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Design and Manufacturing of 4th Axis VMC Fixture

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***Abstract*: The paper describes the design and manufacturing of fixture for 4 axis VMC machine. The design of fixture is such that it reduces individual marking positioning and frequent checking due to which reduces operation time and increases productivity efficiency also by using this fixture initial setting time is reduced by 10 min with reduction in loading and unloading time with minimum cost of setup. As per the specification of given component we have to drill the 4 holes on same side and rotate the component in 90 degree and drill another hole on adjacent side of component the design should be such that should withstand the stresses developed during clamping, loading and unloading of components It should have enough structural strength to withstand operating conditions. It should have high wear resistance. Minimum setting time should be required. Minimum force should be required to clamp and unclamp the job.**

***Keywords*: Fixtures, VMC machines, locators, Stopper Plate, Angle Plate, Round Plate, C washer.**

1. Introduction

Fixture is a work holding or support device used in manufacturing industry. Fixtures are used to securely locate and support the work ensuring that all part produced using fixture will maintain conformity and interchangeability. Using a fixture improves the economy of production by allowing smooth operation and quick transition from part to part, reducing the requirement for skilled labor by simplifying how work pieces are mounted and increasing conformity across the production run.

A fixture's primary purpose is to create a secure mounting point for a work piece, allowing for support during operation and increased accuracy, precision, reliability and interchangeability in finished parts. It also serves to reduce work in time by allowing quick setup. Economically speaking the most valuable function of fixture is to reduce labor costs. Basic fixture design for manufacturing applications envelopes to main aspects: Location and clamping between these two functions, the six degrees of freedom are constrained, while effectively positioning and orienting the part during processing. Fixture design is most cost-justified for batch and mass production runs.

A. Purpose of using fixtures

The fixture is a special tool for holding a work piece in proper position during manufacturing operation. For supporting and clamping the work piece, device is provided. Frequent checking, positioning, individual marking and non-uniform quality in manufacturing process is eliminated by fixture. This increase productivity and reduce operation time. Fixture is widely used in the industry practical production because of feature and advantages. To locate and immobilize work pieces for machining, inspection, assembly and other operations fixtures are used. A fixture consists of a set of locators and clamps. Locators are used to determine the position and orientation of a component, whereas clamps exert clamping forces so that the work piece is pressed firmly against locators. Clamping has to be appropriately planned at the stage of machining fixture design. The design of a fixture is a highly complex and intuitive process, which require knowledge. Fixture design plays an important role at the setup planning phase. Proper fixture design is crucial for developing product quality in different terms of accuracy, surface finish and precision of the machined parts. 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. Hydraulic fixture provides the manufacturer for flexibility in holding forces and to optimize design for machine operation as well as process function ability.

B. Studies related to fixture design

Fixture is an important element in most of the manufacturing processes and related to machining errors the role of fixture is very crucial. Studies pertaining to the design of machining fixture are generally of two categories i.e. fixture analysis and fixture synthesis. While fixture analysis deals with forces and deformations, the fixture synthesis is concerned with the design of fixture configuration to completely immobilize the work part when subjected to external forces. In the fixture analysis and synthesis, a concern on the conditions for constraining a work piece is critical. The essential requirement of fixturing is the century-old concept and the same has been extensively studied by Mishra et al (1987) and Markenscoff et al (1990) in the field of robotics with efficient algorithms to synthesize positive grips for bounded polyhedral objects.

Workpiece location error is examined by considering the fixture geometric error and elastic deformation of the fixture and workpiece due to fixturing forces (Raghu and Melkote 2005). Wang et al (2010) presented a literature survey of computer aided fixture design and automation, including their approaches, requirements and working principles. Related to computer aided fixture design approaches, an interactive Computer Aided Fixture Design (CAFD) system using the Gauss Elimination Method for the design of a fixture to hold prismatic components during machining on a CNC machining center is described by Krishnamachary and Reddy (2005). Cecil (1995), Pehlivan et. al (2009) and Nee et al (1987) have reported the other feature-based methodologies in CAFD.

The automation of fixture design and integration of setup and fixture planning is discussed by Stampfer (2009). Boonsuk and Frank (2009) presented a methodology for the automated design of a fixturing system for a rapid machining process. An adaptive fixture design system with an evolutionary search algorithm has been developed by Fathianathan et al (2007) to deal with the automatic design changes to meet the requirements of different domains

C. Understanding the machining with a vertical machining center & 4th axis

- *VMC machine:* As opposed to the machining with a horizontal machining center (HMC), CNC machines with the vertical machining centers (VMC) have vertically oriented spindles. VMC workpieces are usually mounted on top of their table and perform standard 2.5 or 3 axis machining operations. VMC are useful for creating the parts, die or molds with precision, accuracy, repeat-ability and surface finishes. The term ‘machining center’ almost always describes the CNC (Computer Numerical Control) milling and drilling machines that have an automatic tool changer and a table that clamps the work-piece in one place. CNC machining is a process that is used in the manufacturing sector, it involves the use of computers to control machine tools.
- *Difference between a CNC and VMC*: There is no difference between the two machines. A VMC is a machine with a CNC (Computer Numerical Control) controller, the cutting head in this milling machine is vertical, and is a type of milling machine where the spindle runs in a vertical axis known as the “z” axis. They are typically enclosed and most often used for cutting metal.
- *Vertical Machining Center (VMC) with 4th Axis:* Most VMC machines have three axes, the x, y, and z-axis. Axis stands for the number of motors that can be individually driven for positional control of the tool. The x-axis is usually from left to right, the y-axis is front to back, and the z-axis is up and down. On a standard 3-axis VMC, the cutter stays in the vertical direction. In VMC’s, we can add 4th or even 5th axis as well to increase the benefits of the VMC.
- *Vertical Machining Center (VMC) with the 4th axis*: If the 4th-axis is added in VMC, then the cutter can rotate around the x-axis which allows the VMC machine to drill holes in the front and back of the product. Hence, VMC that have an additional rotary axis are 4 axes machines. There is a fifth axis as well which adds complexity to the VMC. Adding a 4th axis rotary table to a VMC machine in any sort of work setting provides several advantages to machine work Having another axis to work with gives VMC machine users more precision and accuracy, without having to change positions of the part being machined. Also, an additional axis would prove to make any VMC machine more diverse in the work it is capable of doing; lathe machines introduce the aspect of a rotating part, so a rotary table would add the same benefits provided. A 4th axis rotary table, in general, can provide more precision and ease to a complex design, reducing time and costs for the production of a certain piece.


Fig. 1. CNC machine

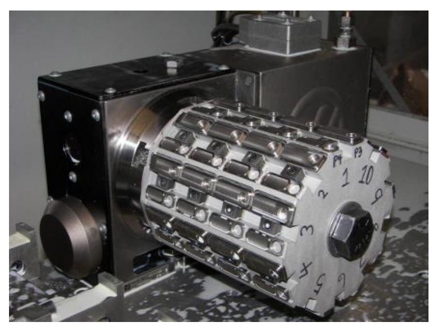
Fig. 2. VMC machine

2. Literature survey

As we finalized our project, we have done through different study materials and studies. We have studied different research papers, different reference books and collected information. From that information some important information is sorted out as a Literature Survey.

Z. M. Bi / W. J . Zhang: This research paper is published in International journal of production research page number 2867-2894 on 14th November 2010. The cost of designing and fabricating fixtures can amount to 10-20% of the total manufacturing system costs. To reduce manufacturing costs, a fixture system is designed to be competent in fixturing as many workpieces as possible. In mass volume production, this can be achieved by fixturing a large quantity of the same kind of workpieces. In low-to-medium volume production, however, improvement of the flexibility of fixture systems becomes a favorable way to reduce the unit cost of product. This paper summarizes the latest studies in the field of flexible fixture design and automation. First, a brief introduction is given on this research area. Secondly, taxonomy of flexible fixture design activities is presented. Thirdly, the flexibility strategies based on the existing flexible fixture systems are discussed. Fourthly, the contributions on design methodologies and verifications are examined. Fifthly, advances on computer-aided design and see-up systems are summarized. Finally, some prospective research trends are presented.

Shailesh S. Pachbhai, Laukik P. Raut: This research paper is published in International Journal of Engineering Research and General Science Volume 2 on Feb-Mar 2014. In machining fixtures, minimizing workpiece deformation due to clamping and cutting forces is essential to maintain the machining accuracy. The various methodology used for clamping operation used in different application by various authors are reviewed in this paper. Fixture is required in various industries according to their application. This can be achieved by selecting the optimal location of fixturing elements such as locators and clamps. The fixture set up for component is done manually. For that more cycle time required for loading and unloading the material. So, there is need to develop system which can help in improving productivity and time. Fixtures reduce operation time and increases productivity and high quality of operation is possible.

J. Cecil: This research paper is published in International journal of Advanced Manufacturing Technology volume 18, page no. 790-793 on Nov 2001. Fixture design is a complex problem that requires a designer to ensure that a work piece is located deterministically, totally restrained and sufficiently supported during a manufacturing process. The use of modular fixtures, while presenting an opportunity to improve the responsiveness of a manufacturing system, adds to the complexity of the fixture design problem. The complexity is a result of the large number of fixture elements in a modular fixture system and the constraints of specified locations in which fixture elements can be placed in a grid-based modular system. This paper presents an evolutionary search algorithm that aids a fixture designer by exploring the large number of possible fixture designs and suggesting an appropriate one. The algorithm can explore the large solution space using a flexible and generic representation and it considers fixture layout and fixture configuration constraints concurrently in arriving at appropriate solutions. The initial results of the algorithm are promising.

3. Problem definition and objectives

A. *Problem definition*

As per the specification of given component we have to drill the 4 holes on same side and rotate the component in 90 degree and drill another hole on adjacent side of component.

B. *Specification of component*

- Diameter of 4 holes
- Depth of 4 holes
- Diameter of one hole on adjacent side
- Depth of hole on adjacent side.

C. *Objectives*

- To reduce job setting time.
- To increase dimensional accuracy.
- To eliminate misalignment of job.

D. *Requirements of project*

- It should withstand the stresses developed during clamping, loading and unloading of components
- It should have enough structural strength to withstand operating conditions.
- It should have high wear resistance.
- Minimum setting time should be required.
- Minimum force should be required to clamp and unclamp the job.

4. Methodology

1. To note down the set of problems involved during the manual setup.
2. To discuss the problem observed during manual setup.
3. Do literature survey to collect data and information from journals, books and on internet.
4. To brain storm for solutions to the set of problems noted amongst the project group.
5. Redefine the objectives of the project if required.
6. Proposing the final design and drawings and getting the same approved from the project guide, other expert faculty and industry.
7. Preparing the layout of proposed work.
8. Designing various parts of equipment proposed.
9. Drawing the various components designed.
10. Manufacturing the parts.
11. Assembly and testing.
12. Testing the dimension of given component after machining.
13. Modification if any.
14. Retesting after modifications.
15. Preparation of report.

A. *Types of fixture and its industrial applications*

Vise Fixture It is easy to clamp work piece with regular shape and parallel sides in a vise. However, workpieces with round or irregular shapes are very difficult to clamp properly. Hence, special jaws are created to hold workpieces with irregular shape properly and at the same time, it also avoids damage to the important surfaces. Stop pin is used to prevent bending of the work piece by the application of clamping force. Guide pins are used to secure alignment. When it is necessary to hold the work piece firmly in all the direction.

Fig. 3. Fixture

Facing Fixture Milling machines are extensively used for facing seating and mating flat surfaces. Milling is often the first operation on the workpiece. The workpiece is positioned by three adjustable spherical ended pads „A‟. These pads are adjusted to suit the variation in the size of workpiece and lock in the position by check nuts. Two self-adjusting supports „A‟ are pushed upward by light spring. These springs are used to make sure that the support „A‟ is positively in contact with the workpiece. Clamping screw is used to lock support „B‟. On tightening the edge clamp, the workpiece is pushed against the fixed jaw. This jaw is keyed in the fixture body to provide solid support to workpiece against the heavy thrust developed in the operation. The cutter should be fed to the workpiece in such a manner that the milling thrust should be directed towards the solid support of fixed jaws. The setting can be set in the path of cutter to set it before starting of facing operation. Four clamping slots are provided to take care of the heavy forces developed during the operation. Boring Fixture According to the type of boring operation, boring fixture are used. Boring Fixture may have characteristics of a drill jig or a mill fixture. The workpiece always has an existing hole which is enlarged by the boring operation. It may be final or may be preliminary to grinding and other sizing operation

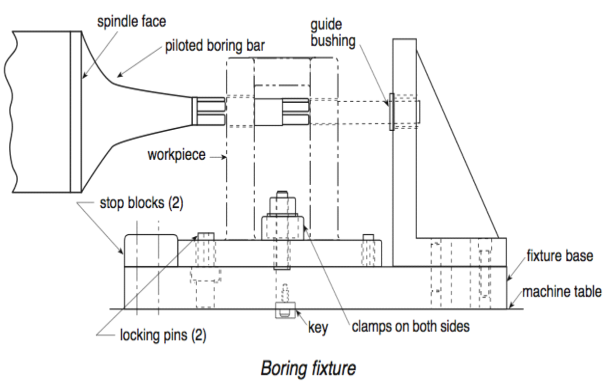

Fig. 4. Boring fixture

Face Plate Fixture: It can be used conveniently for machining of simple and small components. Addition of locators and clamps on face plate help in quick location and clamping of work piece. Face plate fixture is useful for facing number of workpieces simultaneously on the lathe. Turning Fixture. These are generally special face plates. Their swing should be lesser than the swing of the machine. These are used for quick location and clamping. Typical turning fixture. The work piece rests on angle plate and its boss is centralized with machine axis by sliding v-block which can be operated with knurled screw. The overhang of turning fixtures should be minimum bare necessary for the operation. Fixture should be balanced with work piece in position.

Fig. 4. Clamping

The clamping arrangement should be capable of withstanding the various forces developed during operation.

a. Cutting force tangential to cutting circle.
b. Axial force and radial force due to feed of tool.
c. Bending forces due to pressure of tool on workpiece.

Back Plate for Turning Fixture It consists of workpiece locating and clamping elements. These fixtures are generally used for facing turning and boring operation. The workpiece should be located correctly with respect to rotating machine spindle for all these operations. Grinding Fixture the standard magnetic tables are used to rest workpiece such that resting surface will be parallel to the surface to be ground. However, for light workpiece with lesser resting area, the resting area tends to tilt and fly off the magnetic table due to high speed of grinding wheel and due to high feed, also. Hence, it is necessary to provide additional support by nesting the workpiece. This can be done by placing the solid plates around the workpiece. The nest plates are held firmly by the magnetic force of table with more weight and more resting area. The nest plates surround the workpiece from outside and arrest its movement in the horizontal plane. Thus, this arrangement will help in preventing it from flying off and tilting due to high speed and feed in grinding operation.

Fig. 5.

5. Steps of fixture design

Successful fixture designs begin with a logical and systematic plan. With a complete analysis of the fixture's functional requirements, very few design problems occur. When they do, chances are some design requirements were forgotten or under estimated. The workpiece, processing, tooling and available machine tools may affect the extent of planning needed. Preliminary analysis may take from a few hours up to several days for more complicated fixture designs. Fixture design is a five step problem-solving process.

The following is a detailed analysis of each step.

- *Step 1: Define Requirements:* To initiate the fixture-design process, clearly state the problem to be solved or needs to be met. State these requirements as broadly as possible, but specifically enough to define the scope of the design project. The designer should ask some basic questions: Is the new tooling required for first-time production or to improve existing production?
- *Step 2: Gather/Analyze Information:* Collect all relevant data and assemble it for evaluation. The main sources of information are the part print, process sheets, and machine specifications. Make sure that part documents and records are current. Check with the design department for pending part revisions. An important part of the evaluation process is note taking. Complete, accurate notes allow designers to record important information. With these notes, they should be able to fill in all items on the "Checklist for Design Considerations." All ideas, thoughts, observations, and any other data about the part or fixture are then available for later reference. It is always better to have too many ideas about a particular design than too few. Four categories of design considerations need to be taken into account at this time:workpiece specifications, operation variables, availability of equipment, and personnel. These categories, while separately covered here, are actually interdependent. Each is an integral part of the evaluation phase and must be thoroughly thought out before beginning the fixture design.

1) Develop several options

This phase of the fixture-design process requires the most creativity. A typical workpiece can be located and clamped several different ways. The natural tendency is to think of one solution, then develop and refine it while blocking out other, perhaps better solutions. A designer should brainstorm for several good tooling alternatives, not just choose one path right away. During this phase, the designer's goal should be adding options, not discarding them. In the interest of economy, alternative designs should be developed only far enough to make sure they are feasible and to do a cost estimate. The designer usually starts with at least three options: permanent, modular, and general-purpose work holding. Each of these options has many clamping and locating options of its own. The more standard locating and clamping devices that a designer is familiar with, the more creative he can be. Areas for locating a part include flat exterior surfaces (machined and unmachined), cylindrical and curved exterior surfaces. The exact procedure used to construct the preliminary design sketches is not as important as the items sketched. Generally, the preliminary sketch should start with the part to be fixtured. The required locating and supporting elements, including a base, should be the next items added. Then sketch the clamping devices. Finally, add the machine tool and cutting tools. Sketching these items together helps identify any problem are as in the design of the complete fixture.

2) Step 4: Choose the best option

The total cost to manufacture a part is the sum of per-piece run cost, setup cost, and tooling cost. Expressed as a formula:

These variables are described below with sample values from three tooling options: a modular fixture, a permanent fixture, and a hydraulically powered permanent fixture.

3) Step 5: Implement the design

The final phase of the fixture-design process consists of turning the chosen design approach into reality. Final details are decided, final drawings are made, and the tooling is built and tested. The following guidelines should be considered during the final-design process to make the fixture less costly while improving its efficiency. These rules are a mix of practical considerations, sound design practices, and common sense.

Use standard components: The economies of standard parts apply to tooling components as well as to manufactured products. Standard, readily available components include clamps, locators, supports, studs, nuts, pins and a host of other elements. Most designers would never think of having the shop make cap screws, bolts or nuts for a fixture. Likewise, no standard tooling components should be made in-house. The first rule of economic design is: Never build any component you can buy. Commercially available tooling components are manufactured in large quantities for much greater economy. In most cases, the cost of buying a component is less than 20% of the cost of making it. Labor is usually the greatest cost element in the building of any fixture. Standard tooling components are one way to cut labor costs. Browse through catalogs and magazines to find new products and application ideas to make designs simpler and less expensive.

Use prefinished materials: Prefinished and preformed materials should be used where possible to lower costs and simplify construction. These materials include precision-ground flat stock, drill rod, structural sections, cast tooling sections, precast tooling bodies, tooling plates, and other standard preformed materials. Including these materials in a design both reduces the design time and lowers the labor cost.

Eliminate finishing operations: Finishing operations should never be performed for cosmetic purposes. Making a fixture look better often can double its cost. Here are a few suggestions to keep in mind with regard to finishing operations.

Keep tolerances as liberal as possible: The most cost-effective tooling tolerance for a locator is approximately 30% to50% of the workpiece's tolerance. Tighter tolerances normally add extra cost to the tooling with little benefit to the process. Where necessary, tighter tolerances can be used, but tighter tolerances do not necessarily result in a better fixture, only a more expensive one.

6. Design considerations

- The main frame of fixture must be strong enough so that deflection of the fixture is as minimum as possible. This deflection of fixture is caused because of forces of clamping of the workpiece or clamping to the machine table. The main frame of the fixture should have the mass to prevent vibration and chatter.
- Frames may be built from simple sections so that frames may be fastened with screws or welded whenever necessary. Those parts of the frame that remain permanently with the fixture may be welded. Those parts that need frequent changing may be held with the screws. In the situation, where the body of fixture has complex shape, it may be cast from good grade of cast iron.
- Clamping should be fast enough and require least amount of effort.
- Clamps should be arranged so that they are readily available and may be easily removed.
- Clamps should be supported with springs so that clamps are held against the bolt head wherever possible.
- If the clamp is to swing off the work, it should be permitted to swing as far as it is necessary for removal of the workpiece.
- All locator’s clamps should be easily visible to the operator and easily accessible for cleaning, positioning or tightening.
- All clamps and support points that need to be adjusted with a wrench should be of same size. All clamps and adjustable support points should be capable of being operated from the fronts of the fixture.
- Workpiece should be stable when it is placed in fixture. If the workpiece is rough, three fixed support points should be used. If workpiece is smooth, morethan three fixed support points may be used. Support point should be placed as farthest as possible from each other.
- The three support points should circumscribe the centre of gravity of the work piece.
- The surface area of contact of support should be as small as possible without causing damage to the workpiece. This damage is due to the clamping or work forces.
- Support points and other parts are designed in such a way that they may be easily replaced if they break.

7. Principle of location

Any rectangular body mainly has three axes- x-axis, y-axis and z-axis. It can move along any of these axes. At the same time the body can also rotate about these axes too. So total degree of freedom of the body along which it can move is six. For processing the body it is required to restrain all the degree of freedom (DOF) by arranging suitable locating points and then clamping it in a fixed and required position. The basic principle used to locate the points is Six Points Location of a Rectangular Block. It is made to rest on several points on the jig body. Provide a rest to workpieces on three points on the bottom x-y surface. This will stop the movement along z-axis, rotation with respect to x-axis and y-axis. Supporting it on the three points is considered as better support then one point or two points. Rest the workpieces on two points of side surface (x-z), this will fix the movement of workpieces along y-axis and rotation with respect to z-axis. Provide a support at one point of the adjacent surface (y-z) that will fix other remaining free movements. This principle of location of fixing points on the workpiece is also named as 3-2-1 principle of fixture design as numbers of points selected at different faces of the workpiece are 3, 2 and 1 respectively. If the operation to be done on the cylindrical object, it requires restriction of the above mentioned free movements and some more locating provisions must also be incorporated in addition to use of the V block.

Guohua Qin focuses on the fixture clamping sequence. It consists of two parts:

a) For the first time he evaluated varying contact forces and workpiece position errors in each clamping step by solving a nonlinear mathematical programming problem. This is done by minimizing the total complementary energy of the workpiece-fixture system. The prediction proves to be rigorous and reasonable after comparing with experimental data and referenced results.
b) The optimal clamping sequence is identified based on the deflections of the workpiece and minimum position error. Finally, to predict the contact forces and to optimize the clamping sequence three examples are discussed. First mathematical modeling for clamping sequence is done then he determined the contact forces in clamping sequence as shown in fig. 7.1. After that he optimized of clamping sequence for higher stiffness workpiece and low stiffness workpiece. He found that with the use of optimal clamping sequence; good agreements are achieved between predicted results and experimental data and the workpiece machining quality can be improved.
c) For a fixture designer, the major portion of design time is spent deciding how to locate the work piece in the fixture. Any free body has a total of twelve degrees of freedom as

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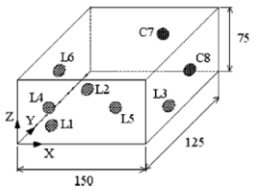
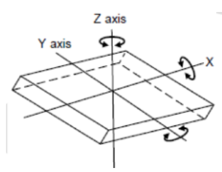


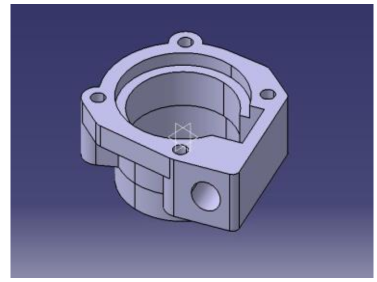
6 translational degrees of freedom: +X, -X, +Y, -Y, +Z, -Z
And 6 rotational degrees of freedom:

- Clockwise around X axis (CROT-X)
- Anticlockwise around X axis (ACROT-X)
- Clockwise around Y axis (CROT-Y)
- Anticlockwise around Y axis (ACROT-Y)
- Clockwise around Z axis (CROT-Z)
- Anticlockwise around Z axis (ACROT-Z)

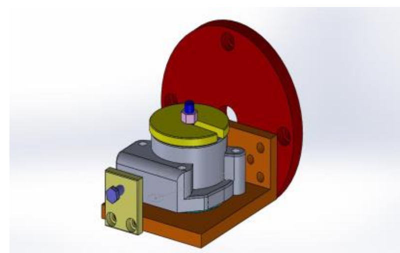
We must fix all the 12 degrees of freedom except the three transitional degrees of freedom (-X, -Y and -Z) in order to locate the work piece in the fixture. So, 9 degreesof freedom of the work piece need to be fixed. but, how? Byusing the 3-2-1 method as shown belowNow, rest the work piece at two points of side surface (XZ), and you will be able to fix the +Y and ACROT-Z degrees of freedom. Now, rest the work piece at one point of the adjacent surface (YZ), and you will be able to fix the +X and CROT-Z degrees of freedom. So, you can successfully fix9 required degrees of freedom by using the 3-2-1principle of fixture design



8. Component drawings



9. Selection of optimum design



10. Parts drawings

- Stopper Plate
- Angle Plate
- Round Plate
- Locator
- Washer

11. Process sheets

Angle plates

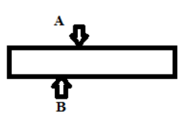
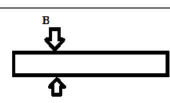
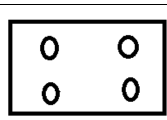
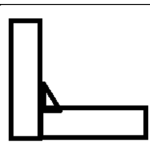
Diagram	Operation Description	Machine	Speed(rpm) Feed (mm/min)
	Hold the job in side B and face milling of side A	Milling Machine	40 0.1
	Unloading job and clamp in Side A Face milling of another side and control length of 15 mm	Milling Machine	40 0.1
	Drill the four hole of diameter of 12	Drilling Machine	20 0.1
	Weld the part first and part second with each other	-	-

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Table 1: Round plate

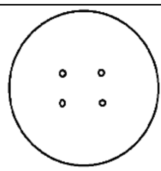
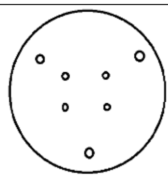
Diagram	Operation Description	Machine	Speed(rpm), Feed (mm/min)
	Hold the job in side B and face milling of side A	Milling Machine	40 0.1
	Unloading job and clamp in Side A Face milling of another side and control length of 15 mm	Milling Machine	40 0.1
	Drill the four hole of diameter of 12	Drilling Machine	20 0.1
	Drill the 3 holes of 20mm with PCD 125mm	Drilling Machine	20 0.1

Table 2: Locator

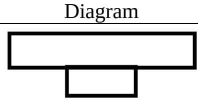
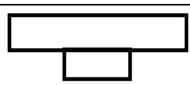
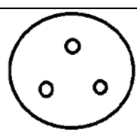
Diagram	Operation Description	Machine	Speed rpm, Feed mm/min
	Hold the job in side B and face milling of side A	Milling Machine	40 0.1
	Unloading job and clamp in Side A Face,milling of other side,control length of 15 mm	Milling Machine	40 0.1
	Drill the 3 hole of diameter of 12	Drillng Machine	20 0.1

Table 3: Supporting block

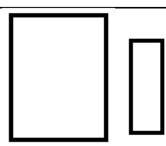
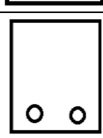
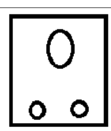
Diagram	Operation Description	Machine	Speed(rpm) Feed (mm/min)
	Hold the job in side B and face milling of side A Unloading job clamp in Side A Face milling of another side, control length of 15 mm	Milling Machine	40 0.1
	Drill the 2 hole of dia 12mm	Drilling Machine	20 0.1
	Drill the hole of dia 14mm	Drilling Machine	20 0.1

Table 4: C Washer

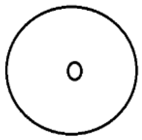
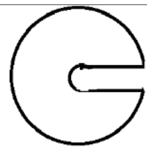
Diagram	Operation Description	Machine	Speed rpm, Feed mm/min
	Hold the job in side B and face milling of side A Unloading job and clamp in Side A Face milling of another side and control length of 10 mm	Milling Machine	40 0.1
	Drill the 2 hole of diameter of 15mm	Drilling Machine	40 0.1
	Make a slot of 15mm through the diameter	Laser machine	-

Table 5
Bill of materials

No.	Component name	Material	Material cost	Machining cost	Quantity	Total cost
1.	Round plate	MS	600	300	1	900
2.	Angle plate	MS	775	400	1	1175
3.	Stud	EN31	100	40	1	140
4.	C washer	MS	50	40	1	90
5.	Locator	MS	150	120	1	270
6.	Allen Screw	STD	270	-	9	270
7.	Stopper plate	MS	100	50	1	150
8.	Hexagonal nut	STD	50	-	1	50
					Total	3045

12. Calculations

- Cutting speed of aluminium alloy = 35-55 m/min Feed for hole 9-11.5 mm dia is = 0.12-0.2 mm/rev
  Drilling
  Diameter of drill = 11mm
  Cutting speed v=40 m/min
  V = $\pi DN/1000$
  N = 40*1000/π*11= 1157.49 rpm
  N = 1200 rpm
  S= Feed Rate per Revolution
  S=0.4 mm/rev
  Power at spindle P (KW)
- P = 1.25D2 K N (0.056 +1.5S)/105
  =0.2355 KW
  Torque at spindle (Ts)
  Ts =975*P/N
  =975*0.2355/1200
  =17.19 N.mThrust Load
  F=1.16*KD (100S)0.85
  =1.16*0.55*11*(100*12)0.85
  =569.09 N
- Tapping
  Thread diameter D=22mm
  Spindle speed (n) =1200
  Pitch (P) =1.5
  Material factor (K) =0.55
  Power at spindle (PW)
  PW=0.326*D*P2nK/104
  =0.326*22*1.52*1200*0.55/104
  =1.065 kw
  Torque
  Ts =975*PW/n
  =0.865 (kg.f)
  =8.48 N.m

13. Testing

A. *Testing machine information*

- Machine name: BFW, ASni BMV45TCO
- Machine Coordinates:

X-Axis: 600mm
Y-Axis: 450mm
Z-Axis: 500mm

- Automatic Tool Changer:
- Type: Circular
- Total Tool Mounted: 20
- Programming Coding: Fanuc
- Display: Fanuc Series Oi-mc
- Programming Software: Dell Cam
- 4th Axis Machine Tool: Accuracy=1 Degree

B. Procedure

- Surface plate was mounted on 4th axis.
- Angle plate fixed on circular surface plate.
- Component was loaded on the fixture.
- Programme was made with the help of Dell cam software.
- Feed the Programme to the VMC.
- Set reference point by using offset.
- Set Tool travel distance.
- Start Operation

C. Setup figure

1. First operation

2. Second operation

D. Testing results

1. Initial setup time = 20 min
2. Component loading time = 10 sec
3. Combined operation time = 3 min 40 sec
4. (Operation description: 1. 4 holes of diameter 11mm & depth 28mm.
5. Tapping operation of PCD 22mm & depth 35mm.)
6. Component unloading time = 10 sec

As per above testing result we can reduce 1 min 30 sec total cycle time per component.

14. Conclusion

1. Reduces Individual marking positioning and frequent checking due to which reduces operation time and increases productivity and efficiency.
2. We successfully designed & manufactured 4th axis VMC fixture. By using this fixture initial setting time is reduced by 10 min.
3. Reduction in the loading –unloading time by 1 min 30 sec per component.
4. Initial setup cost is reduced.
5. Skill reduction.

References

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