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Design optimization and Analysis of Multi station Jig

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ABSTRACT: This project aims to optimize the design and analyse the performance of a multi-station jig for efficient drilling and threading operations on multiple components. By incorporating fast clamping mechanisms and precise workpiece location features, the project aims to minimize costs and reduce loading and unloading times. The multi-station jig enables simultaneous machining of four components, streamlining the production process. To ensure accuracy, the jig parts undergo meticulous machining, including surface grinding for precise locating surfaces and CNC lathe machining for tool guiding. The design process involves utilizing advanced software tools such as AutoCAD and SolidWorks for detailed modelling and simulation. The outcomes of this research will contribute to enhancing productivity and cost-effectiveness in multi-component machining operations.

I. INTRODUCTION

This chapter serves as a comprehensive literature review, exploring the research area established in chapter one. It provides an extensive overview of relevant fields, delving into the current boundaries of knowledge. The concept of Jigless Assembly, the primary focus of this research, is introduced and defined, ensuring consistent terminology usage throughout the thesis. The motivation behind the widespread pursuit of Jigless Assembly by aerospace manufacturers is discussed, supported by examples of successful implementations in the industry and ongoing academic developments. These examples showcase the diverse applications and techniques employed in achieving Jigless Assembly. In order to develop effective methods and methodologies for designing jigless assembly and modelling the assembly process, the ability to explicitly deliver a Jigless Assembly solution while accommodating conventional assembly methods is crucial. The literature review further examines three key areas contributing to the realization of Jigless Assembly: Design and Assembly Processes' Methods and Methodologies, Feature Based Methods, and Tolerance Representation and Analysis. Established examples in these areas, developed by researchers and practitioners, are presented, highlighting their relevance in designing jigless assembly. The growing significance of 'Features' in product design, manufacturing, and assembly is emphasized, with Feature Based Methods advocated for designing jigless assembly. The state-of-the-art in Feature Based Methods is illustrated through relevant works. Additionally, the review explores examples of Feature Based Tolerance Representation and Analysis, with a focus on AnaTole as a representative system. This exemplifies the potential of Computer-Aided Telebanking systems as enablers for jigless assembly. By synthesizing existing knowledge, this literature review sets the stage for the subsequent research, contributing to the advancement and implementation of Jigless Assembly across industries. The literature review also highlights the importance of precise machining in the various components of a jig. The locating surfaces of the jig require proper finishing, which is achieved through the utilization of surface grinding machines. To guide the tools used in operations such as boring, drilling, reaming, and threading, bushings are employed, and CNC Lathe machines are utilized for their production. The entire design and modelling process is carried out using software such as AutoCAD and SolidWorks, ensuring accurate representation and optimization of the multi-station jig. This research aims to address several key challenges in jig design, including cost optimization, reduction of loading and unloading times, and improved clamping mechanisms for quick and efficient workpiece placement. By optimizing the design and analysis of the multi-station jig, this project aims to enhance manufacturing efficiency and productivity while maintaining dimensional accuracy and part quality. The integration of advanced techniques and technologies into the design and manufacturing process of jigs contributes to the advancement of

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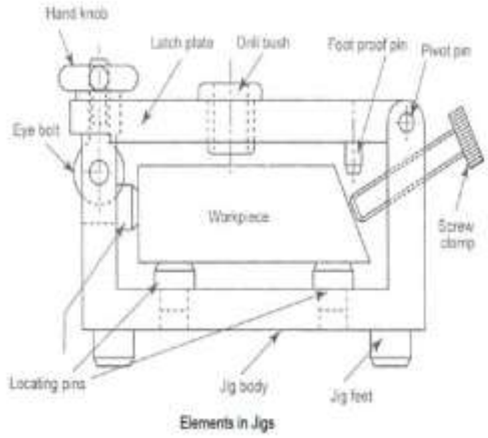
jigless assembly concepts and fosters innovation in the field.



Above Figure shown Parts of Jig and Fixture Design.

II. OBJECTIVES

1. Design optimization and Analysis of Multi station Jig.
2. Check for Location with fool Proofing
3. Quick clamping
4. Tool cost minimization.
5. Reduction of loading and unloading time

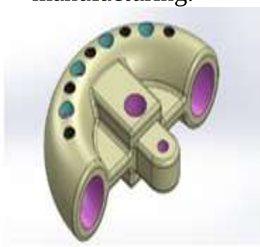
III. SCOPE OF WORK

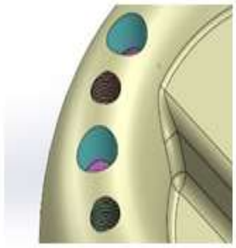
1. Doing provision to perform multiple operation in a single setting
2. Bush design for multiple operation.
3. Check for the vibrations during machining process
4. Design calculations

IV. METHODOLOGY

The complete study of Design optimization and Analysis of Multi station Jig through the CAD Software Auto CAD, Solid Works 21. & Ansys.

1. Study of drawing is done to identify clamping area from which our component is clamp on the JIG
2. Using Auto Cad software drawing is prepared to proceed for the Jig design.
3. Design calculation of Bushing and jig elements for design of Jig.
4. Static Stress analysis of plates with boundary conditions by using Ansys 19 software.
5. Conceptual design of multi station with provision of machining of multiple work piece by using Auto CAD software
6. Final Design and modelling of JIG prior to approval of Client.
7. Modelling of Multi station Jig by using Solid works 21 software.
8. Drafting as per the requirement of manufacturing.





V.LITERATURE REVIEW

The Section aims to explore and analyse the existing body of knowledge related to fixture design, rigidity, vibration analysis, finite element analysis (FEA), fixture stability, workpiece deformation, clamping forces, and part location error. This section provides a comprehensive understanding of the concepts, theories, and research conducted in these areas, which serves as a foundation for the research conducted in this project.

[1] **Sheldon Levine**,thepaper emphasizes the importance of rigidity in the fixture design. It states that the fixture should be as rigid as possible within weight limits. It also highlights the need to avoid resonances within the frequency range of interest, with the first resonant frequency being above the maximum specified tested frequencies.

[2] **Eiji Nabata& Yuji Terasaka**, the paper addresses the problem of vibration in machining processes and proposes the development of vibration analysis technology using 3D-CAD to analyze the system and mitigate the effects of insufficient dynamic rigidity.

[3] Necmettin **Kaya**, the paper highlights the significance of proper clamping in fixture design for achieving rigidity. Additionally, it recommends the use of ANSYS for finite element analysis of the fixture.

[4] **Yi Zheng**,the paper presents a finite element model for fixture unit stiffness and experimental methods for contact stiffness identification. It also proposes a mathematical calculation approach for finite element analysis, facilitating the construction of a fixture stiffness database for use in Computer-Aided Fixture Design (CAFD).

[5] **J.E. Akin**, The paper highlights Finite Element Analysis (FEA) as the common tool for stress and structural analysis across various fields. It explains the concept of FEA, which involves replacing

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complex shapes with a union of simple shapes (finite elements) to accurately represent the original part in analysis.

[6] **Xiamen Kang and Qingjin Peng**The paper concludes by discussing the research trend of computer-aided fixture planning and emphasizes the usefulness of Finite Element Analysis (FEA) for modelling fixture-workpiece interactions and optimizing fixture layout and clamping forces to minimize workpiece deformation.

[7] **David Roylance**, FEA is proposed as the foundation of a multibillion-dollar industry, enabling numerical solutions to complex stress problems.

[8] **Haiyan Deng**, the paper presents a procedure for analysing dynamic stability in machining fixture design, considering work piece deformation, machining motion, geometry changes, and material removal effects to ensure fixturing stability.

[9] **S.Ratchev, K.Phuah, G.Lammel, W.Huang**, The paper introduces an innovative simulation methodology for dynamic analysis of fixture-work piece systems using FEA, incorporating spring-damper elements for contact modelling. Experimental work using design of experiment techniques validates the approach.

[10] Shane P. Siebenaler, Shreyes N. Melkote Finite element analysis (FEA) is employed to model a fixture-work piece system, considering the influence of fixture body compliance on work piece deformation, which is crucial for ensuring quality part production.

[11] Peter**Avitabile**Vibration fixtures with resonant frequencies in the test range cause issues. Control at a point doesn't address fixture resonant behaviour. This article addresses these problems.

[12] Vaibhav **H. Bankar**Milling fixtures can be created during intermediate process steps by referencing gauge blocks. Modelling explores the influence of fixture compliance on work piece deformation and examines the effects of vibration on natural frequency prediction.

[13] **KulankaraKrisnakumar, Shreys N. Melkite**Machining fixtures function to locate, constrain, and support the work piece. Optimizing the fixture layout minimizes work piece deformation and ensures dimensional/form accuracy.

VI. DESIGN PRINCIPLES OF JIGS AND FIXTURES

The design principles of jigs and fixtures play a crucial role in the field of metalworking, particularly in achieving precise and accurate machining results. One of the key objectives is to accurately locate the part to be machined in relation to the fixture or platform. This ensures that a CNC machine starts the machining process from the designated point, allowing for consistent and reliable production.

The precision and accuracy of the machining process heavily rely on the accuracy of the fixture. Therefore, it is essential to ensure that every part loaded into the fixture is properly located. Any deviation in part location can introduce dimensional variations, leading to tolerance issues in the finished pieces. To avoid this, careful consideration must be given to the design and implementation of techniques for supporting, clamping, and locating the parts within the fixture.

Proper support and securement of the part within the fixture are critical factors that directly impact the surface finishes of the machined components. Incorrect supporting or inadequate clamping can result in temporary or permanent deformation of the part, affecting the overall quality of the finished product. Therefore, it is necessary to develop effective techniques that address both supporting and securing requirements, ensuring repeatability and consistency in the production process.

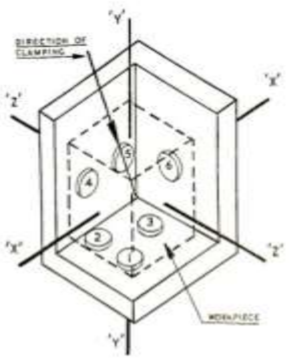
By adhering to these design principles, jigs and fixtures can significantly enhance the accuracy, repeatability, and efficiency of metalworking operations. The careful consideration of part location, supporting mechanisms, and clamping techniques helps minimize dimensional variations, improve surface finishes, and ensure the production of high-quality components.

VII. ADVANTAGES OF JIGS AND FIXTURES

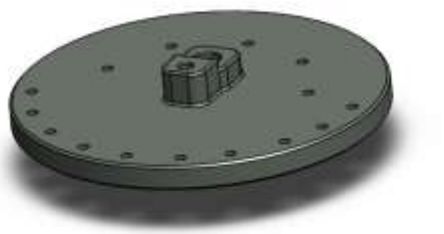
Jigs and Fixtures have made manufacturing processes less time-consuming, more precise, and hassle-free from a human factor perspective. The benefits of jigs and fixtures include but are not limited to the following:

- Increase in production
- The consistent quality of manufactured products due to low variability in dimension
- Cost reduction
- Inter-changeability and high accuracy of parts
- Inspection and quality control expenses are significantly reduced
- The decrease in an accident with improved safety standards
- Due to relatively simple maneuverability, semi-skilled workers can operate these tools, reducing the workforce's cost.

- The machine tool can be automated to a reasonable extent
- Complex, rigid and heavy components can be easily machined
- Simple assembly operations reduce non-productive hours
- Eliminates the need for measuring, punching, positioning, alignments, and setting up for each work piece, thereby reducing the cycle and setting up a time
- Increases technological capacities of machine tools
- More than one device can be used simultaneously on a work piece
- Setting higher values of some operating conditions like depth of cut, speed, and rate of feed can be attained because of the increased clamping capability of jigs and fixtures.



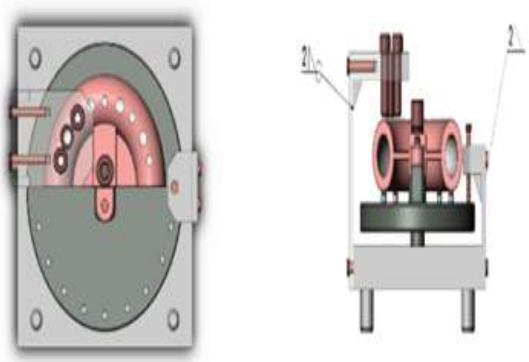
The 3-2-1 principle



ROTATING PLATE / INDEXING DISC

VIII. MASS PROPERTIES OF COMPONENT CONFIGURATION:DEFAULT

Coordinate system: -- default (software generated)
Material of Component- Alloy Steel
Density = 0.01 grams per cubic millimeter
Mass = 9107.37 grams
Volume = 1182775.82 cubic millimeters
Surface area = 144004.68 square millimeters
Center of mass: (millimeters)
X = -0.11
Y = 40.55
Z = -0.43
Principal axes of inertia and principal moments of inertia: (grams * square millimeters)
Taken at the center of mass.
Ix = (-0.01, 0.00, 1.00) Px = 39788900.30
Iy = (1.00, 0.00, 0.01) Py = 39902402.79
Iz = (0.00, 1.00, 0.00) Pz = 78682247.98
Moments of inertia: (grams * square millimeters)
Taken at the center of mass and aligned with the output coordinate system.
Lxx = 39902380.42 Lxy = 523.92 Lxz = -1593.84
Lyx = 523.92 Lyy = 78682242.25 Lyz = 14919.90
Lzx = -1593.84 Lzy = 14919.90 Lzz = 39788928.41
Moments of inertia: (grams * square millimeters)
Taken at the output coordinate system.
Ixx = 54875942.77 Ixy = -38432.16 Ixz = -179.88
Iyx = -38432.16 Iyy = 78684034.21 Iyz = -144175.72
Izx = -179.88 Izy = -144175.72 Izz = 54760901.52.



i) Top View **ii) Front View**
3D VIEWS OF MULTI-STATION INDEXING JIG

IX. MASS PROPERTIES OF MULTI-STATION INDEXING JIG CONFIGURATION

Coordinate system: -- default (software generated)
Density = 7.0246 grams per cubic millimeter
Mass = 34251.27 grams
Weight = m x g = 34.25 kg x 9.81 = 335.9925 ≅ 336 N
Volume = 4875809.86 cubic millimeters
Surface area = 633860.03 square millimeters
Center of mass: (millimeters)
X = -6.40
Y = 28.32
Z = -5.67
Principal axes of inertia and principal moments of inertia: (grams * square millimeters)

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Taken at the center of mass.
Ix = (0.96, -0.12, 0.26) Px = 249564137.52
Iy = (0.27, 0.06, -0.96) Py = 312762186.15
Iz = (0.10, 0.99, 0.09) Pz = 465598031.62
Moments of inertia: (grams * square millimeters)
Taken at the center of mass and aligned with the output coordinate system.
Lxx = 256419922.66 Lxy = -23415837.61 Lxz = 14204515.69
Lyx = -23415837.61 Lyy = 461774683.29 Lyz = -15236123.95
Lzx = 14204515.69 Lzy = -15236123.95 Lzz = 309729749.33
Moments of inertia: (grams * square millimeters)
Taken at the output coordinate system.
Ixx = 284998070.49 Ixy = -29629357.27 Ixz = 15448331.34
Iyx = -29629357.27 Iyy = 464280825.70 Iyz = -20736459.44
Izx = 15448331.34 Izy = -20736459.44 Izz = 338611937.14

X. FACILITIESAVAILABLE

1. Library facilities are available in the Vidarbha Institute of Technology, Nagpur.
2. Also, internet facilities available in college.
3. JMD Engineering Hingna, Industry is available for support and technical data sharing.

XI. CONCLUSION

In conclusion, the multi-station indexing jig has proven to be a valuable tool in the field of machining. Its incorporation in the manufacturing process has resulted in improved positioning accuracy, enhanced machining efficiency, reduced operator workload, and decreased processing costs. By utilizing drill bushings and a clamping device, this jig enables precise drilling on vertical planes of the workpiece, ensuring high-quality output.

Furthermore, the use of jigs and fixtures in production work has demonstrated significant advantages. These devices serve as guiding and holding mechanisms, facilitating the accurate location, support, and machining of components. By eliminating repetitive layout and setup tasks, jigs and fixtures save time and reduce the reliance on skilled labour. Their precise guidance and support result in workpieces with superior accuracy, minimizing the need for additional fitting during assembly.

The multi-station indexing jig and the broader utilization of jigs and fixtures have revolutionized the machining industry, providing a systematic approach to achieve precision, operational efficiency, and cost-effectiveness in production work. These tools have streamlined manufacturing processes and opened doors for increased productivity and higher quality output.

In conclusion, the incorporation of the multi-station indexing jig and the effective use of jigs and fixtures contribute to the success of machining operations, offering improved outcomes, reduced costs, and enhanced overall performance in the manufacturing industry.

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