Automation of a Vertical Machining Centre using Six-Cylinder Pneumatic Fixture.

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Abstract, *In this fast-paced world, there is little room for error, and time is a valuable commodity now, we cannot waste time and money manufacturing/fabricate products. So, this means that in modern industries quick actions done very precisely are becoming very valuable when compared to conventional human responses, mounting a workpiece in a CNC machine takes time because we have to set the workpiece with no errors in axis points. So, a smart clamping system can fix the workpiece with the required force without deforming the workpiece. In this report, a detailed description of materials, methods, design, and calculations along with the fabrication of the model of an intelligent clamping system for aluminum workpiece is explained. we can clamp six workpieces in no time with the help of the pneumatic fixture*

1. INTRODUCTION

Mass production aims at high productivity to reduce unit cost and the interchangeability to facilitate easy assembly. This necessitates production devices to increase the rate of manufacture and inspection device to speed up inspection procedures. By using computers, hydraulics, pneumatics, robotics, etc. we can achieve automation. Among these sources, pneumatics form an attractive medium, low-cost automation. Nowadays almost all the manufacturing process is being automated to deliver the products at a faster rate. The manufacturing operation can be automated for the following reasons, to achieve mass production, reduce manpower, increase the efficiency of the plant, reduce the production cost and reduce the production time. The main advantage of all pneumatic systems is economy and simple automation plays an important role in mass production. A pneumatic system requires air to work so an air compressor is used to compress it and it is supplied to the system. Valves are fitted to the system to control air direction, pressure, and flow rate. An actuator is provided to convert the air energy into mechanical force or torque to do useful work. And piping is provided to carry the compressed air from one place to another. A fixture is a special-purpose tool that is used to facilitate production like machining, assembling, and inspection operations. The mass production of the workpiece is based on the concept of interchangeability according to which every part is produced within an established tolerance. Fixture helps for manufacturing interchangeable parts since they establish a relation with predetermined tolerances, between the work and the cutting tool. Once the fixture is properly set up, any number of parts can be produced without additional setup. To increase production in the drilling and milling and threading process for the valve body, it is a challenge to hold six valve bodies at one time. The background of this project is to design a fixture for holding six valve bodies and the importance to use the fixture in the production line. A vertical machining centre is a saddle-type construction with sliding bedways.it is equipped with:

- Single spindle with Auto turret control.
- Multi-spindle with turret head (Turret machining centre)
- X-Axis transverse provided by table or column.

- Y-Axis transverse provided by the saddle or the
- column or bed.
- Z-Axis provided by the headstock. In this machining centre,
- the tool is capable of generating more complex states compared with the horizontal machining centre.

The additional accessories provided in the VMC help in performing multiple operations in a single setup. VMC has mostly used in machining dies and molds. Components of vertical machining centre are:

- Bed
- Saddle
- Spindle
- ATC
- Column
- Table

Servomechanism Machining axis: Five-axis machining centres have the following facilities, x, y, z-axis for linear movements.

A - Axis for tilt and contour spindle,
B - Axis for rotary table.

The centre consists of multifunction CNC machines equipped with ATC which are capable of carrying out milling, drilling, reaming, tapping, boring, counterboring, and allied operations without operator intervention which are called machining centres. Classification of machining centres:

- Horizontal machining centre
- Vertical machining centre
- Universal machining centre

Holding valve body parts to be drilled is one of the major problems faced by manufacturing companies, especially small and medium companies. For certain processes, they need expensive equipment to hold the parts to be drilled. Today, customers' requests in industries are enormously sized orders. So, the company must find a new method to improve its production rate. A fixture is an important accessory used in any production industry. Before this, fixtures always had limited functions like just being a part that served as a support for a process. This makes the production slow and cannot full-fill the customer demand. Nowadays, there are several methods available to improve the design of manufacturing layout to increase productivity. The fixture is a simplified device for locating and clamping the workpiece. A fixture with a simple setting that can hold more than one component should be designed to reduce the cost and production time. In this paper, design, analysis, model and fabrication of six-cylinder fixture body parts with a thickness of 32 mm. To perform milling, drilling, and threading operations over a workpiece for a vertical machining centre.

2. COMPONENTS USED

2.1 Work – piece dimensions:

The workpiece is made of aluminum and its grade is H2H4 the requirement of the pr4. Dimensions of the work piece is Length = 70 mm, Width = 68 mm, Thickness = 32 mm. The operations to be done after the clamping of the work piece is Milling, Drilling, Counter boring, Threading.

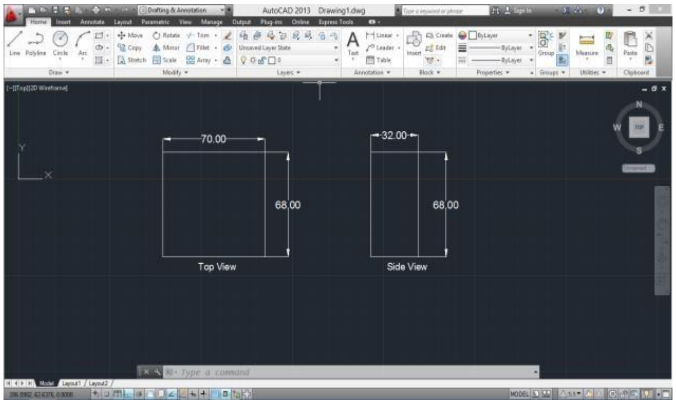

Fig 2.1 Work-piece dimension

2.2 Fixture design using solid works

The requirement of the project is designed with the help of Solidworks application. By calculating the force and dimensions given to the projects we derived the actual design known as final design. Major Parts of the fixture are

- Base plate
- Vertical support plate
- Clamping plates

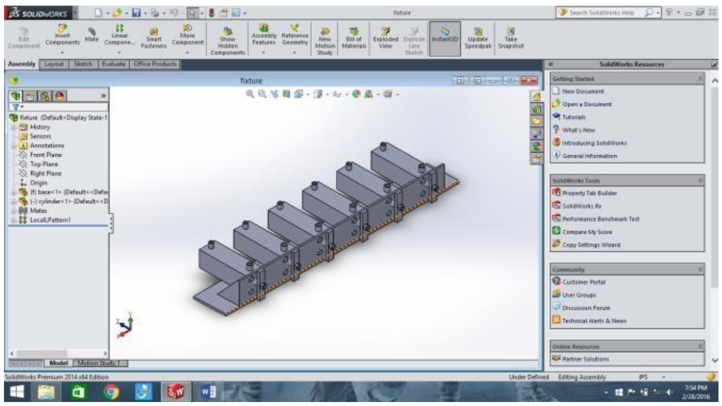

Fig 2.2.1 Fixture design

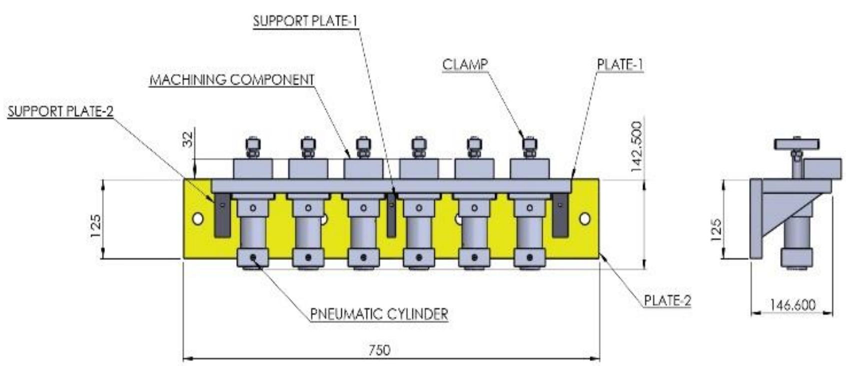

Fig 2.2.2 Fixture design with parts name

2.3 Base Plate

The base plate is the main part of fixture assembly. The bottom surface of the base plate should be machined perfectly. In which all parts of the fixture are mounted. The base is heavy and robust in construction and is made of mild steel. It is the only part to support all other parts. Because all parts are mounted on top of the space, it should be made to absorb vibrations due to load and cutting forces while machining. The base plate preview is shown in Fig 2.3

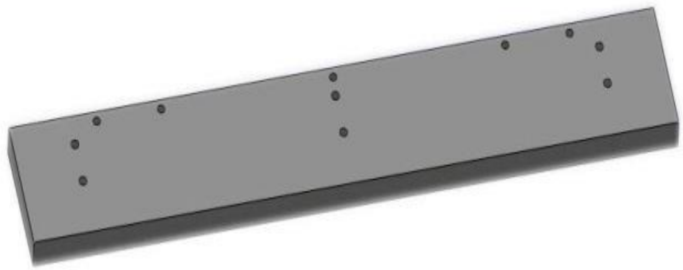

Fig 2.3 Base Plate

Length = 750 mm

Width = 130 mm

Thickness = 25 mm

2.4 Vertical Support Plate

Cylinders are fastened in the fixture with the help of vertical support. The vertical support is mounted on the base plate. It is made of mild steel. It should be made to absorb vibrations due to cylinder movement. The support plate is shown in Fig 2.4

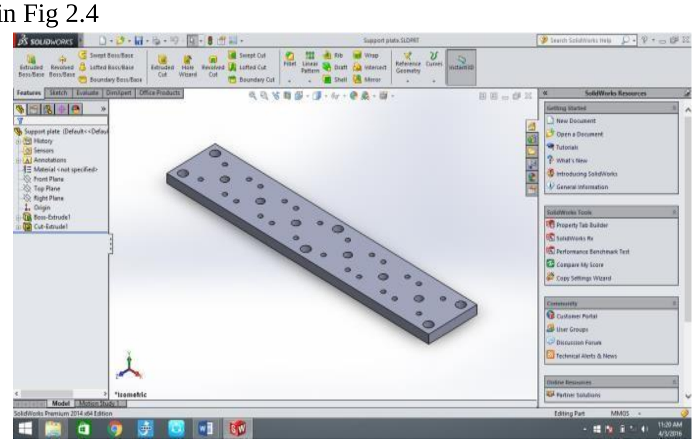

Fig 2.4 Vertical support plate

Length = 650 mm

Width = 70 mm

Thickness = 25 mm

2.5 Locating Pin

Location refers to the establishment of a proper relationship between the workpiece and fixture. Location pins are used to position the workpiece accurately with respect to the setting elements in the fixture. There are different types of locating pins available. In this fixture round locating pins are used. Locating round pin are shown in Fig 2.5

Fig no 2.5 Round locating pins

2.6 Dowel Pin

Dowel pins are solid cylindrical rods typically fabricated using plastic, wood, or metal. It's also called a dowel rod. Dowel pins are constructed by cutting dowel rods into small pieces. They are typically used in precise applications like locating devices in machinery. The dowel pins and their corresponding pins are reamed to tight tolerances. The hole of the dowel pin has a greater diameter than the diameter of its pin. This is done to allow the pin to slip in and out easily. Some allowances and play are tolerated. Mechanical tolerances are inversely proportional to the costs. This is why engineers need to balance cost with mechanical precision along with serviceability and manufacturability Dowel pins are shown in Fig 2.6

Fig 2.6 Dowel pins

Diameter = 8mm

Length = 50 mm

Material = Mild steel

Dowels are typically used when precise mating alignment is required. For example, differential gear casings engines and transmissions. Bolts, the same as dowels have the important function of resisting shear forces. This is why many bolts have unthreaded sections to their shank. This method is used to avoid problem with fretting wear when an unthreaded components bears against a screw thread.

2.7 Clamp

The main purpose of the clamping element is to exert a force to press the workpiece against the locating surfaces and holds it against the action of machining forces such as milling, drilling, and tapping. The clamp is connected with a double-acting cylinder rod. The cylinder actuates the clamp. The side the view is represented in Fig 3.8

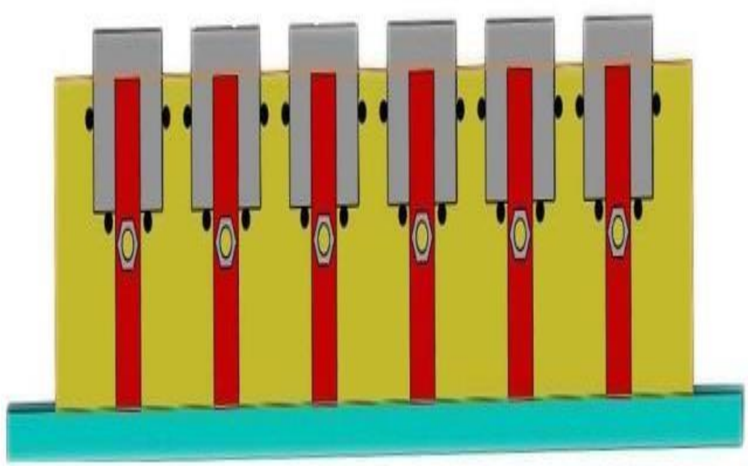

Fig 2.7 Side view of mixture

3. FABRICATION

3.1 Blackening process

In contrast to an applied coating that attaches to the metal but does not react chemically, black oxide is a conversion coating generated by a chemical reaction with the iron in metal to form an integral protective surface. When a mixture of caustic, oxidizers, and additives react with iron to generate magnetite Fe3O4, the black oxide of iron, a black oxide coating is applied to ferrous alloys. Black oxide coatings go by many other names, including Black Magic Black Penetrate, Black Passivation, Gun Bluing, and others. The black oxide will not affect the part in any way. A black oxide coating can be produced, in either a hot or cold solution, The cold black oxide technique produces soft deposits that are less corrosion and abrasion resistant than the hot oxide process when applied at ambient temperature or slightly increased temperatures. Colour changes in cold black oxides are common on the same part or from part to part. For black oxide coatings, the cold process does not meet automotive or military criteria. Only the hot black oxide method is used by Premier Finishing.

3.2 Process

For the black oxide conversion coating, there are five essential processes. They've had a thorough cleaning. Black oxide pieces are rinsed and further coated in an alkaline salt solution at approximately 285 ° Fahrenheit If the part has rust or scale, further processes such as acid pickling or alkaline de-scaling may be required before applying black oxide. Over plated zinc, chromium, cadmium, and phosphate parts, the black oxide cannot be generated. Before the black Oxide process, this plating must be stripped. The blackened fixture is shown in fig 6.1

Fig 3.1 Blackened Fixture

Advantages of black oxide coating

1) Dimensional Stability

Black oxide adds just 5 to 10 millionths of an inch to a part's dimension and penetrates to a depth of 5 to 10 millionths of an inch. The dimensions as-formed do not alter. Where mating component break-in is required, the anti-galling surface allows the outer lubricating layer to be sacrificed during initial contact and abrasion while work-hardened surfaces are created. Oil or wax post-treatments enhance the lubricity of mating parts while also protecting them from corrosion.

2) Decorative Finish

The black end result makes the product a more professional and glossier look. A glossier finish is given to parts that have a hardness of 40 Rockwell or more. The matte finish is more common on softer elements. Black oxide coating can provide corrosion resistance comparable to 400 humidity hours exposure depending on the post-treatment used. The parts need a longer lifespan because they might be stored for long periods before the surface treatment. For this purpose, several other applications are used

3) Cost-Effective

It is extremely difficult to attain the same level of protection, look, and performance as Black oxide at a lower cost than alternative finishing techniques.

3.3 Bill of material

Table 1. Bill of materials

S. No	Items	Quantity	Price	Total
1	Fixture frame	1	2000	2000
2	Double acting Cylinder	6	1500	9000
3	PTO Switch	1	800	800
4	Mounting plate	6	900	5400
5	Clamp	12	100	1200
6	Dowel pins	24	10	240
7	Pneumatic hose	20 m	20 (perimeter)	400
8	Blackening Process	-	300	300
9	Bolt, nut, others	-	-	500
			Total (Rs)	**19840**

3.4 Working

The compressor is used to compress the atmospheric air. The normal atmospheric air usually is at a pressure of 1.013 bar. This pressure is increased with the help of the compressor. The highly pressurized air reaches the FRL unit (filter, regulator, and lubricator). In the FRL unit first, the air gets filtered to get rid of all particulate matter that can easily damage the connecting tubes and the inner walls of the cylinders. The particles can produce a lot of friction while the operation of the cylinders during their forward and reverse motion. It also decreases the lifetime and efficiency of the cylinder. As the inner walls of the cylinder get damaged the pressurized air will leak from either side of the piston head. This will result in a loss of efficiency.

Next, the air is regulated by the regulating unit. The regulator makes the pressure differences uniform between the incoming air and the air leaving the unit. This process is important as the pressure differences may result in an explosion of any parts in contact or can reduce the force of clamping imposing a risk on the operator and the machine too.

After being regulated the air is lubricated by a lubricating unit. The air is lubricated to reduce the friction between the air molecules and the contact surface. This will increase the rate of flow of the medium through the tubes, valves, and cylinders. This also allows free movement of the cylinders supporting their forward and reverse motion. Lubricated air does less or no damage to the contact surface such as the internal walls of the cylinders and the internal walls of the polyurethane tubes that connect the cylinders, valves, and levers.

The air is passed to the direction control valve where the direction of the air is controlled as required by the user. The lever from the direction control valve is actuated then the compressed air flows into the blind end of the cylinder and hence the cylinder extends. The schematic flow is shown in fig 2.2 The workpiece is placed in between the clamp and vertical plate with the help of locating pin. After setting the workpiece the lever from the direction control valve is deactivated then the compressed air flows into the rod end of the cylinder and hence the cylinder retracts.

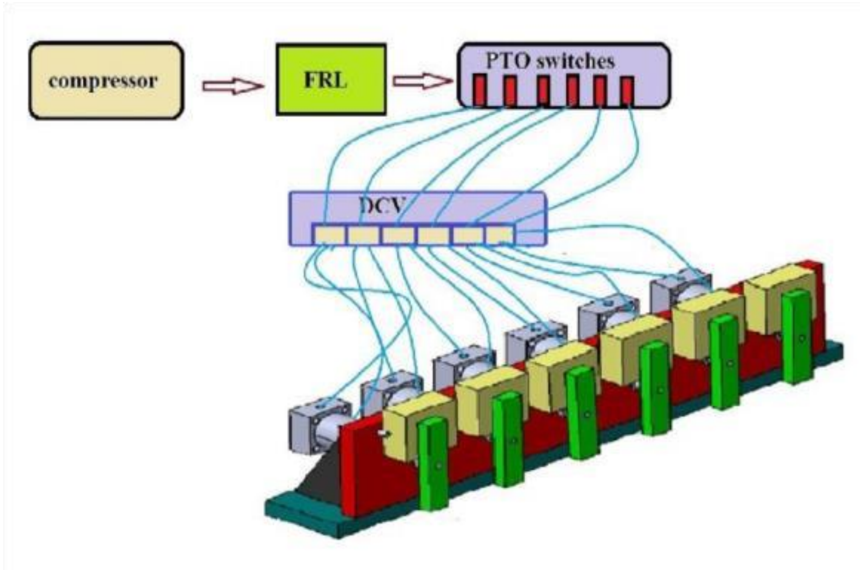

Fig 3.2 Schematic Diagram

So, the workpiece gets clamped rigidly. After the machining gets over the lever from the direction control valve is actuated then the compressed air flows into the blind end of the cylinder and hence the cylinder extends. Then the workpiece is taken out for inspection.

4. RESULTS AND DISCUSSIONS

The overall problem faced by the industry is increased clamping and locating time due to manual locating and clamping procedure. This is due to absence of automated fixtures that can be used to hold the work-pieces. As there are no proper fixtures to hold the work-pieces the accuracy of the finished products is very low. This results in poor finishing and imposes huge risks over the final user of the product. To solve this problem various systems can be used:

- Power clamping system
- Electrical motor clamping
- Magnetic clamping
- Spring loaded clamping.

Due to repeatability factors and economic factors, the best solution is to design and fabricate a pneumatic fixture. The fixture will include the use of double-acting cylinders, directional control valves, polyurethane tubes, FRL unit, compressor, etc. The fixture uses pressurized air as a source of energy to actuate and drive the cylinders. It also used to retract the cylinders using the atmospheric pressure to push back the pistons.

4.1 Design calculations

Calculation of force acting on the work piece

Recommended cutting speed $V_{C=}$76.27 m/min
Spindle speed (n): N= (V_{C*}1000 / ∏*D_C)
Where,
V_C=Cutting speed
D_C= diameter of the drill
N = (76.27*1000/∏*16)

N = 1518 rpm

Recommended feed per revolution for aluminium material f_n=0.2- 0.25mm/rev we can take 0.2 mm/rev Feed per minute: V_f (mm/min)

$V_f = f_n*N$

$V_f = 0.2*1518$

$V_f =$ 303.6 mm/min

Metal removal rate: Q(cm^3/min)

$Q = (D_C * f_n * v_c / 4)$

Q = (16*0.2*76.27/ 4)

Q = 61.01 cm^3/min

Recommended specific cutting force for aluminium (k_c=700 N)

Power of cutting Pc= fn*vc*dc*kc/240*10^3

Pc = 0.2*76.27*16*700/240*10^3

Pc = 712w (or) 0.712 kw

Torque (mc) = Pc*30*10^3/∏*n

mc = 0.712*30*10^3/3.14*1518

mc= 4.47 N-m

Thermal conductivity of aluminium(H2H4) k = 0.5 w/mk

Thrust force = (k*kc*d*f) / 2

= 0.5*700*16*0.2/2

= 560 N

To find the cylinder bore D and rod diameter d

F=A*P

Where A=Piston area (m^2)

P = Operating pressure (bar) = 6 bar

F = 2 * 560 N (2 * Thrust force)

F = 1120 N

F = A * P

A= (∏/4) * (D^2)

1120 = (∏/4) * (D^2) * 6 * 10^5

D^2 = (1120 * 4) / (∏ * 6 * 10^5)

D = 44mm

So, we are considering the nearest available cylinder bore

D = 40 mm and rod diameter d = 16 mm

Froward stroke

Return stroke force F_{fwd} = A*P

Where;

A = Piston area (m^2)

P = Operating pressure (bar) = 6 bar

A= (∏/4) * ($D^{2-}d^2$)

A= (3.14*/4) * ((40*10^{-3})^2- (16*10^{-3})^2)

A=1.055*10^{-3} m^2

F = A*P

F= (1.055*10^{-3}) * (6*10^{-5})

F = 633N

Force return = 633 N (Clamping force)

Therefore, the clamping force is greater than the thrust force the design is safe.

4.2 Optimized factors

4.2.1 Productivity

Fixture eliminates the process of individual marking, positioning, and frequent checking. This eliminates this pre-machining time of the work-pieces on a large scale which is in turn is used as machining time that increases the production rate.in single pull of the switch clamping is done so the productivity will be increased in the vertical maching centre

Production rate with manual vice = 24 pieces/hour

Production rate with pneumatic fixture = 52 pieces/hour

4.2.2 Interchangeability

There is no need for selective assembly. And all components are similar and interchangeable. Fixture facilitates uniform quality in manufacture When the components to be machined change provide, they are of comparable sizes the clamper end of the fixture can be dismantled and the appropriate clamper end can be fixed to the end of the piston.

4.2.3 Skill reduction

Fixture simplifies locating and clamping of the workpieces. Tool guiding elements ensure the correct positioning of the tools for the workpieces. There is no need for a skillful setting of the workpiece or tool. Any unskilled person can be trained to use fixtures. The replacement of a skilled workman with an unskilled workman brings down the overall labour cost of the plant on a significant scale.

4.2.4 Cost reduction

The main aim of an industry is to produce a higher amount of pieces, reduction in scrap, easy to assemble, and savings in labour costs result in a substantial reduction in the cost of workpieces produced with the fixture. It reduces or most of the time eliminates the effort of marking, measuring, and setting the workpiece on a machine and maintains the accuracy of performance. The variability of dimensions in mass production is very low. So, manufacturing processes supported by the use of fixtures maintain consistent quality.

4.2.5 Quality assurance

Due to the employment of pneumatic fixtures, the force of clamping is uniform throughout the machining process the accuracy and quality are uniform in all the machined products. The accuracy is greater as the clamping force is greater than the machining forces.

Maximum machining force of VMC = 560 N

Force exerted by the fixture = 633 N

4.2.6 Accuracy

Accuracy before employing fixture = 21 microns (0.021mm)

Accuracy after employing fixture = 8 microns (0.008mm)

5. CONCLUSION

Thus, we have designed a pneumatically operated fixture. This fixture will reduce the time and cost of manufacturing the product by reducing the time required for locating and clamping. It increases the accuracy of the finished product as the clamping force is far greater than the machining force over the workpiece, this results in a uniform clamping force throughout the machining time. Reducing setup expenses offers manufacturers additional benefits. In addition to lower production costs, benefits include lower tooling expenses, reduced lead time, increased production time, higher production volume, and faster production changeovers. From this, we can conclude production will be increased by easily locating and clamping the workpiece with help of the pneumatic fixture.

REFERENCES

1. Janatics product catalogue pneumatics, air cylinder series A12, A13, CAP NO: A12, A13- 01-03.
2. faculty of mechanical engineering, PSG College of Technology, Design data, Data book for engineers.
3. Henriksen, E.K. Jig and Fixture Design Manual. New York: Industrial Press. 1973. IMAO. IMAO Venlic Block Jig System (BJS) Fixturing Guide. IMAO Corporation. Institution of Production Engineers. Data Memoranda on Jig and Fixture Design.
4. [Lim B.S. and J.A.G. Knight. Holdex - Holding Device Expert System. Proc.1st Int. Conf Applications of Artificial Intelligence in Engineering Problems, pp.483- 493. 1986,
5. Sakurai, H. Automatic Set-up Planning and Fixture Design for Machining. PhD thesis, Massachusetts Institute of Technology. 1990.
6. Nee, A.Y.C., K. Whybrew and A. Senthil Kumar. Advanced Fixture Design for FMS. London: Springer-Verlag. 1995.
7. Nee, A.Y.C., A. Senthil Kumar, S. Prombanpong and K.Y. Puah. A Feature-Based Classification Scheme for Fixtures. Annals of the CIRP, Vo1.41, No.1, pp.189- 192. 1992.
8. Mannan, M.A. and J.P. Sollie. A Force-Controlled Clamping Element for Intelligent Fixturing. Annals of the CIRP, Vol. 46, pp.265-268. 1997.
9. A. Senthil Kumar and Z.J. Tao. An Intelligent Fixture with a Dynamic Clamping Scheme. Proceedings of the Institution of Mechanical Engineers,214 Part B, pp.183-196.2000.
10. Pneumatic application and reference handbook, Bimba manufacturing company P.0.BOX 68 Monee, Illinois 60449-0068.