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DESIGN & MANUFACTURING KEY FACTORS FOR INCREASING PERFORMANCE & ACCURACY OF FIXTURE

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ABSTRACT
Maintaining accuracy during manufacturing processes heavily relies on the performance of fixtures. This paper investigates the critical factors that influence the accuracy of fixtures, thereby impacting the dimensional and geometrical quality of the final product. These factors encompass design considerations such as locator placement, clamping mechanisms, material selection, and rigidity. Furthermore, manufacturing errors in the fixture itself, wear and tear during operation, and the influence of external forces and vibrations are analysed. Understanding and mitigating these factors are crucial for achieving and sustaining high levels of manufacturing accuracy, reducing scrap rates, and ensuring the interchangeability of manufactured parts. This study provides a comprehensive overview of these influencing parameters and highlights the importance approach in fixture design, manufacturing, and maintenance to optimize manufacturing precision. Minimizing manufacturing errors from these sources is crucial to ensure consistent and high-quality manufactured parts.

Keywords: CAD-Modeling, Fixture designing, Manufacturing, Accuracy, Productivity, Interchangeability, Errors.

I. Introduction
Manufacturing fixtures play a crucial role in achieving precision, repeatability, and efficiency in production processes. Maintaining the accuracy of these fixtures is paramount for ensuring the quality of manufactured parts and optimizing production cycle times. This summary addresses the critical aspects of fixture accuracy in the context of both increasing and decreasing cycle times. While increased cycle times might necessitate heightened fixture precision for complex operations, decreased cycle times demand robust fixtures capable of maintaining accuracy under accelerated operational demands. This document will explore key considerations and best practices for maintaining fixture accuracy to effectively support scenarios, ultimately contributing to improved product quality, reduced waste, and optimized manufacturing process.
In the real world of manufacturing, particularly machining operations performed on machines like Vertical Machining Centres (VMCs), **fixtures** stand as indispensable tools. Simply put, a fixture is a work holding device designed to **securely locate and support a work piece** during a manufacturing process, ensuring that each part is machined according to the required specifications and tolerances.

II. Objective
1. Precision and Accuracy:
a) Consistent Results: By precisely locating and holding work pieces, jigs and fixtures minimize human error, leading to consistent part quality.
b) Dimensional Accuracy: These devices ensure that parts are machined to exact specifications, reducing the need for rework and scrap.

2. Increased Productivity:
a) Reduced Setup Time: Pre-engineered jigs and fixtures streamline the setup process, allowing for quicker production cycles.
b) Enhanced Efficiency: Simplified operations and reduced operator fatigue contribute to higher productivity.

3. **Improved Safety:**

a) Reduced Risk of Accidents: By securely holding work pieces, jigs and fixtures minimize the risk of operator injury.
b) Safer Work Environment: Proper tool and work piece alignment reduces the chance of accidents.

4. **Cost Reduction:**

a) Lower Labor Costs: Simplified operations and reduced setup time lead to lower labor costs.
b) Reduced Material Waste: Consistent part quality minimizes scrap and rework.

III. Literature

In below information has given about referred papers and fixture design process and concept generation related to milling fixture and accuracy in which collected papers give various techniques, design methods and used technical data.

[1] **Kedar S. Kawnaikar** [2017] et al.: - Design, Modelling and Manufacturing of Fixture for Machining over conventional setup. In existing set up the work piece is manufactured on conventional machining operations, so the aim of this project is to replace with fixture for HMC machine to increase production rate of work piece.

[2] **S. Nallusamy** [2017] et al.: - Optimization of Production Process and Machining Time in CNC shop floor. The primary focus on lean production system is the systematic elimination of non-valuable added activities from the production process.

[3] **Ru Li [2021]** et al.: - Impact of material selection on fixture accuracy of CNC machine tools. In the experiment, two fixture materials of 45C and 65Mn were selected, and the two fixtures with wedge-shaped positioning surface and circular positioning surface were compared.

[4] **Okpala Charles** [2024] et al.: - Evolution and Impact of Jigs and Fixtures in Modern Manufacturing. The paper also examines the economic and operational impacts of jigs and fixtures, highlighting their role in reducing production costs, minimizing human error.

[5] **Kulkarni. Kaustubh A.** [2016] et al.: - Design and Development of VMC Milling Fixture. The main objective of our project is to design and optimize the fixture for shafts having various dimensions. Design of new setup is a modified over the old fixture due to some drawback.

[6] **Hemanth. M [2020]** et al.: - Design of work holding part for wheel hub for drilling of five lug bolts. This assists the forged work piece used for the wheel hubs of an automobile for drilling and tapping at required positions. The forged component already manufactured needs to be drilled as per the drawings.

IV. Main elements of fixture

1. **Base of fixture: -**A base plate in a fixture is the foundation upon which all other components of the fixture are mounted. It provides a stable and accurate platform for holding the work piece during manufacturing processes like machining or welding.

Key Features:
Size and Shape: Customized to accommodate the specific work piece and other fixture elements.
Material: Typically made of a durable and stable material like cast iron or steel to resist deformation.
Mounting Surface: Features precisely machined surfaces, T-slots, or threaded holes for attaching other fixture components.
Datum Holes: Precisely located holes used as reference points for accurate alignment and measurement.

2. **Holding element for job: -** A cylindrical locating pin in a fixture is a crucial component for accurately positioning a work piece during manufacturing or assembly. Here's a breakdown of the design considerations:

Function and Purpose:

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Precise Positioning: The primary function is to ensure repeatable and accurate placement of the work piece within the fixture.
Degrees of Freedom: The pin restricts specific degrees of freedom of the work piece, typically two translational and one rotational

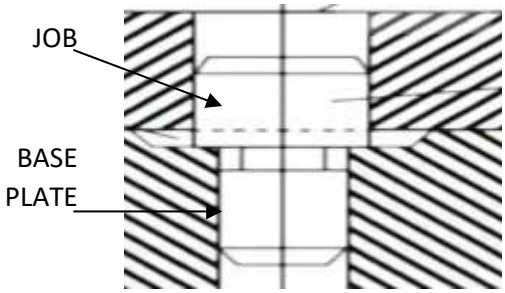

Fig: -1: Locator

3. Clamping element

In fixture design, a clamp element plays a crucial role in securely holding a work piece in place during manufacturing operations like machining, welding, or assembly. Its primary functions are:
Secure Work piece: The most vital role is to firmly hold the work piece against the locating elements of the fixture. This prevents any movement, vibration, or displacement of the work piece during the operation.
Maintain Stability: Clamps ensure the stability of the work piece against all forces exerted on it, such as cutting forces, welding stresses, or assembly pressures.
Ensure Accuracy and Repeatability: By consistently holding the work piece in the correct position, clamps contribute significantly to the precision and repeatability of manufacturing processes, which is essential for high-quality results, especially in series production.

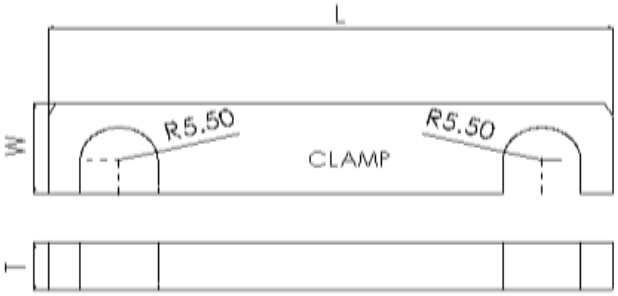

Fig: - 3) Common Double Support clamp

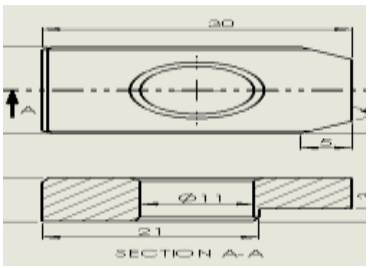

Fig: - 4) Strap clamp

4. Restriction device

Blocks play a crucial role in fixtures, particularly when dealing with cylindrical work pieces. Here's a breakdown of their primary functions:
Securely Holding Cylindrical Work pieces: The V-shaped groove in a V-block provides a stable and reliable way to hold round objects like rods, pipes, and shafts. This is essential for various machining and inspection operations.
Centering and Positioning: The design of a V-block inherently centers a cylindrical work piece within the groove. This ensures accurate and consistent positioning for tasks like drilling, milling, and grinding.
Facilitating Precision Machining: By securely holding and centering the work piece, V-blocks enable precise machining operations. They minimize the risk of the work piece shifting or rotating during machining, which could lead to inaccuracies.

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V-blocks are essential tools for holding cylindrical work pieces in machining and inspection.

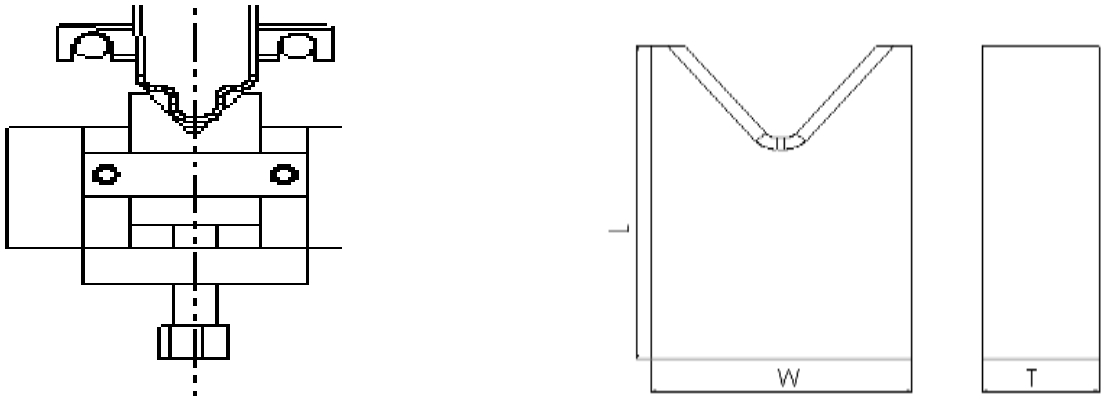
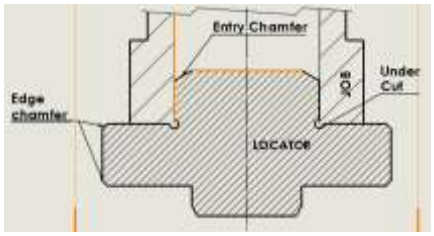
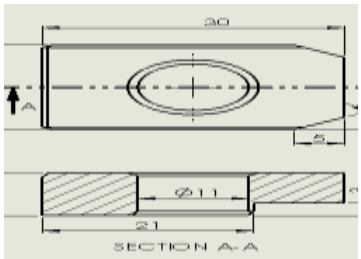


Fig: - 4: Job Alignment Restriction Block

V. Design consideration & manufacturing process

3D-DESIGN	Manufacturing Consideration	Impact on Fixture
Locator 	• Apply entry chamfer of 30^{o} • Ensure that of undercut Min. 0.8 mm. • Debarring at sharp edges or apply chamfer at edge/corners. • Contacted area of locator should be heat-treated	• Job will easily take guide to locate in fixture without damage. • Avoid edges clash during resting & for safety and handle easily. • Avoid wear of locator outer surface
Base plate 	• Consider min- 5 mm overall allowance over finish size • To maintain flatness and parallelism do grinding operation after milling.	• Helps to over-come in warpage or bending problem • Gives accurate starting or resting reference to machining
 **Clamp**	• Min thickness: -12 mm • Use heat treated steel • Min width:- 10 mm • Tempering should be done after quenching or flame hardening.	• For good rigidity against clamping force • Heat treated steel give you minimum wear and tear at contacted area.

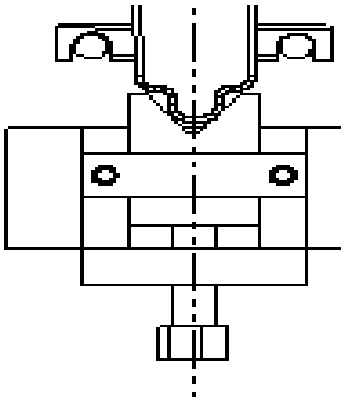
V-Block 	• V- Angle should be within tolerance size. 1^0-2^0 error acceptable. • Consider height off-set of cutting tool while manufacturing. • Consider one fix and another block movable which give accurate positioning of round work piece.	• Provides a stable and reliable way to hold round objects like rods, pipes, and shafts. • By securely holding and centering the work piece, V-blocks enable precise machining operations
Spares(Bolt, dowel pin…)	• Manufactured with high precision and close tolerance to avoid looseness. • Spare should be case heat-treated or surface treated.	• High durability against shear. • Surface treated part has low corrosion rate

Table: - 1: Design & MFG. Consideration

VI. Conclusion

Precision fixture design is essential for maintaining dimensional accuracy during machining operations. Fixtures must securely hold work pieces in the correct orientation to prevent any movement that could lead to errors. The implementation of advanced design principles, such as the 3-2-1 locating method, ensures that parts are positioned accurately with minimal degrees of freedom. This meticulous attention to detail directly impacts the consistency and interchangeability of parts produced in mass production environments. To significantly enhance performance and accuracy in design and manufacturing, a holistic approach integrating several key aspects is crucial. From a design perspective, implementing robust Design with manufacturing principles early in the product development lifecycle is paramount. This includes simplifying designs, minimizing part count, standardizing components, and optimizing material selection to ensure inherent manufacturability and reduce potential error sources. Leveraging advanced manufacturing techniques such as high-precision CNC machining, laser-based processes (e.g., micro-machining, cutting), and additive manufacturing (e.g., 3D printing) allows for the creation of intricate geometries with tighter tolerances and superior surface finishes.

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