

# Various Flexible Fixturing Systems in Manufacturing-A Review

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**ABSTRACT:** Fixtures are designed to locate, hold and support work pieces accurately against deformation. Due to customer demand of low volume high varieties of products with shorter delivery time and mass customization, a need of flexible manufacturing system (FMS) is emerged. The flexibility of any flexible manufacturing system not only includes flexibility of its components but the fixturing system also associated with these components. To cope up with flexibility in machining and assembly operations, various flexible fixturing systems have been developed. Some of the major commercially used flexible fixturing systems are modular fixturing, adaptive fixturing, phase change based fixturing, sensor based fixturing, and chuck based fixturing. This paper reviews these flexible fixturing systems along with the research carried out for development of these systems.

**KEY WORDS:** Flexible fixturing, adaptive fixturing, modular fixturing

## I. INTRODUCTION

Fixtures are used during machining and assembly operation to locate and hold work pieces accurately without any damage to work pieces. [1] The work piece motion with 12 degrees of motion in 3 dimensional spaces is required to be constrained using locators and clamps. Total of these 12 degrees of freedom comprise of 6 movements along positive and negative directions of the x, y and z axes and 6 rotary clockwise and counter clock wise motions about these three axes. [4] Apart from this, fixturing system has to ensure a strong and rigid support against deformation, easy work piece accessibility and quick loading and unloading. [1]

Due to customer demand of low volume high varieties of products with shorter delivery time and volume production of great variety of customized goods i.e. mass customization, a need of flexible manufacturing system (FMS) is emerged.[2] Flexibility of manufacturing environment indicates how it responses to any manufacturing change. [1] The flexibility of any flexible manufacturing system not only includes flexibility of its components but the fixturing system also associated with these components. Hence flexible fixture system is gaining more importance. [2]

### Importance of Flexible Fixturing System

Customized dedicated fixtures are designed for the production of specific workpieces.They are time consuming and lose flexibility while dealing with parts or assemblies of different shapes and sizes.[2] Also the design, fabrication and testing of fixtures require significant time and cost in the production development cycle.[3] To tackle with flexibility and quality in manufacturing sector due to increase in product mix ,manufacturers are seriously thinking about flexible fixturing system.[4]

In mass production a dedicated fixture is used for large number of similar components. In low volume high variety production, one of the ways to reduce manufacturing cost can be use of flexible fixturing system. [2] Flexible fixturing uses a single fixturing system to hold parts of various shapes and sizes when subjected to various external forces and torques associated with manufacturing operations. It reduces the lead-time and effort required to design special-purpose

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fixtures. There is no need to store and retrieve multiple fixtures for various components. It will also help for rapid changeovers between different manufacturing operations. All these factors of flexible fixturing system lead to overall reduction in manufacturing cost. [5]

## II. VARIOUS FLEXIBLE FIXTURING SYSTEMS

To cope up with flexibility in machining and assembly operations, various flexible fixturing systems have been developed; however a few of them have become commercial. Though the purpose of most of the flexible fixturing system is typical, they are mean to accommodate a class of part family. [2] Some of the major flexible fixturing systems which are used for commercial purpose are. [1, 2, 3]

- a. Modular fixturing
- b. Adaptive fixturing
- c. Phase change base fixturing
- d. Sensor based fixturing
- e. Chuck based fixturing

This paper reviews these flexible fixturing systems along with the research carried out for development of these systems.

### a. Modular Fixturing

Due to flexibility and varying design requirement of products, need of modular fixtures have emerged. Here Modular fixtures use multipurpose fixturing elements for flexibility purpose. [4] While developing modular fixturing systems a combination of standard elements like V-blocks, toggle clamps, rectangular blocks with a cast iron base-plate is used. Modular fixtures are classified into 'T' slotted base plates and grid holes base plate. [9] Standard elements are precisely manufactured with desired tolerance as per component requirements and are used to build a fixture configuration for holding the work piece. For assembling the fixture, T-slots, grid holes or dowel pin holes are provided on base plate. T nuts with bolts, cap screws are used for fastening these elements. After disassembling, these modular fixturing elements can be re-used for other products. Interchangeability of modular fixture elements is also important due to smaller batch sizes and the high usage of CNC machine tools. [4]

Several commercially available modular fixturing systems are [4]

(I) T-Slot base plate

(a) Erwin Halder Modular Jig and Fixture System, USA

(b) CATIC (China National Aeronautical Technology Import and Export Corporation) System

(II) Grid base plate

(a) Venlic Block Jig System, MAO Corporation, Japan

(b) Yuasa Modular Flex System, USA

(III) Dowel pin base plate

(a) Bluco Technik, Germany

(b) SAFE (Self Adapting Fixture Element) System, USA

Modular fixture design is a complex and lengthy task. To simplify this task a system was developed by U. Farhan and M. Tolouei-Rad determining fixture elements and assembly sequences in a 3D-modelling environment depending on geometries and functions. Various parameters used here are number of work pieces to be machined, type of machining operation, locating method and clamping mechanism. [6]

Zone-Ching Lin and Ching-Been developed an expert system using modular fixture for work pieces with different shapes such as L, I, T, and U types. Apart from this they also determined clamping position of the modular fixtures, kinematics constraint balance and cutting forces. [7]

Automatic fixture element assembly relationship when geometric models and fixturing functions are specified was developed by W. Ma, Z. Lei and Y. Rong. The system provides interactive design and design modification functions by taking base of core programs in C, C++ and interface programs in a specific CAD environment. [8]

Previous experience is important in modular fixture design. New problem similar to several days or months ago may recur repeatedly in manufacturing environment. Shu Huang Sun and Jahau Lewis Chen proposed case based reasoning

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software for designing a modular fixture which searches all previous recorded experience to find one suitable solution by analysing problem description and work piece shape. [9]

## Limitations of modular fixturing

- Modular fixture elements and their kits are costly. [1]
- Due to poor tolerances of fixturing elements and less accuracy while assembling modular elements, location results are not good in some cases. While component machining, fixturing elements may displace by small amount which can also cause inaccuracy. [1]
- Expert knowledge is required for determining configuration of modular fixture system and assembly. [2]
- Limited combinations of standard modular fixture components for building the fixture configurations can limit the flexibility. Modular fixtures are inconvenient when dealing with complex work piece geometry and operations as inventory of standard elements get increased. [2]

## b. Adaptive Fixturing

An adaptive fixture design system incorporates complicated fixture structures as well fixture bases. It is realized on the basis of part families. [3] In part family, parts similarity is considered based on geometric shape and size as well as based on similarity in processing steps required for their manufacturing. Though there are different parts in a part family, their similarities can help them to justify their belongingness of the part family. [10] Part families have their typical fixture configuration and well defined fixture assembly called as common fixture. In adaptive fixturing one of the approaches for part analysis is to see whether any common fixture exists for the family. Also it is seen that though the shape and size of new parts are changed somehow, yet it still belongs to the same class of family. Thus a comparison is made with existing fixtures and a new fixture will be generated according to differences identified. One way to design an adaptive fixture is to identify an existing fixture that is designed to work with similar parts in the same family. Modify this fixture minimally to accommodate the requirements of the new part. [3]

James Cunov and Habermann C. proposed adaptive manufacturing system for composite aircraft components. It consists of a robotic fixture and precision motion machine with an integrated process head. This fixture allows the entire family of parts to be managed with one fixture that remains within the machine footprint. [11]

Eduarne Olaiz et al came up with a solution of adaptive fixturing system for the smart and flexible positioning of large volume work piece family in the wind power sector. The adaptive fixture is presented for the accurate positioning of planet carrier with very strict requirements of tolerances and for intelligent adjustments during machining process when required. [12]

Angelo Merlo, D.Ricciardi, E.Salvi developed a novel adaptive fixturing for thin walled aerospace parts. An actuator based clamping mechanism is used for developing adaptive fixturing while grinding thin walled components like nozzle guide vane (NGV) .It is used to perform automatic error free clamping and for reducing overall fixturing time to large extent.[13]

Ceglarek proposed adaptive sheet metal assembly for automobile application considering flexibility and adaptability of a family of products using multivariate analysis and evaluation. He developed an adaptive assembly system evaluation, based on its ability to compensate for part dimensional variability caused by upstream processes. [14]

## Benefits of part Family based adaptive fixturing

- Adaptive fixture design helps in designing fixtures rapidly and thus reduce new product development time. [3]
- It reuses existing fixture data to the maximum extent for generating a reconfigurable manufacturing system thus reducing new fixture development cost. [3]
- Adaptive fixture design system can be effectively used with complicated fixture structures and fixture bases. [3]
- They can reduce the lead-time and overhead cost associated with storing and retrieving multiple fixtures and can achieve quick changeovers .[5]

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## c. Phase-Change Based Fixturing

In this system work piece is restricted from its mobility apart from its machining areas by immersing it in a phase-change substance. [1] Fixturing is achieved by using functional material properties which change the status from liquid to solid under certain conditions. The work piece is located in the liquid fixture material and held firmly which is then changed into the solid state. Therefore, in such cases to achieve production success, material strength is important. [15] Solidification depends on the substance that is used for immobilization of work piece. Usually this type of flexible fixturing is used for complex and fragile parts for protecting them against possible damage caused by the fixture clamping. These substances can be pseudo-phase change material, low-melt alloy, bi-phase liquid, electro and magneto-rheostatic liquids, etc. [1]

Y. Rong, R. Tao and X. Tang presented an experimental study of magneto rheological (MR) fluid material from flexible fixturing point of view. By using a compression technique, a thick column structure of MR fluid was formed and enhanced. This developed a high shear strength solid status of the MR fluid which was used for fixturing purpose. [15]

## d. Sensor Based Fixturing

Here correct location of part in fixture for the purpose of fool proofing is achieved by using vision and sensor systems. [1] The objectives of Sensor Based Fixture Design and Verification (SFDV) research are to provide the means for detecting contact failure of the work piece with fixture locators and for preventing incorrect loading of the work piece in a fixture. [16]

Purushothaman in his research on sensor based fixturing focused on three areas. One area is to generate algorithms for automatically fool proofing the fixtures .Second is building sensor embedded locators for verification of the contact and fool proofing the existing fixtures. Finally he designed and experimentally validated fixtures for free-form surfaces with sensors to verify the location. [16]

## e. Chuck Based Fixturing

These systems are particularly used when the machining forces are low and one of the sides of the work piece is flat. Thus this flat side is fitted in chuck. Usually chuck holds the component with the help of magnetic or vacuum forces or the work piece is frozen onto the chuck by suitable means. [1]

## III. CONCLUSION

Many solutions are reported for the fixturing problem in above literature. Though there are various flexible fixturing systems developed commercially, each system has its specific working area. Modular fixtures have limited combinations of standard elements for fixturing. They are inconvenient for complex shapes as with increasing complexity, inventory of standard elements increases. Under part family environment with complicated fixture structure requirement, adaptive fixtures are more reliable. For fixture development, they use existing fixture data with minimum modifications enabling rapid fixture development and less fixture cost. Adaptive fixtures can play important role in set up time reduction and achieving quick set up changeover. Complex and fragile parts are protected against damage due to fixture clamping forces by using phase change based flexible fixturing. Chuck based flexible fixturing is specifically used for one side flat components. Ultimately it can be concluded that customer demand of low volume high varieties of products with shorter delivery time can be effectively tackled using these flexible fixturing systems.

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