International Journal of Engineering Inventions
e-ISSN: 2278-7461, p-ISSN: 2319-6491
Volume 13, Issue 7 [July. 2024] PP: 125-131

The Evolution and Impact of Jigs and Fixtures in Modern Manufacturing

Okpala Charles Chikwendu, Igbokwe Nkemakonam Chidiebube, and Nwankwo Constance Obiuto

Correspondence Address
Industrial/Production Engineering Department
Nnamdi Azikiwe University, P.M.B. 5025 Awka
Anambra State - Nigeria.
Emails: cc.okpala@unizik.edu.ng; nc.igbokwe@unizik.edu.ng; co.nwankwo@unizik.edu.ng

Abstract
Jigs and fixtures have been pivotal in transforming manufacturing processes, enhancing precision, efficiency, and productivity across various industries. This study provides a comprehensive overview of the historical development, technological advancements, and contemporary applications of jigs and fixtures. It explores their origins in early industrialization, tracing significant innovations that have shaped modern manufacturing. The integration of Computer Aided Design (CAD) and Computer Aided Manufacturing (CAM) technologies, along with the advent of additive manufacturing, has revolutionized the design and functionality of these tools. The paper also examines the economic and operational impacts of jigs and fixtures, highlighting their role in reducing production costs, minimizing human error, and ensuring consistent quality. Furthermore, the research delves into future trends, such as the integration of smart technologies and automation, which promise to further enhance the capabilities and applications of jigs and fixtures. This study underscores the critical importance of these tools in modern manufacturing and provides insights into their continued evolution and potential for future advancements. By understanding their evolution and impact, manufacturers can leverage these tools to enhance productivity, quality, and cost-effectiveness in their operations.

Keywords: *jigs, fixtures, manufacturing, quality improvement, cost reduction, drilling and milling operations, industrial revolution, industry 4.0, additive manufacturing*

Date of Submission: 16-07-2024 Date of acceptance: 31-07-2024

I. Introduction

The use of jigs and fixtures has significantly evolved alongside advancements in manufacturing technology. Originally simple in design and function, these tools have become sophisticated systems that optimize production processes, as they are essential tools used in manufacturing and assembly processes to improve efficiency, accuracy, and repeatability. A jig is a device used to hold and guide a tool (such as a drill or cutter) in a fixed position relative to the workpiece during a manufacturing operation. They ensure precise and accurate positioning of the tool to produce standardized parts.

Kataria and Bhimani (2017), stated that a jig is a work holding device that holds, supports and locates the work piece and guides the tool for a very specific operation. A jig can also be defined as a specialized tool or device used to guide, hold, or support a workpiece during manufacturing processes. Its primary purpose is to ensure that a specific operation (like drilling, milling, or welding) is performed accurately and consistently. Jigs are designed to position the tool relative to the workpiece and often incorporate components like drill bushings, templates, or clamps to facilitate precise operations. They are particularly useful in mass production to speed up processes and maintain quality standards.

A fixture is a work-holding device that holds, supports, and locates a workpiece securely during machining or assembly. Fixtures are designed to withstand machining forces and maintain the workpiece in the desired orientation. They are work-holding devices used to securely hold and support the workpiece during manufacturing or assembly. Unlike jigs, fixtures are primarily used to locate and hold the workpiece in place, ensuring stability and repeatability throughout the manufacturing process. Fixtures can be customized for specific parts or assemblies and are designed to withstand the forces and stresses generated during machining or assembly operations. They are critical for achieving consistent quality and reducing errors in production.

Okpala and Ezeanyim (2015), defined jigs and fixtures as manufacturing tools that are employed to produce interchangeable and identical components, as they are unique tool-guiding and work-holding devices

designed specifically for machining and assembling large number of parts. They explained that they eliminate the need for a special set-up for every work-piece thereby facilitating production, and also ensuring that every work piece is manufactured within a pre-determined tolerance. Jigs and fixtures are indispensable tools in modern manufacturing, as they provide efficiency, accuracy, and versatility across a wide range of industries. Their continued evolution and integration with advanced technologies promise to further enhance manufacturing capabilities in the future. However, Said et al. (2023), noted that jig and fixture as depicted in figure 1 include attachments for guiding, positioning and supporting the tools, which ensures that all work pieces produced by a particular jig or fixture are identical. Additionally, they explained that the employment of these devices can result in a high degree of accuracy, allowing for the assembly of wok pieces with minimal fitting.

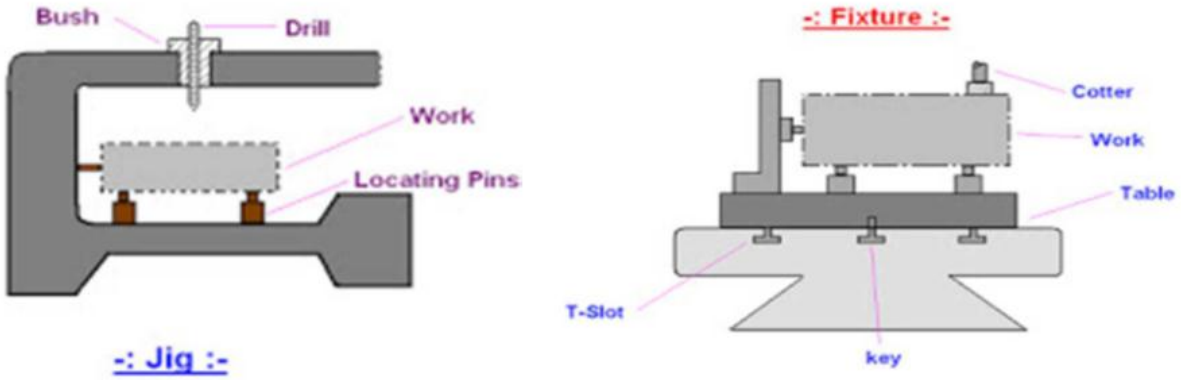

Fig. 1: A typical jig and fixture

Together, jigs and fixtures streamline production by reducing errors, minimizing setup time, and improving workflow. They play a crucial role in mass production, where repeatability and uniformity are paramount. By facilitating standardized processes, these tools contribute to higher quality outputs while also optimizing resource utilization. In essence, jigs and fixtures are the unsung heroes of manufacturing, silently enabling the creation of countless products across various industries, from automobiles to electronics, by providing the stable foundation necessary for precision manufacturing. According to Mohitkar et al. (2017), jigs and fixtures play a very crucial role in manufacturing tools that are employed to produce substitutable and indistinguishable components, as they are exceptional tool-guiding and work-holding equipment designed accurately for machining and assembling large number of parts.

Jigs and fixtures play vital roles in modern manufacturing by streamlining processes, improving accuracy, reducing waste, and ultimately enhancing productivity. Their use is widespread across industries such as automotive, aerospace, electronics, and general machining, where precision and efficiency are paramount.

1. Historical Development

The origin of jigs and fixtures can be traced back to ancient civilizations, where rudimentary tools were used to aid in repetitive tasks. However, the systematic development of jigs and fixtures gained prominence during the Industrial Revolution. With the rise of interchangeable parts manufacturing, the need for standardized and efficient production methods became apparent. This led to the emergence of specialized tools and devices for guiding, holding, and positioning workpieces during machining operations. Jigs and fixtures play a crucial role in manufacturing by enabling repeatable, accurate, and cost-effective production processes. The development of jigs and fixtures has evolved alongside advancements in manufacturing technologies and practices. According to Radhwan et al. (2019), the general factors to consider when designing jigs and fixtures include the shape, material and state of the work-part, pre-machined surface tolerance, type of operations and the machine tools used, workpiece handling, ergonomics, and safety considerations.

The history of jigs and fixtures traces back to ancient civilizations, where craftsmen employed rudimentary forms of these tools to aid in the fabrication of various objects. Ratwinsme (2019) pointed out that the first manufactured products were made one at a time, thereby making each part individually and fitting the parts into the finished product. He observed that as they worked, the early manufacturing pioneers realized the need for better methods and developed new ideas, which led to the secret of mass production and standardized parts, not only speeding production but also ensuring the interchangeability of parts.

Jigs and fixtures in manufacturing were closely tied to the evolution of machining processes and the need for efficient, accurate, and repeatable production methods. They have played a crucial role in the advancement of manufacturing technologies, enabling mass production and standardization of parts. The earliest forms of jigs and fixtures can be traced back to ancient civilizations such as the Egyptians, Greeks, and Romans. These early

craftsmen devised simple devices to hold workpieces in place while shaping or assembling them. For example, the use of wooden clamps and fixtures can be seen in the construction of furniture and chariots during these times.

During the Middle Ages, advancements in metallurgy and machining techniques led to the development of more sophisticated jigs and fixtures. Craftsmen began to use metal jigs and fixtures to enhance the precision of their work, particularly in industries such as armor making and blacksmithing. In the early stages, jigs and fixtures were predominantly crafted from wood and metal, designed to hold workpieces securely in place and guide machining tools. With the advent of precision engineering and the growth of assembly line manufacturing in the early 20th century, jigs and fixtures became integral components of efficient production systems.

The use of jigs and fixtures can be traced back to ancient times when craftsmen devised simple tools and templates to aid in repetitive tasks like woodworking and metalworking. However, the modern concept of jigs and fixtures began to take shape during the Industrial Revolution in the 18th and 19th centuries. With the rise of mechanized production and interchangeable parts, especially in industries like firearms and textiles, the need for tools that could ensure consistent quality and efficiency became apparent. Jigs and fixtures were developed to guide cutting tools and hold workpieces in place during machining operations, reducing errors and speeding up production.

Carrlane (2023) observed that yesterday's work-holders had the same two basic functions as today's work-holders: securely holding and accurately locating a workpiece. While early jigs and fixtures may have lacked modern refinements, they followed many of the same principles as today's work-holder designs. Carrlane noted that more powerful and more precise machines are of little value if the work cannot be held securely so that the capabilities of the machine can be utilized. They emphasized that new concepts and devices like jigs and fixtures have been developed to locate, support, and clamp the part in place while it is being machined.

The Industrial Revolution marked a significant turning point in the history of manufacturing and the evolution of jigs and fixtures. With the advent of mechanized production processes and the rise of mass manufacturing, there was a growing demand for tools that could streamline production and ensure uniformity in the final products. Jigs and fixtures became essential components of early factories, enabling the efficient machining, assembly, and inspection of parts.

One of the key drivers behind the development of jigs and fixtures, according to history.com (2023), was the concept of interchangeable parts pioneered by Eli Whitney in the early 19th century. Jigs and fixtures were instrumental in achieving this milestone by facilitating the precise machining of parts to standardized dimensions, thereby enabling the assembly of products from parts produced independently. The 20th century saw significant advancements in machining technology and materials, which further propelled the development of jigs and fixtures. As manufacturing processes became more sophisticated and automated, jigs and fixtures evolved to accommodate these changes, integrating features like automation, precision control, and adaptability.

Jigs and fixtures became indispensable in industries such as automotive, aerospace, and electronics, where mass production of complex parts with tight tolerances was required. They enabled manufacturers to achieve economies of scale by reducing setup times, minimizing waste, and ensuring consistent quality across large production runs. In recent decades, the integration of CAD/CAM technologies has revolutionized the design and fabrication of jigs and fixtures. Computer simulations and precision machining have allowed for more complex and efficient designs, optimizing the performance and versatility of jigs and fixtures in modern manufacturing.

Today, jigs and fixtures have continued to evolve alongside advancements in additive manufacturing (3D printing), robotics, and digital manufacturing. They remain essential tools for achieving high precision, flexibility, and productivity in diverse manufacturing environments. The evolution of jigs and fixtures reflects the ongoing quest for efficiency and quality in manufacturing. From humble beginnings to sophisticated modern applications, jigs and fixtures have been instrumental in shaping the way products are made, contributing to the evolution of manufacturing processes worldwide.

2. Key Principles and Design Considerations

Jigs and fixtures are essential tools used in manufacturing processes to ensure accuracy, repeatability, and efficiency. They are designed based on fundamental principles of precision engineering. A jig is typically used to guide tools and control the motion of the workpiece, ensuring accurate and repeatable manufacturing processes. Fixtures, on the other hand, securely hold workpieces in place during machining, welding, or assembly. Design considerations include material selection, geometry optimization, ergonomic factors, and compatibility with manufacturing processes. The major elements of jigs and fixtures are shown in figure 2.

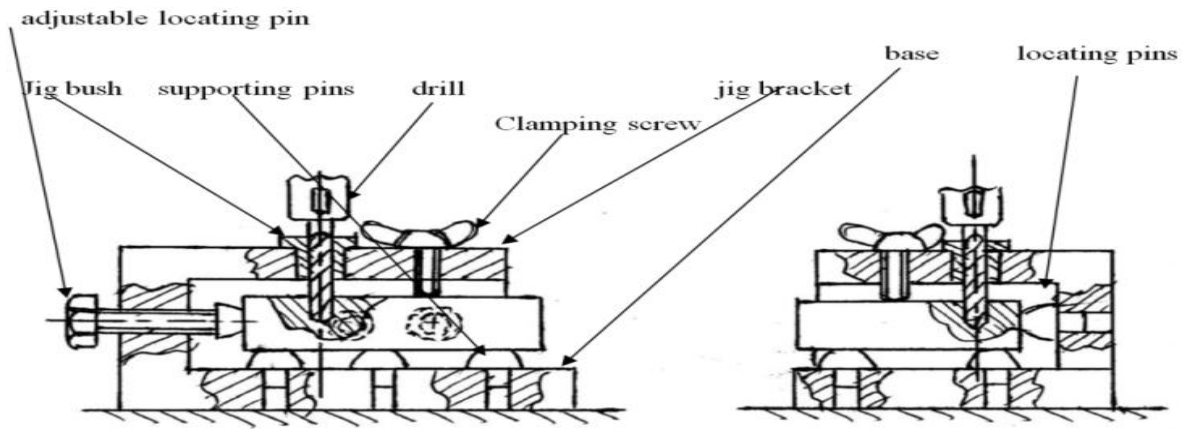

Fig. 2: Major elements of jigs and fixtures. Source: Okpala and Ezeanyim (2015)

Khan (2018), listed the following as the factors to be considered before designing a jig or fixture: study of the component, study of locating elements, type and capacity of the machine, loading and unloading arrangement, clamping arrangement, study of power devices for operating and clamping element and also a safety arrangement device, the clearance between a jig and the component, swarf removal arrangement, fool-proofing arrangement, study of ejecting devices, table fixing arrangement, and the indexing device, as well as study of tool guiding, cutter setting elements, rigidity and vibration problems.

Here are key principles and design considerations for jigs and fixtures:

3.1 Key Principles

Precision and Accuracy: Jigs and fixtures are designed to hold workpieces securely and accurately in place during machining or assembly operations. Precision is crucial to ensure that each part is produced consistently within specified tolerances.

Interchangeability: Jigs and fixtures should be designed to accommodate different workpieces of similar geometry or dimensions. This promotes flexibility in manufacturing processes and reduces the need for custom tooling for each part.

Reduction of Setup Time: Effective jigs and fixtures reduce setup time by simplifying the process of loading and unloading workpieces. Quick-change features can further enhance productivity.

Enhanced Safety: Properly designed fixtures ensure the safety of operators by securely holding workpieces and preventing movement during machining operations.

Cost-Effectiveness: Jigs and fixtures should be designed to optimize material usage and manufacturing processes, minimizing waste and reducing overall production costs.

3.2 Design Considerations

According to Ascend-tech (2022), the design of jigs and fixtures is based on several principles, including the workpiece position, clamping force, guiding elements, and repeatability. They listed the following as the conditions for effective design: the workpiece position needs to be accurately located to ensure that the machining or assembly process is performed correctly; the clamping force must be sufficient to hold the workpiece securely in place during the machining or assembly process; guiding elements, such as bushings or pins, should be used to guide the cutting tool or assembly components; and repeatability is critical to ensuring consistent quality and accuracy in the manufacturing process.

Modern jigs and fixtures are designed based on engineering principles to optimize manufacturing processes. The design considerations include factors such as material selection, ergonomics, ease of setup, and compatibility with automated systems. Computer Aided Design (CAD) and simulation tools have revolutionized the design process, enabling engineers to create highly specialized jigs and fixtures tailored to specific manufacturing tasks. Kumbhar and Pandit (2017) observed that the design of jigs and fixtures is a highly complex and intuitive process requiring knowledge. They explained that fixture design plays an important role at the setup planning phase, as proper fixture design is crucial for developing product quality in different terms of accuracy, surface finish and precision of the machined parts. Some of the design considerations for the production of jigs and fixtures include the following:

Workpiece Stability: Efforts should be made to ensure that the jig or fixture securely holds the workpiece to prevent movement during machining. Consider the material and geometry of the workpiece to determine the best clamping or holding mechanism.

Accessibility: Design fixtures should allow easy access to critical features of the workpiece for machining or assembly operations. This includes considerations for tool clearance and operator ergonomics.

Material Selection: Materials for jigs and fixtures should be chosen based on factors such as durability, wear resistance, and cost-effectiveness. Common materials include steel, aluminum, and different plastics.
Modularity and Standardization: Design modular fixtures that can be easily reconfigured or adapted for different manufacturing processes or workpieces. Standardized components can streamline production and maintenance.
Alignment and Tolerance Control: Ensure that the fixture components are aligned accurately with the machining tools to achieve desired part dimensions and tolerances.
Ease of Setup and Adjustment: Incorporate features such as quick-release clamps, adjustable stops, and reference points to simplify setup procedures and minimize adjustment time.
Coolant and Chip Management: Consider provisions for coolant delivery and chip evacuation to maintain machining efficiency and prolong tool life.
Maintenance and Durability: Design fixtures with considerations for ease of maintenance, such as replaceable wear components and accessible fasteners.
Integration with Automation: If applicable, design fixtures that are compatible with automated manufacturing systems to enhance productivity and reduce labour costs.
Testing and Validation: Prototype and test jigs and fixtures to ensure they meet design requirements before full-scale production. Validate accuracy, repeatability, and reliability under operating conditions.
By adhering to these principles and design considerations, manufacturers can leverage jigs and fixtures to optimize their production processes, improve quality, and reduce costs associated with manufacturing operations.

3. Types and Applications

The diversity of jigs and fixtures reflects the range of manufacturing processes they support. Common types include drilling jigs, assembly fixtures, welding fixtures, inspection jigs, and machining fixtures. These tools find applications in automotive manufacturing, aerospace, electronics, and general machining industries. Advanced technologies such as CNC machining have further expanded the capabilities and precision of jigs and fixtures.
Jigs and fixtures are essential in various industries, including automotive, aerospace, electronics, and general manufacturing. Some of the key applications of jigs and fixtures include:
Drilling and Milling Operations: Jigs and fixtures are commonly used in drilling and milling operations to hold the workpiece securely and accurately in place. This ensures precise hole placement, depth, and alignment, reducing errors and improving productivity.
Welding and Assembly: In welding and assembly processes, jigs and fixtures are used to position and align components correctly. They help maintain uniformity across multiple parts, speeding up assembly while ensuring consistency in the final product.
Turning and Grinding: For turning and grinding operations, fixtures are crucial to securely hold and position the workpiece. This ensures accurate dimensions and surface finishes, especially in mass-production settings.
Quality Control: Jigs and fixtures are also used in quality control processes. They can be designed with measurement features to quickly verify the dimensions and tolerances of manufactured parts, enabling efficient inspection.
Mass Production: In industries where large quantities of identical or similar parts are produced, jigs and fixtures play a vital role in maintaining production consistency and reducing setup time between batches.
Circuit Board Assembly: In electronics manufacturing, specialized fixtures are used for assembling and soldering components onto circuit boards. These fixtures hold the boards and components in precise positions for automated or manual assembly.
Automated Manufacturing: Jigs and fixtures are integrated into automated production lines to facilitate robotic handling and machining of parts. They enable the efficient operation of robotic systems by providing repeatable positioning of workpieces.
Prototype Development: Even in prototype and custom manufacturing, jigs and fixtures can be employed to streamline processes and ensure accuracy during the initial development stages.
Complex Shapes and Structures: For manufacturing complex shapes or structures, custom jigs, and fixtures are designed to support intricate workpieces, allowing for precise machining or fabrication.
Safety and Ergonomics: Jigs and fixtures can improve workplace safety and ergonomics by reducing manual handling and operator fatigue. They enable tasks to be performed more comfortably and efficiently. Well-designed fixtures can enhance workplace safety by securing workpieces and tools, reducing the risk of accidents during machining operations. They also contribute to ergonomic work practices by minimizing operator strain and fatigue.
Cost Reduction: By reducing setup time, minimizing scrap, and optimizing machining processes, jigs and fixtures contribute to overall cost savings in production. They also help reduce labor costs by simplifying tasks that would otherwise require skilled operators.
Quality Improvement: The use of jigs and fixtures leads to improved product quality and consistency. By eliminating human error and variation, they contribute to higher reliability and performance of manufactured parts.

Overall, the applications of jigs and fixtures are diverse and critical across manufacturing industries. They contribute significantly to improving production efficiency, product quality, and overall cost-effectiveness in manufacturing processes.

4. Benefits and Impact on Manufacturing

The adoption of jigs and fixtures offers several significant advantages to manufacturers. First and foremost, they enhance production efficiency by reducing setup times and improving process repeatability, thereby leading to higher throughput and lower manufacturing costs. According to Pandit (2022), jigs and fixtures serve multiple purposes, including cutting production costs, speeding up production, ensuring flawless goods, making parts interchangeable, simplifying the machining of complex shapes, and lowering quality control expenses. Pandit noted that jigs and fixtures eliminate the need for a unique setup for each workpiece, as they facilitate production and ensure that each workpiece is created within a predetermined tolerance. Additionally, jigs and fixtures contribute to improved product quality and consistency by minimizing errors and deviations during production.

Ghandi et al. (2018) listed several benefits of using jigs and fixtures, including increased production and reduced costs, low variability in dimensions leading to consistent quality of manufactured products, reduced need for inspection, improved safety and reduced accidents, enhanced technological capacities of machine tools, and the ability to apply more than one tool simultaneously on a workpiece.

5. Challenges and Future Trends

Challenges

Jigs and fixtures are essential tools in manufacturing, designed to ensure repeatability, accuracy, and interchangeability in the production process. However, despite their benefits, designing and implementing effective jigs and fixtures can pose challenges related to complexity, cost, and integration with automated systems, including:

a) **Design Complexity:** Creating jigs and fixtures requires a thorough understanding of the workpiece, machining processes, and the production environment. Complex designs can lead to longer development times and higher costs.

b) **Cost:** The initial investment in designing and manufacturing jigs and fixtures can be high, especially for custom or highly specialized tools. Costs include materials, labor for design and fabrication, and maintenance.

c) **Flexibility:** Jigs and fixtures are often designed for specific tasks or workpieces, which can limit their flexibility in handling different products or changes in product design. Adapting or redesigning them for new tasks can be time-consuming and costly.

d) **Wear and Tear:** Repeated use can lead to wear and degradation of jigs and fixtures, thereby affecting their accuracy and reliability. Therefore, regular maintenance and timely replacement are necessary to ensure consistent quality.

e) **Precision and Accuracy:** Achieving the desired level of precision and accuracy in the construction of jigs and fixtures can be challenging, particularly for complex geometries or tight tolerances. This is because any deviation in the fixture can directly impact the quality of the finished product.

f) **Alignment and Calibration:** Proper alignment and calibration of jigs and fixtures are crucial for maintaining consistency in production. Also, misalignment or improper calibration can result in defective products and increased waste.

g) **Material Selection:** Choosing the right materials for jigs and fixtures is critical to ensure durability, stability, and minimal thermal expansion, as inappropriate material selection can lead to frequent replacements or adjustments.

h) **Skill Requirements:** Training and retaining skilled workers can be challenging, as designing and using jigs and fixtures require skilled personnel with expertise in machining, design, and understanding of the production process.

i) **Storage and Handling:** Inefficient storage solutions can lead to increased downtime and difficulties in managing multiple fixtures. This is because proper storage and handling are necessary to prevent damage and ensure the longevity of jigs and fixtures.

j) **Technological Integration:** Ensuring compatibility and synchronization with modern manufacturing systems requires careful planning and execution, as integrating jigs and fixtures with advanced manufacturing technologies such as CNC machines, robotics, and automation systems can be complex.

k) **Quality Control:** Regular inspections and quality checks are essential to identify and address issues promptly, as implementing effective quality control measures for jigs and fixtures themselves is necessary to maintain high standards in the manufacturing process.

l) **Environmental Factors:** Environmental conditions such as temperature fluctuations, humidity, and dust can affect the performance and accuracy of jigs and fixtures. Therefore, measures need to be taken to mitigate these effects, such as climate-controlled environments or protective coatings.

Addressing these challenges requires a combination of good design practices, regular maintenance, skilled personnel, and continuous improvement efforts in the manufacturing process.

Future Trends

Future trends in the application of jigs and fixtures in manufacturing processes include the integration of smart technologies such as sensors and actuators for real-time monitoring and adaptive manufacturing. Additive manufacturing techniques also promise rapid prototyping and customization of jigs and fixtures.

a) **Digital Integration:** Industry 4.0 initiatives are incorporating jigs and fixtures into smart manufacturing systems, enabling real-time monitoring, adaptive machining, and data-driven process optimization.

b) **Additive Manufacturing:** 3D printing technologies are rapidly creating custom jigs and fixtures, reducing lead times and enabling more flexible manufacturing setups

c) **Materials Innovation:** Advancements in materials science are leading to the development of lightweight, durable, and cost-effective jigs and fixtures that can withstand high loads and prolonged use.

6. Conclusion

Jigs and fixtures have proven to be indispensable tools in the manufacturing industry, ensuring precision, efficiency, and repeatability in production processes. Their evolution from rudimentary aids to sophisticated systems reflects the advancements in manufacturing technologies and practices. By enabling accurate and consistent production, jigs and fixtures contribute significantly to the quality and cost-effectiveness of manufacturing operations.

The continuous integration of advanced technologies such as CAD/CAM, additive manufacturing, and smart systems into jig and fixture design promises further enhancements in their capabilities. These innovations will enable manufacturers to achieve higher levels of precision, flexibility, and productivity, thereby meeting the ever-evolving demands of various industries.

Moreover, the future of jigs and fixtures lies in their adaptability to new manufacturing paradigms, including Industry 4.0 and digital manufacturing. By embracing these trends, manufacturers can leverage jigs and fixtures to optimize production processes, reduce waste, and improve overall operational efficiency.

References

[1]. Ascend-tech (2022), "Design Principles of Jigs and Fixtures for Improved Manufacturing Efficiency and Quality" [Online]. Accessed on 19 February 2024, from https://www.ascend-tech.com/blog/design-principles-of-jigs-and-fixtures-for-improved-manufacturing-efficiency-and-quality

[2]. Carrlane (2023), "History of Workholding" [Online]. Accessed on 18 April 2024, from https://www.carrlane.com/engineering-resources/technical-information/design-standards-engineering-information/history-of-workholding

[3]. Gandhi, A., Gupte, A., Gorivale, S., Khedkar, M., and Dhavale, S. (2018), "Principles for Effective Design of Fixtures" International Journal for Research in Engineering Application and Management, vol 4, special issue

[4]. History.com (2023), "Interchangeable Parts" [Online]. Accessed on 12 January 2024, from https://www.history.com/topics/inventions/interchangeable-parts

[5]. Kataria, M. and Bhimani, J. (2017), "Design and Development of Jig for an Auto Part" International Journal of Engineering Development and Research" vol. 5, iss. 1

[6]. Khan, A. (2018), "Jigs and Fixtures Types, Differences, Pros and Cons, Applications" [Online]. Accessed on 27 April 2024, from https://dizz.com/jigs-and-fixtures-difference-types-applications/

[7]. Kumbhar, J. and Pandit, H. (2017), "A Review Article on Jigs and Fixture" International Journal of Science and Research, vol. 6, iss. 4,

[8]. Mohitkar, M., Bhende, A., Bais, B. and Khanpasole, H. (2017), "A Review an Jigs and Fixture" IJARIIE, vol. 3, iss. 6

[9]. Okpala, C. and Ezeanyim, O. (2015), "The Design and Need for Jigs and Fixtures in Manufacturing" Science Research Journal, vol. 3, iss. 4

[10]. Prandit, H. (2022), "Jigs and Fixtures in Manufacturing" International Journal of Engineering Research and Applications, vol. 12, iss. 10

[11]. Radhwan, H., Effendi, M., Rosli, M., Shayfull, Z. and Nadia, K. (2019), "Design and Analysis of Jigs and Fixtures for Manufacturing Process" Joint Conference on Green Engineering Technology and Applied Computing 2019, IOP Conference Series: Materials Science and Engineering, 551

[12]. Ratwinsme (2019), "Jig and Fixture" [Online]. Accessed on 25 May 2024, from https://www.scribd.com/document/412094144/Jigs-Fixture-Engineering108-Com

[13]. Said, N., Roslan, M., Ngah, N., Mohamad, A., Shari, N., Roslan, U., Mamat, R., Baba, N., Ibrahim, M., Aziz, K., and Yusof, M. (2023), "Design and Fabrication of Jig and Fixture for Drilling Machine in the Manufacturing Industry to Improve Time Productivity" Journal of Advanced Research in Applied Sciences and Engineering Technology, vol.29, iss. 2