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DESIGN AND DEVELOPMENT OF A FIXTURE FOR VALVE BODIES ON VERTICAL TURNING LATHES (VTLS)

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Abstract-**Fixtures are essential components across various industrial applications, designed to securely hold, position, and support workpieces during machining operations to ensure precision and consistency. The process of fixture design and fabrication is intricate, requiring a solid understanding of geometry, dimensional tolerances, operational procedures, and manufacturing methods. This study presents an overview of the 3-2-1 location principle as it applies to the fixture design for complex geometries, alongside a discussion of effective clamping strategies. It also outlines a systematic approach for designing fixtures, with comparisons between modular and dedicated fixture systems, offering practical insights into their implementation in machining valve bodies on VTL machines.**

Keywords - **Fixture design, 3-2-1 locating principle, clamping strategies, modular fixtures, dimensional tolerances, workpiece positioning, industrial applications.**

I. INTRODUCTION

Over the last hundred years, the manufacturing industry has undergone significant advancements. The introduction of high-speed machine tools, efficient cutting instruments, and innovative manufacturing techniques has enabled industries to produce components with improved speed and precision. Although work holding methods have evolved alongside these advancements, the fundamental concepts of locating and clamping remain largely unchanged.

In high volume production environments, there is a growing need for quick and accurate positioning of components to perform machining operations efficiently. Jigs and fixtures serve as essential tools in such scenarios, playing a key role in producing identical and interchangeable parts with precision. These tools are specifically engineered to facilitate the mass production of components, ensuring consistency and interchangeability across units.

Jigs and fixtures simplify complex operations that would otherwise require considerable time and skilled labour. By accurately positioning and firmly securing the work piece, they minimize errors caused by movement during machining, ultimately enhancing productivity and product accuracy. Their application is crucial in modern engineering for achieving efficient, repeatable, and costeffective manufacturing outcomes.

II. LITERATURE SURVEY

1.S. S. Pachbhai and L. P. Raut, "A Review on Design of Fixtures," International Journal of Engineering Research and General Science, Vol. 2, Issue 2, Feb–Mar 2014, ISSN 2091-2730. This study emphasizes that the primary function of a fixture is to minimize workpiece deformation during machining. Fixtures help in reducing operation time, simplifying machining processes, and decreasing cycle times, ultimately enhancing the overall production rate. The paper categorizes various clamping methods tailored to specific industrial applications and outlines different types of locating mechanisms, including:

•Flat locators
•Jack pin locators
•Drill bush locators
•V-locators

2.N. P. Maniar and D. P. Vakharia, "Design & Development of Rotary Fixture for CNC," International Journal of Engineering Science Invention, Vol. 1, Issue 1, Dec 2012, pp. 32–43

This research introduces the Computer Aided Mass Balancing Method (CAMBM) to simplify the complex task of locating the center of gravity and offset distances in irregularly shaped parts. The method enhances fixture design efficiency by reducing the need for manual calculations. Two CAMBM techniques are compared, with the VIII Quadrant CAMBM proving more accurate reducing percentage errors by approximately 6% compared to the IV Quadrant method.

A. Principles of Location

The fundamental principle of locating a workpiece involves constraining its movement along the three primary axes: X, Y, and Z. For example, a rectangular part can potentially

move along or rotate about these axes. Proper fixturing must prevent this movement. In the case of cylindrical components, additional constraintssuch as Vblocks or custom supportsmay be needed to fully immobilize the part.
Recent studies have also focused on optimizing clamping forces and minimizing workpiece deformation. One such study evaluates varying contact forces and positional errors by minimizing the total complementary energy within the workpiece-fixture system. The resulting predictions have shown strong agreement with both experimental and previously published results, validating the method. Additionally, identifying the optimal clamping sequence can reduce part deflection and improve overall accuracy.

III. TYPES OF FIXTURES:

1. Plate Fixtures
These fixtures consist of a flat plate equipped with various locators, supports, and clamps. Due to their versatility, plate fixtures are widely used across different machining setups. The material choice depends on the component and machining operation.

2. Angle Plate Fixtures
A variation of plate fixtures, angle-plate fixtures have surfaces oriented perpendicular to the base, enabling the workpiece to be held vertically or at specific angles.

3. Vise Jaw Fixtures
Designed as customized inserts for standard vises, these fixtures adapt the vise to hold specific parts. They are cost-effective and simple but limited by the size of the work piece and vise capacity.

4. Indexing Fixtures
Used when parts require features machined at regular intervals or angles, indexing fixtures provide accurate and repeatable positioning through mechanical indexing mechanisms.

5. Multi-Part or Multi-Station Fixtures
These fixtures allow multiple components to be machined simultaneously or enable sequential operations on individual parts across different stations, increasing productivity and reducing setup time.

6. Milling Fixtures
Common in milling operations, these fixtures range from simple vises and clamps to complex setups like tombstones, which hold several parts on multiple faces. Fixtures are often secured to machine tables via standardized T-slots using bolts, clamps, and other accessories.

7. Lathe Fixtures
Lathe or turning fixtures follow similar principles as milling fixtures but must account for the rotating workpiece. Work holding methods include jaw chucks, collets, and between-center setups, with additional consideration for centrifugal forces during rotation.

8. Grinding Fixtures
Fixtures for grinding operations are typically designed for surface or cylindrical grinding. Magnetic chucks are common in surface grinding, while cylindrical grinding may reuse turning centers. These fixtures must also ensure proper coolant flow and debris removal due to higher friction levels.

9. Broaching Fixtures
Broaching fixtures are tailored to align the workpiece with the broach tool. Internal broaching generally requires less clamping due to the downward cutting force, whereas external broaching demands greater resistance to both pulling and pushing forces, necessitating more robust fixture designs.

IV. DESIGN OF FIXTURES

A. Key Considerations in Fixture Design.
Designing jigs and fixtures requires careful analysis of several factors that influence the overall efficiency and accuracy of the manufacturing process. Key considerations include:
•Understanding the size, geometry, and features of the raw workpiece and final component.
•Identifying the type and automation level of the machine tool used.
•Reviewing the machine’s built-in locating and clamping mechanisms.
•Evaluating the precision and availability of indexing systems.
•Assessing variations in machine performance.
•Considering the machine tool's structural rigidity.
•Examining the availability and design of ejectors and safety features.
•Determining the desired accuracy and quality standards for the finished product.

B. Fixture Design Principles.
Fixture design is a critical aspect of process planning in product development. It defines the location, orientation, and physical support for parts during machining and assembly, significantly influencing dimensional accuracy and yield.

1. The 3-2-1 Locating Principle
A work piece in space has 12 degrees of freedomsix translational (±X, ±Y, ±Z) and six rotational (clockwise and

counterclockwise around each axis). Effective fixturing involves restricting 9 of these 12 degrees of freedom through supports and locators, with the remaining 3 constrained using clamps.

The 3-2-1 principle works as follows:
Three points on the bottom surface (XY plane) restrict movement in +Z and rotation about the X and Y axes (CROT-X, ACROT-X, CROT-Y, ACROT-Y).
Two points on the side surface (XZ plane) control movement in +Y and rotation about the Z axis (ACROT-Z).
One point on the adjacent surface (YZ plane) constrains movement in +X and clockwise rotation about the Z axis (CROT-Z).

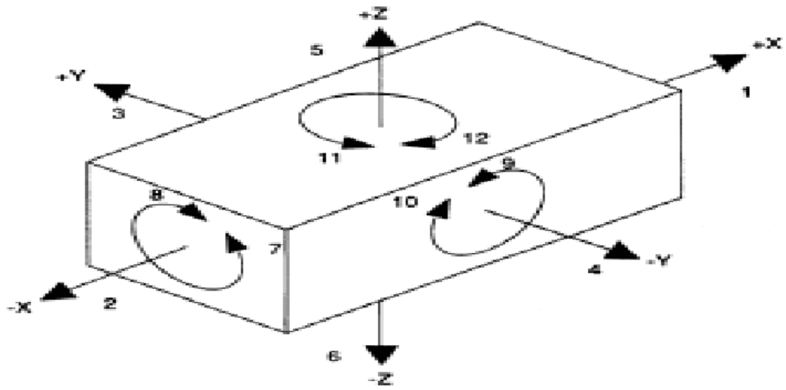

Fig 1.Degrees of Freedom

By positioning the workpiece against these six contact points, a total of 9 degrees of freedom are eliminated, ensuring stability and repeatable positioning.

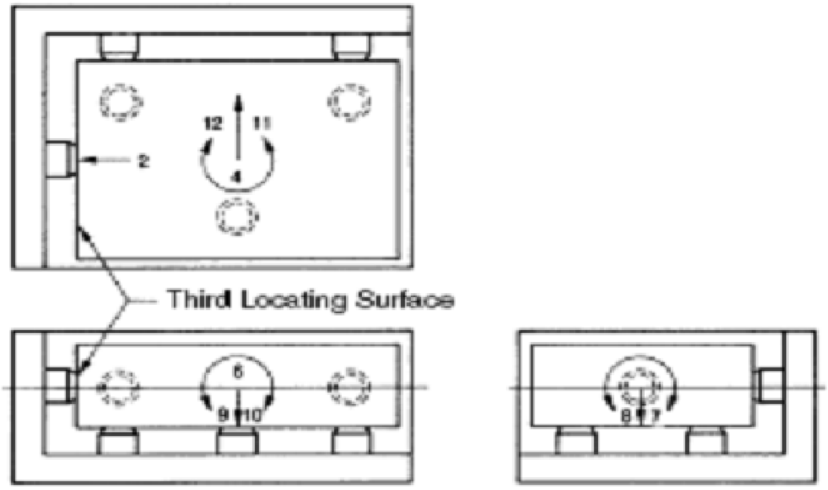

Fig 2. 3-2-1 Principle

C. Clamping Principles.
Clamping is used to eliminate the remaining 3 degrees of freedom (typically −X, −Y, and −Z) that are not already constrained by locators and supports. Clamping should be applied in directions that oppose machining forces to prevent displacement of the workpiece. It must also be designed to avoid over-constraining or distorting the part, ensuring uniform pressure and reliable holding throughout the operation.

1. Horizontal Clamping
Horizontal clamps are applied to faces of the workpiece that are not used as locating surfaces. Typically, they are positioned on the side opposite the secondary or tertiary datum faces to counteract the forces generated during machining. When clamping non-planar horizontal surfaces, multiple clamps may be required on a single face to effectively restrict movement and ensure stability.

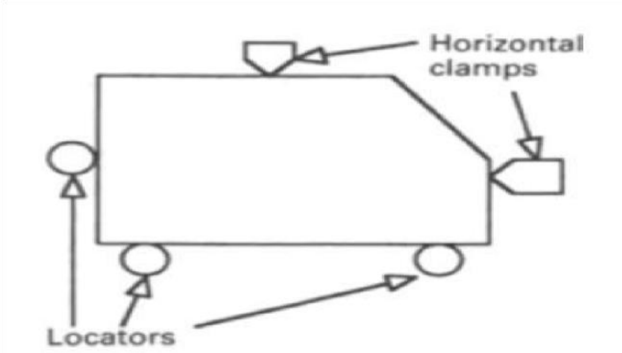

Fig 3.Horizontal Clamping

2. Vertical Clamping
Vertical clamps are placed on the top surface of the workpiece opposite to the primary locating face. To avoid deformation such as bending or cracking during machining, clamps should engage the most rigid sections of the part. Ideally, vertical clamps should be aligned directly above vertical supports to maintain a strong, balanced configuration.

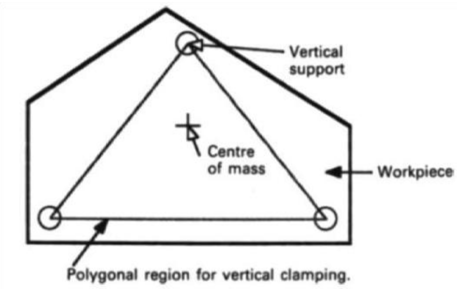

Fig 4.Vertical Clamping

D. Fixture Design Process
Designing a fixture involves identifying the correct combination of clamping, locating, and supporting elements to securely hold the workpiece during machining. The fixture design process is generally divided into four stages:

1.Setup Planning
This stage defines how many setups are required to complete all machining tasks. Each setup specifies the manufacturing operations to be performed, the orientation of the workpiece, and how it is positioned within a machine. A setup includes all the processes that can be carried out without changing the part's orientation manually.

2.Fixture Planning
At this stage, designers determine which surfaces will be used for locating and clamping. The number and placement of locators and clamps are selected to ensure the workpiece remains fully constrained during operations, based on the required degrees of restriction.

3.Fixture Unit Design
This phase involves the detailed creation of the fixture's components including locating elements, clamping mechanisms, and the base plate. The design must account for load-bearing capacity, accessibility, and ease of use.

4.Verification
The final step ensures the fixture meets functional and operational requirements. This includes checking for dimensional accuracy, proper constraint of movement, collision avoidance, usability, and cost-effectiveness. Verification helps confirm that the fixture will perform reliably under real-world machining conditions.

V. CONCLUSION

The application of the 3-2-1 locating principle plays a crucial role in fixture design, particularly for complex components requiring multiple machining operations. This geometric method remains fundamental in achieving accurate and repeatable positioning of parts. By effectively reducing cycle time for loading and unloading, it contributes to higher production efficiency.
Furthermore, the integration of CAD and CAE tools into fixture design significantly enhances precision and functionality. Optimizing fixture layout and clamping forces helps in minimizing workpiece deformation and achieving uniform clamping pressure. These improvements not only streamline the setup process making it easier for operators but also allow for the use of semiskilled labour, reducing overall manpower costs.
In mass production scenarios, the use of well-designed jigs and fixtures leads to minimal dimensional variation and supports consistent product quality, thereby reinforcing the reliability and efficiency of the manufacturing process.

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