for operating of sliding base:-

Mass of component on sliding base (m) = 81 kg.
Mass of sliding base (m1) = 103 kg.
Mass of 4 M.S. brackets with 12 Rest Flats (m2) = 12 kg.
Mass of 3 Screw jack assemblies on sliding base (m3) = 7 Kg.
Thus total mass (M) = m + m1 + m2 + m3 = 81 +103 + 12 + 7 = 203 kg.
Total weight to be pushed by pneumatic cylinder = M x g Newton's.
= 203 x 9.81 = 1991.43 N

Considering coefficient of force of friction for hard steel plates on hard steel plates (Dry) μ = 0.42……………………… (μ is taken from catalogue of Applied Industrial technology)

So resultant force to push by cylinder = μ x M x g
= 0.42 x 203 x 9.81 =836.400 N
With 20% Factor of safety [14] = 1003.68 N
We have to use 1 pneumatic cylinder, therefore
Force for one cylinder will be =1003.68 N
=1003.68 / 9.81 = 102.311 kgf.
Pressure = Force / Area
= F / {[3.14/4] / D^2}
Considering 6 bar air pressure,
Pressure x Area = Force
6 x 0.785 x D^2 = 102.311
D = 4.66 cm =46 mm.

Thus, we select Ø 80 mm bore & 650 mm stroke pneumatic cylinder with foot mounting.

VIII. DESIGN OF PNEUMATIC SYSTEM FOR CLAMPING & LOADING OF JOB USING FLUIDSIM SOFTWARE

A. Design of pneumatic cylinders used for clamping:-

Maximum Cutting force coming during cutting operation = 7163 N
With 20% Factor of safety [14], Cutting Force = 8595 N
We have to use 3 pneumatic cylinders, therefore
Force for one cylinder will be = 8595 / 3 = 2865 N =2865 / 9.81 = 292.04 kgf.
Pressure = Force / Area
= F / {[3.14/4] / D2}
Considering 6 bar air pressure,
Pressure x Area = Force
6 x 0.758 x D2 = 292.04
D = 8 cm =80 mm.

We select Ø 80 mm bore & 50 mm stroke pneumatic cylinders.

As we are going to mount these cylinders against component on top of jig plate, it is essential to use front flange mounting cylinders.

B. As discussed above, we select Ø 80 mm bore & 650 mm stroke pneumatic cylinder with foot mounting for actuation of sliding base used for loading of job inside fixture.

C.Use of FLUIDSIM software done to simulate pneumatic clamping & loading system.Pneuamatic system used for clamping circuit is shown in fig. No.3 & pneumatic system used for sliding base actuation circuit (loading system) is shown in fig.no.4..

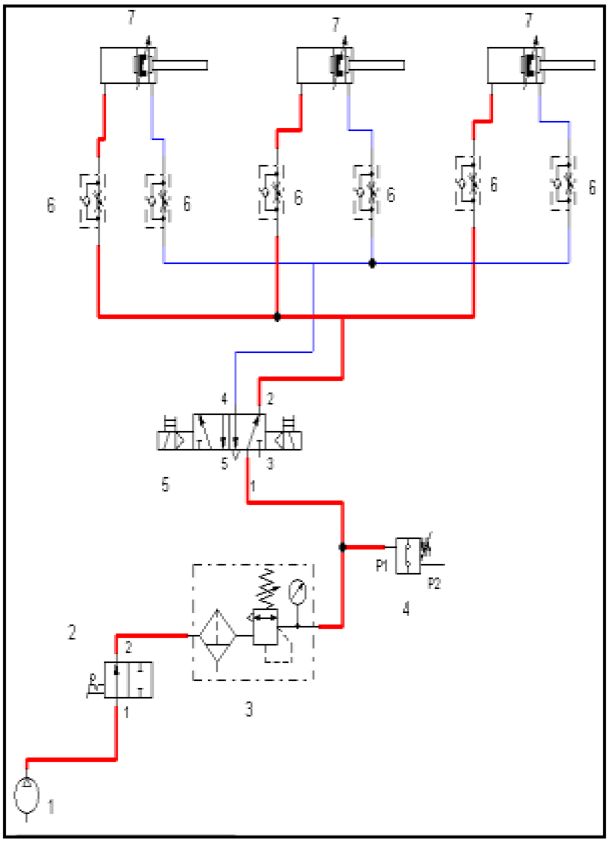

Figure no.3 Job clamping circuit

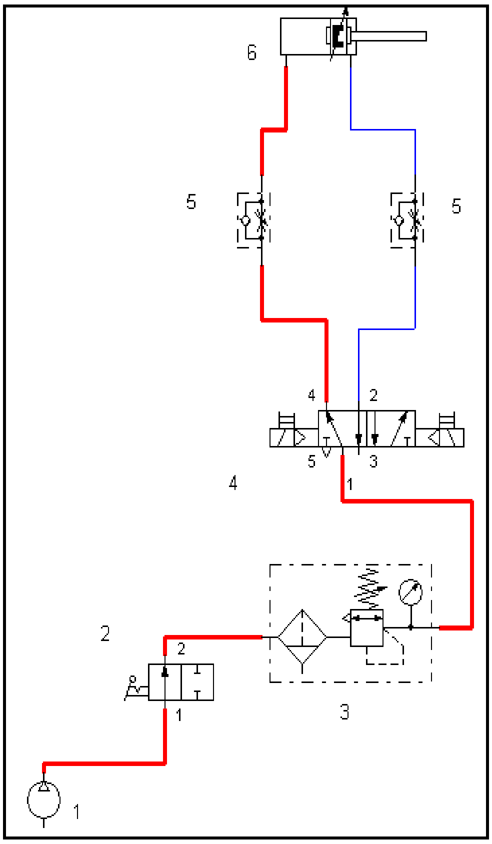

Figure no.4 Sliding base actuation circuit

IX. DESIGN OF FIXTURE ELEMENTS & PERFORMING DMFEA :-

Old type of averaging fixture consists of hinged type jig plate. For every cycle operator has to lift this jig plate which is leading to major fatigue to operator along with variation in center distance of dowel holes. To avoid this fixed type jig plate design is implemented in this fixture. This jig plate is made up of gray cast iron which is stress relieved.

Main base is in the form of solid frame of casting, which is hollow & box structured .It is made up of gray cast iron material. Templates are provided on four sides of the casting to gauge the machining allowances. These templates are given shape of casting corresponding to respective sides of casting. To gauge the minimum machining allowance the templates have edges showing final machined faces. The thickness of templates is chosen as 12 mm depending upon overall sizes of templates. All other parts such as guide bush, liners are also designed along with guide bars required for actuation of templates.

After completion of assembly design, failure mode & effect analysis [16] is performed for reducing weakness in design at early stages of design.

X. TO DEVELOP MANUFACTURED & ASSEMBLED MODEL OF SEMIAUTOMATIC AVERAGING FIXTURE.

In manufacturing stage, all parts such as main base, sliding base, jig plate, top side bracket, sump side bracket, front side bracket & rear side bracket are made up of using hand molding method for producing casting. These parts are then heat treated to relieve stresses. Then by using suitable machining methods such as milling,boring,drilling tapping, jig boring,screpping etc.these parts are finished to required sizes. All other parts such as templates, linear bushes, guide bars, liner & bushes along with hardware's are out souresed.

During assembly stage, all manufactured parts & Procured standard brought out items mentioned above are verified according to drawing specifications. All sharp corners of parts were removed by using deburring tools such as sander, files & oil stones. All manufactured parts are washed by using kerosene for removal dist & foreign particles. After washing pressurized air from compressor was blown over all the components.

Firstly rest flats are mounted on main base , then assembly of main base along with sliding base is done. Top liner bore side bracket & sump side bracket are then mounted on main base .On these fixed type jig plate is mounted. Front side bracket, rear side bracket are then mounted at their required places. All necessary pneumatic connections are done at their required positions. Dry trial run are then taken for sliding base cylinder actuating , clamping cylinders & fixture is released for tryout on component.

XI. TO SET & ESTABLISH AVERAGING OPERATION ON NEWLY MANUFACTURED SEMI AUTOMATIC AVERAGING FIXTURE USING RADIAL DRILLING MACHINE .

Engine block casting is lifted from conveyor &loaded on sliding base with help of crane. Now job is taken inside fixture with help of push button for sliding base actuation cylinder & close front side hinge bracket manually by hand knob. Setting of job inside fixture for gauging machining allowances is done with help of four side templates & job is adjusted for these templates by adjustable screw jacks& eight hand knobs. After ensuring this, clamping is done with the help of three pneumatic clamping cylinders with help of push button. Firstly spot face operation at three points is carried out with indexable insert spot face cutter Ø42 & with help of flush pin gauge required depths are maintained , 22.22 distance on component is achieved. Now drilling operation is carried out with Ø 13.5 x 250 mm HSS drill on component. After this directly reaming operation is performed with Ø14.25 x 250 mm HSS reamer to generate two dowel holes at desired specifications. Now chamfering operation for dowel holes is performed with chamfer tool.

After this job is de clamped , released from four side i.e de clamped manually by eight hand knobs & taken outside of fixture with help of push buttons. Diameters & depths of dowel holes are checked with plain plug & depth gauges. Snap gauge is used to judge initial spot face level from water jacket cavity. Newly manufactured centre distance checking gauge is used for checking centre distance of dowel holes. Now this averaged component is then lifted with crane & taken on conveyor. Now this component is checked on CMM machine for ensuring dowel hole C.D.& Layout of component is done by marking it on surface plate with digital height gauge for ensuring necessary machining allowances on it. Schematic diagram for proposed set of averaging fixture is as shown in figure no.5

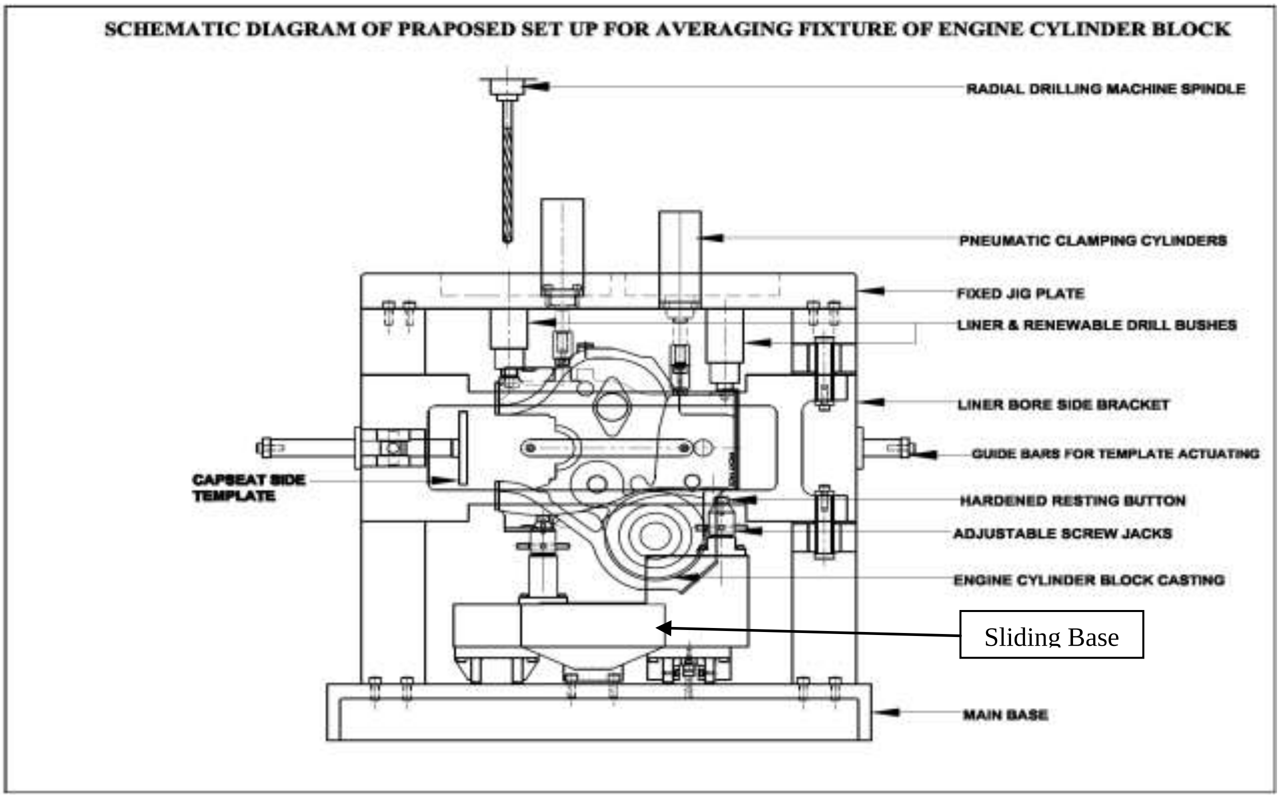

Figure No.5. Schematic diagram for semiautomatic averaging fixture of engine cylinder block.

XII. Results & Discussions

After design & manufacturing of semiautomatic averaging fixture, Tryout activity of this fixture is conducted & results achieved with this fixture are stated as below,
Firstly, it is found that from cycle time study there is reduction in cycle time as stated below, Thus net saving in cycle time after implementation of averaging fixture is 34.352%.This is resulted in increase in productivity of components.

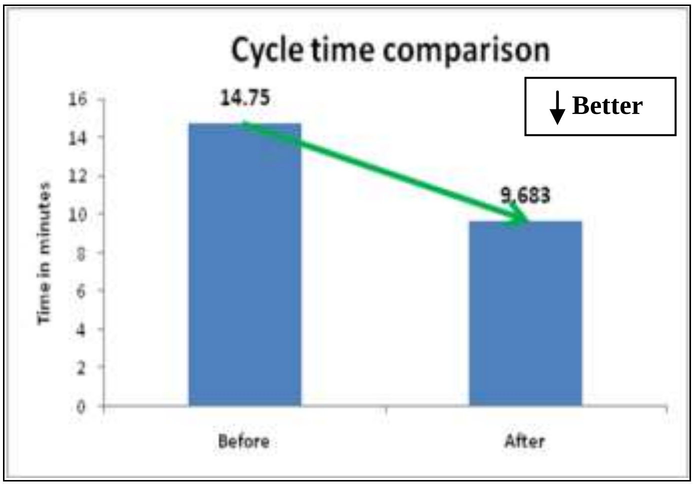

Fig.No.6 cycle time comparison in minutes.

Secondly, before because of use of hinge type jig plate & manual clamping mechanism, there is uncertain variation in averaging dowel hole centre distance and values of Cp & Cpk become observed as 0.78 & 0.68. Now with use of newly manufactured semiautomatic averaging fixture, it is observed that values of quality parameter for averaging dowel hole centre distance are consistent within specified limits. Also, we found that values of Cp = 1.46 & Cpk = 1.43 which are greater than 1.33 So process which we are using is capable of producing jobs within required specifications. Along with this from marking (or layout) report it is clear that condition for minimum machining allowance required for machining is satisfied. Thus chances of rejection are reduced.

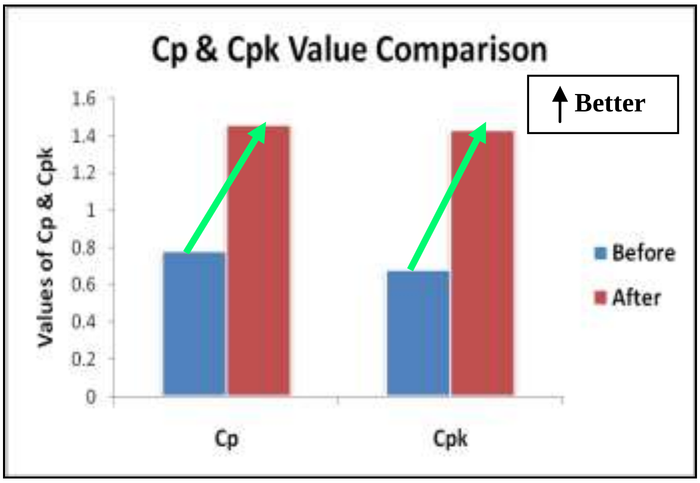

Fig.No.

While summarizing results some of intangible benefits achieved are stated as, Fatigue to operator for loading & unloading of job inside fixture with old hinge typed jig plate is totally eliminated with fixed type jig plate design. Before operator has to clamp job manually, now new fixture is provided with pneumatic clamping mechanism with single press of button. Also visualization passage is provided for side brackets which resulted in easy setting of job inside fixture. Fatigue while pushing & pulling of templates with guide bars is totally reduced.Cummulative effect of above points is moral of operator is improved. He is very happy with operating this new semiautomatic averaging fixture.

XIII. CONCLUSION

Semiautomatic averaging fixture for engine cylinder block is designed, developed and installed satisfactorily Any saving done due to use of advanced manufacturing technique directly contributes to the net profit of the product.. The following satisfactory conclusion is drawn after installation of averaging fixture as, Reduction in cycle time is achieved as compared to old conventional averaging fixture. Productivity has improved in both ways that is qualitative and quantitative. This newly manufactured averaging fixture can be used for improving productivity with reducing chances of rejection due to averaging centre distance variation. There is less human intervention compared to conventional averaging fixture, which directly resulted in less operator fatigue. Also this reduces the labor cost. Hence increase in the production rate is achieved with reduction in production cost. Overall moral of operator operating this fixture is improved with reduction in fatigue.

Now for future use such averaging fixture can be employed horizontally for averaging any type of 2,3 or 4 cylinder bored engine block.

XIV. FUTURE SCOPE

From future scope point of view it is possible to convert this semiautomatic fixture to fully automatic version by incorporating pneumatic cylinder for actuating front side bracket which is manually operated in current fixture.

ACKNOWLEDGEMENT

I take this opportunity to thank my guide Prof.Dr.V.R.Naik sir for his valuable guidance and for providing all the necessary support for completion of design & development of semiautomatic averaging fixture for engine cylinder block.

REFERENCES

[1] Crouse & angling , “Automotive Engines”, Mc Graw hill internal additions – 8th edition 1994, pp.67-68
[2] Hui wang, Yoming(kevi)Rong, Hua Li, Price Shaun, “Computer Aided Fixture Design:-Recent research and Trends” Computer Aided Design , vol -42,2010,pp 1085-1094.
[3] A Reference Course Material by Foundry & Forge training Centre, Pune , on “Design Of Jigs & Fixtures” April 2011,pp50-52.
[4] Xiumei Kang and Qingjin peng, “Recent Research on Computer Aided Fixture Planning” Recent Patents on mechanical engineering,2009,pp8-18.
[5] Central Machine Tool Institute’s(CMTI),” Machine Tool Design” Handbook
[6] “FESTO” Key Product Catalogue.
[7] “SMC Hydraulic, Hydro pneumatic, Pneumatic Clamping Elements for production tooling’s” Product Catalogue.
[8] “HYPOWER CLAMPS” product catalogue.
[9] P.H.Joshi, “Jigs And Fixtures”, 3rd Edition from Tata McGraw Hill company Ltd.
[10] J. C .Trappey & C.R. Liu, “A Litrature Survey Of Fixture Design Automation”, The International Journal Of Advanced Manufacturing Technology,vol-5,1990,pp 240-255
[11] Shane.P.Siebenaler,& Shreyas N.Melkote, “Prediction Of Work piece Deformation in Fixture System using Finite Element Method”, International Journal Of Machine Tolls & Manufacture ,Vol-46,2006,51-58.
[12] N.P.Maniar & D.P.Vakharia , “Design & development of fixtures for CNC –Reviews, Practices & Future Directions”, International Journal Of Scientific & Engineering Research,Vol-4,Feb 2013,pp1-11.
[13] Tarcisio Abreu Saurin,Jose Luis Duarte Reberieo & Gabriel Vidor, “framework for assessing poka yoke devices”, Journal Of Manufacturing Systems,vol-31,2012,pp358-366.
[14] “MEAD-Pneumatic application & reference handbook”, pp12.
[15] Peter croser & frank Ebel, “Pneumatics-Basic Level (FESTO)”, 2002, pp173.
[16] Robin E. McDermott , Raymond J. Mikulak , Michael R. Beauregard, “BASIC FMEA” - 2nd Edition by productivity press book, pp.1-38, (2009).
[17] MANUAL OF “Potential FMEA” by FORD MOTOR CARPORATION 3rd edition , pp.8-31, July 2001.
[18] Reference manual for “Statistical Process Control(SPC)’’, Chrysler Corporation, Ford Motor Company, and General Motors Corporation,2nd edition 1995.