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A STUDY ON DESIGN OF FIXTURE FOR VALVE BODY FOR CNC MACHINE

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Abstract-*A fixture is designed and built to hold, support and locate every component to ensure that each is drilled or machined with accuracy and manufactured individually. The fixture designing and manufacturing is considered as complex process that requires the knowledge of different areas, such as geometry, dimensions, tolerances, procedures and manufacturing processes. This paper will give brief overview about the 3-2-1 locating principle to design the fixture for complex parts and other clamping principles. This paper also gives the idea and procedure for fixture design. This paper gives the idea about the modular fixture and dedicated fixture.*

Keywords-*Fixture; Design; 3-2-1 Principle; Clamping; Modular Fixture.*

I. INTRODUCTION

A Fixture is a device/mechanism used in manufacturing to hold a work piece, position it correctly with respect to a machine tool, and support it. During manufacturing operations such as machining, inspection and assembly, fixtures provide a means to reference and align the cutting tool to the work piece but they do not guide the tool. Fixtures that have the added function of guiding the tool during manufacturing processes are called jigs. Fixtures have direct impact upon product quality, productivity and cost. Fixture devices includes various standard clamps, chucks, and vises, Metal plates containing dowel and/or tapped locating holes or key slots and dedicated fixtures with specific design and build requirements.

For complex part; locators, clamps, supports and tooling parameters are key concepts while making the design of fixture. A fixture design may take from a few hours up to several days for complicated parts.

1.1 Types of Fixtures:

Generally the fixtures are categorized into five groups:

- Plate Fixtures
- Angle Plate Fixtures
- Vise-Jaw Fixtures
- Indexing Fixtures
- Multi-Part or Multi-Station Fixtures

1.1.1 Plate Fixtures

Plate fixtures are constructed from a plate with a variety of locators, supports and clamps. They are the most common type of fixture because their versatility makes them adaptable to a wide range of machine tools. They are made from many different kinds of materials, which are governed only by the part being machined and the process being performed.

1.1.2 Angle-Plate Fixtures

Angle-plate fixtures are a modification of plate fixtures. In this type a surface is set perpendicular to the mounting surface instead of parallel in the case of plate fixtures.

1.1.3 Vise-Jaw Fixtures

Vise-jaw fixtures are modified inserts for vises designed to accommodate a particular work piece. These fixtures are the least expensive and simplest to modify. The only limitations to these types of fixtures are size of the part and capacities of available vises.

1.1.4 Indexing Fixtures

Indexing fixtures are used to reference work pieces that need machining details set at prescribed spacing. Indexing fixtures must have a positive means to accurately locate and maintain the indexed position of the part.

1.1.5 Multi-Part or Multi-Station Fixtures

Multi-part or multi-station fixtures are normally used for either machining multiple parts in a single setup, or machining individual parts in sequence with the performing different operations at each station.

1.1.6 Milling Fixtures

Milling fixtures are the most common type of fixture. It includes standard vises and clamps. However, as the work piece size, shape and complexity become more sophisticated so does the fixture. Tombstones, which are commonly used on horizontal machining centers, come in a wide variety of configurations to hold multiple parts on up to four sides of the fixture. The t-slots of the machine table are standardized in size and spacing and are the primary used for holding work and fixture devices for machining. Fixtures are typically mounted to the table with a variety of accessories like clamps, jacks, t-slot bolts, straps and nuts.

1.1.7 Lathe Fixtures

The same basic design principles that apply to milling fixtures also apply to lathe, or turning, fixtures, with one major difference. In most milling operations, the cutting tool rotates during machining, while with turning the part rotates. This situation creates another condition the tool designer must deal with - centrifugal, or rotational, force. Work holding devices include two to six jaw chucks and collets of varying shapes and diameters. Work may also be held between the head and tail stock of the lathe or “between centers.”

1.1.8 Grinding Fixtures

The two major types of grinding fixtures are available for surface grinding and cylindrical grinding. The magnetic table is the preferred work holding device on surface grinders. Cylindrical grinding is usually a secondary operation after turning. Often the same center holes used for between-centers turning may be used for grinding the part. In this case, the friction is more as compared to other processes, So fixture design must allow for coolant flow and swarf removal.

1.1.9 Broaching Fixtures

Broaching fixtures hold and locate the part in relation to the broaching tool. Internal and external broaching is available with the different approaches to their respective designs. Internal broaching requires less clamping because the process tends to keep the part firmly seated on the fixture where as external broaching requires resistance to both pull and push forces that are exerted on the part, requiring more sophisticated fixtures.

II. FIXTURE DESIGN

Fixture design is one of the most important design tasks during process design for a new product development since it involves defining the locations and orientations of parts during assembly processes as well as providing physical support, which can greatly affect product dimensional variations and process yield.

2.1 The 3-2-1 Principle

As we know that any free body has a total of twelve degrees of freedom as below:

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

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)

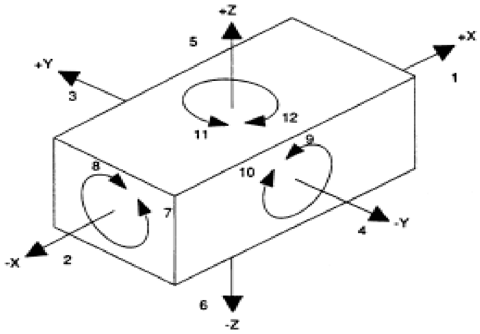

Figure1. Degrees of freedom [1]

So 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. Usually, supporters and locators restrict 9 degrees of freedom of the work piece need to be fixed, with the remaining 3 degrees of freedom by clamps.

The 3-2-1 principle is stated as below:

The work piece is rested on three non-collinear points of the bottom surface (XY), and you will be able to fix the +Z,CROT-X,ACROT-X, CROT-Y and ACROT-Y degrees of freedom. Now, 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. Next, 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, we can fix 9 required degrees of freedom by using the 3-2-1 principle of fixture design.

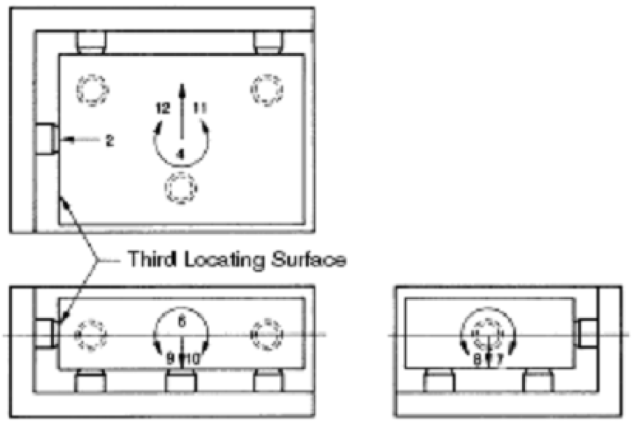

Figure 2. The 3-2-1 Principle [2]

2.2 Clamping Principles

Clamping is used to restrict the possible movement of a work piece usually three (-X, -Y and -Z) degrees of freedom that is not bounded by locators and supports. The general clamping principles are discussed below according to the clamping direction with respect to the work piece set up.

2.2.1 Horizontal Clamping

A horizontal clamp is applied on the “horizontal clamping face” which has not been used as the locating face. Also, the clamp is located on the side of the work piece that is opposite to the second or third datum face in order to resist the locating force. If the horizontal clamping faces are nonplanar faces, multiple horizontal clamps can be applied on one face to ensure the restriction of the movement. [1]

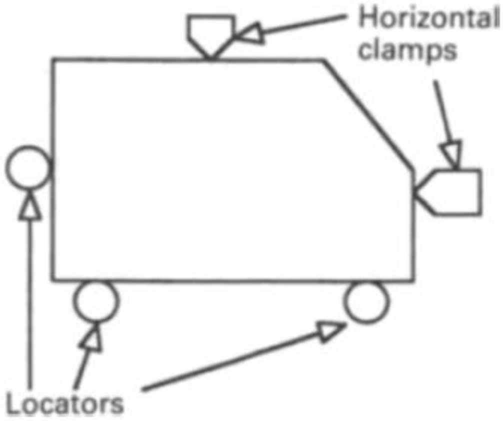

Figure 3. Horizontal Clamping [1]

2.2.1 Vertical Clamping

A vertical clamp is applied on the "vertical clamping face", which is a face that is the top surface of the work piece and is on the opposite side of the work piece to the first datum plane. The most rigid area is used as the clamping position to prevent cracking or bending during the machining process. So, locating the vertical clamp on the area directly above a vertical support is the most secure vertical configuration. [1]

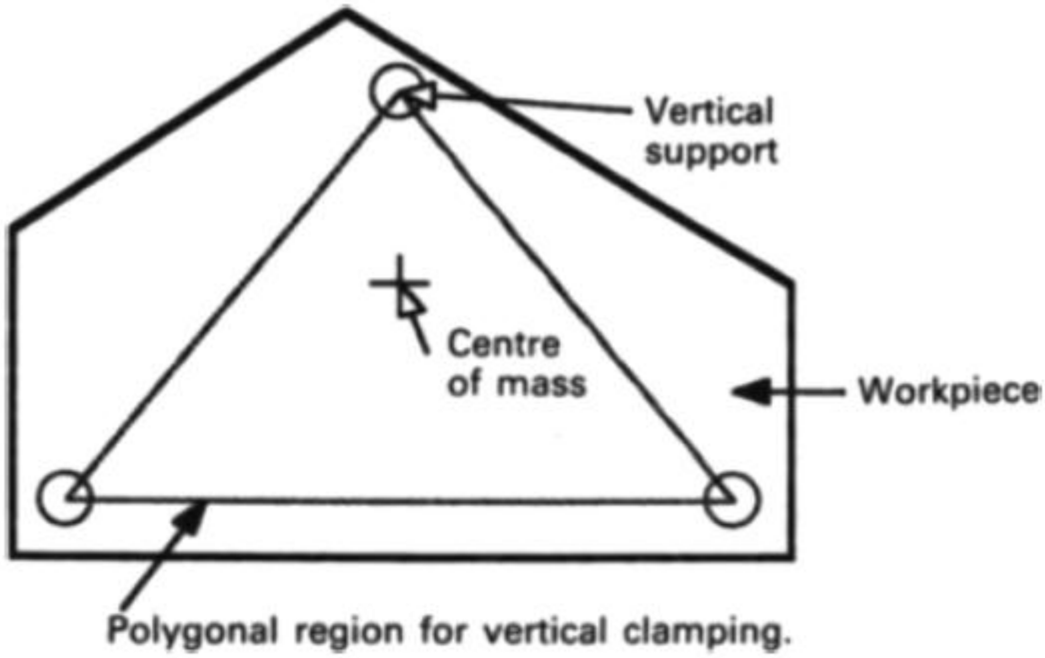

Figure 4. Vertical Clamping [1]

2.3 Fixture Design Process

Fixture design includes the identification of clamps, locators, and support points, and the selection of the corresponding fixture elements for their respective functions. There are four main stages within a fixture design process—(i) setup planning, (ii) fixture planning, (iii) fixture unit design and (iv) verification

Setup planning determines the number of setups required to perform all the manufacturing processes, the task for each setup, e.g., the ongoing manufacturing process and work piece, orientation and position of the work piece in each setup. A setup represents the combination of processes that can be performed on the work piece by a single machine tool without having to change the position and orientation of the work piece manually.

During fixture planning, the surfaces, upon which the locators and clamps must act, as well as the actual positions of the locating and clamping points on the work piece, are identified. The number and position of locating points must be such that the work piece is adequately constrained during the manufacturing process.

In the third stage of fixture design, suitable units, (i.e., the locating and clamping units, together with the base plate), are generated.

Verification focuses upon ensuring that developed fixture designs (in terms of their setup plans, layout plans, and physical units) satisfy the fixturing requirements. Verification takes place against the tolerance, constraining, collision detection, usability, and affordability requirements. [2] [3]

2.3 Dedicated Fixtures vs Modular Fixtures

The fixtures designed for a particular work piece are called 'dedicated fixtures'. Due to the current trends in manufacturing promoting a larger product mix, flexibility, and quality, many companies are demanding fixturing systems to be more 'flexible'. Flexible systems allow a variety of individual parts to be held during machining or assembly, thus minimizing cost to produce each dedicated fixture, and reducing storage of a multiplicity of fixtures. With typical costs of dedicated fixtures amounting to 10-20% of the total manufacturing costs, the economic impact of flexible fixturing could be dramatic.

However, the trend toward greater flexibility in production volume and product variety has led to more multi-purpose fixtures. Flexible fixtures for rotational components have been in use for several decades and they are capable of holding a large variety of workpieces. Common fixtures for rotational parts are centres, mandrels, collets and chucks. A centre is used to help mount and hold a work piece typically one centre at each end. The mandrel is a device in which through holes are provided to hold the work piece and machining operations are performed within specific regions of the part. Collets are tapered bushings used typically for holding bar stock of circular, square, and hexagonal cross sections. Chucks are the most popular fixture for rotational components, specifically for lathes, and are usually equipped with three or four jaws.

With the need for flexibility and the increasing design complexity of products, modular fixtures have emerged. A modular fixture attempts to achieve flexibility via multipurpose fixturing elements. A modular fixturing system consists of a large number of standard fixturing elements such as base plates, locators, clamps, and supporting elements. Using these standard components, elements are selected to build a fixture configuration to hold the work piece. Modular fixturing elements can be re-used for other products once disassembled, and they are manufactured with high tolerances to meet work piece requirements.

Modular fixtures reduce the need for storage space compared to dedicated fixturing, and the time and labour cost in designing dedicated fixtures. Machine shops have demonstrated these advantages in many instances. The major faults of modular fixtures are in accounting for repeatability and tolerance stack up with the assembly of standard components. Vendors of modular fixtures attempt to resolve these inadequacies by hardening and grounding fixture elements. Hence, modular fixtures are more commonly used for low production volume components with a wide product variety. [3]

III. CONCLUSION

From the study we can conclude that for designing the fixture the geometry method (3-2-1 principle) is very useful for the complex component having various machining processes though it is the basic principle of the fixture design.

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