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DEVELOPMENTS IN WORKHOLDING DEVICES – A REVIEW

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Abstract— With the advancement in the latest technologies and the competitiveness in the market of the modern era, the custom design fixtures for a specific workpiece are very time consuming and expensive to manufacture, but also they are not having the enough flexibility to tackle with the components or assemblies of the different geometry and sizes. This is truly an unwilling situation in the manufacturing to deliver a wide variation in the parts or products for the marketplace. Hence, the selection of appropriate holding devices affects the cost and quality of manufactured components. This paper presents the state-of-the-art review on developments in the fixtures for flexible manufacturing.

Keywords— Jigs and Fixtures; Machining; Flexible Manufacturing System; Reconfiguration

I. INTRODUCTION

The manufacturing industry targets on the dimensional accuracy of the workpiece and surface finish, enhancing the functioning of the machined parts [1]. The process of designing the fixture and development in the existing fixture is complicated and intuitive process, that requires an extensive experience and knowledge of the fixtures. An essential design consideration within the design process of the workholding device is to draw the layout of fixtures. Fixture layout process is basically to position the fixture components, and has the purpose to position the fixturing elements. The costs related to the design and manufacturing of workholding devices are sizeable, accounting for some 10-20% of the total manufacturing cost of a production system [2].

In every workstation, there are number of machining operations *viz.* turning, drilling, milling, boring, shaping, etc. to be performed on the workpiece. These operations are either to generate the new part from raw material or to fabricate the existing part. Holding devices/fixture plays a significant role in providing the proper stability to workpiece without deforming the surface and deteriorating the surface roughness of work piece, and also to reduce the holding/unholding time of work piece. A fixture is a device used to "fix" (to constrain the all DOF) a workpiece in a given coordinate system relative to the cutting tool [3]. The primary aim of holding devices is to support, hold and locate the work piece in required space during operations. Due to significant effect of fixtures in the manufacturing process, fixtures has got the expensive efforts of research. At present, a variety of holding devices has been developed on the basis of shape, strength and operation to be performed that provides the proper holding strength to work piece without damaging the workpiece.

II. CLASSIFICATION OF HOLDING DEVICES

In the manufacturing unit, number of work holding devices and fixtures are used as per their requirement for specific operations or for specific geometry. Broadly, these fixtures are classified into three categories as given below:

I Basic Purpose: mechanical vice, chucks of lathe machine
II Permanent/Dedicated Fixture: these types of fixtures are specially developed for clamping specific part in a consistent number of operations and are generally used in high volume production.
III Flexible/Reconfigurable: these are used for clamping the parts of more than one type geometry and for multiple operations like modular fixtures, pin array, phase change, etc. [3]. Figure 1 shows the variation of lot size with the repetition of job for selecting the appropriate fixture.

Now just consider a bench vice, the basic holding device is used in almost every manufacturing industry or workshop, in which the device has one fixed jaw and one movable jaw that requires the manual input to hold the work piece by rotating the handle of bench vice. The holding force produced in simple bench vice varies with the operator capabilities. Hence, skilled operator is required to operate the bench vice for holding the workpiece with suitable clamping force without any loss Similar to bench vice, other fixtures like c-clamps, hook bolt clamp and bridge clamp etc. require more skill and time to hold the work piece. Due to the major impact of holding devices in any operation, an efforts have been given on the design of automatic fixtures because latest manufacturing units are based on Flexible Manufacturing Systems (FMS). In FMS, the operations (holding, unholding and performing operations) are performed automatically using CNC machines. Some special holding devices have been developed for special work piece that are very fragile and having complex shapes.

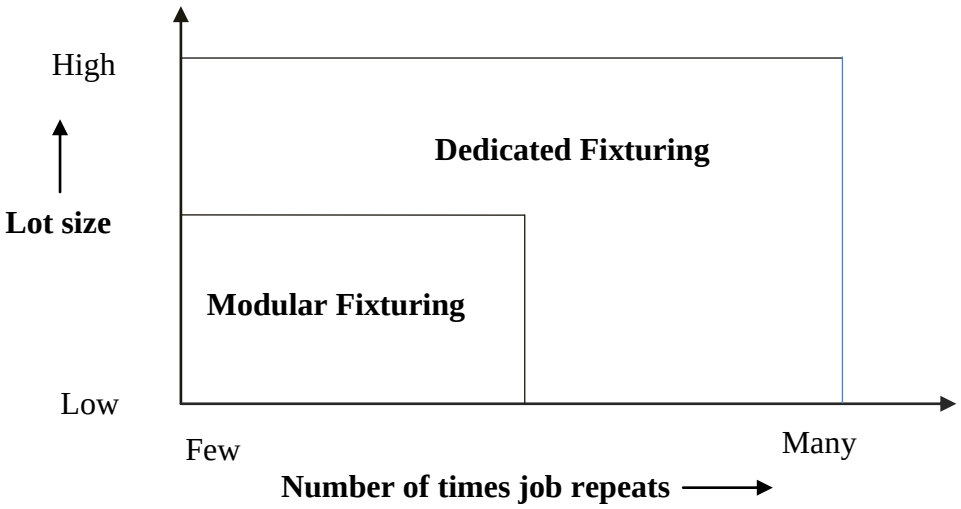

Figure 1: Selection of fixture for lot size

III. GEOMETRIC AXIS CONTROL

The basic 3-2-1 locating principle, is used to control the relative coordination of work piece during operation, enough to completely locate the rigid prismatic workpiece in some fixtures. According to this principle, only six locators are required to completely constrain the degree of freedom of the workpiece, however, increasing the number of locators in any fixture can be redundant and may give rise to uncertainty. Hence, only three locators are required to define the plane and only one direction of each degree of freedom is located, in which each degree of freedom has one locator. It has also been reported that the six locators should be placed as far as possible to provide the maximum stability level to the work piece. Many dedicated fixtures are designed on the basis of the 3-2-1 principle as illustrated in Figure 1.2 [3].

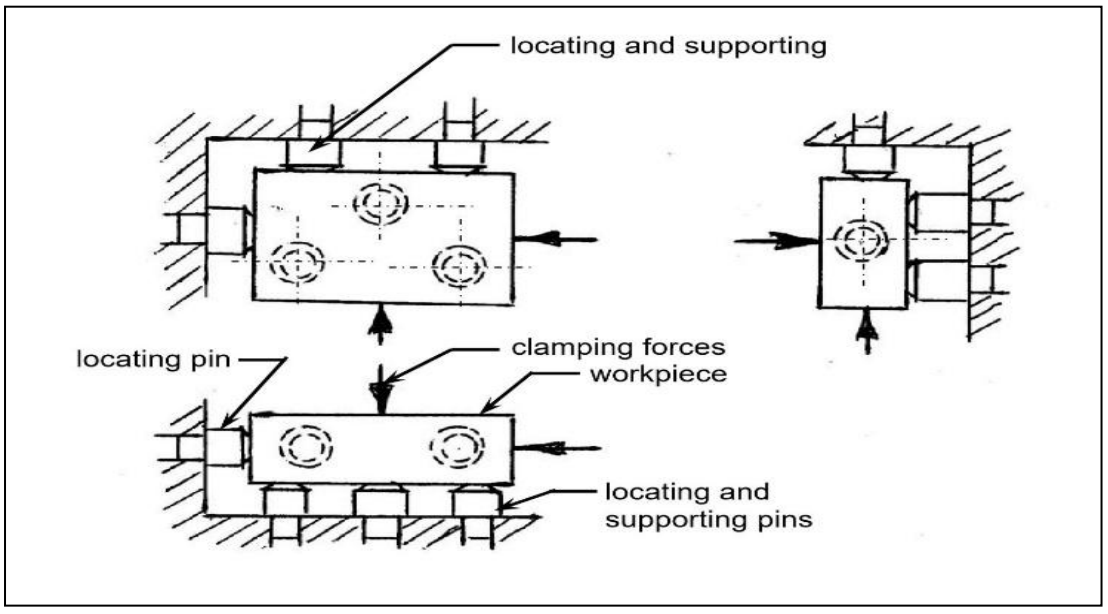

Figure 2: Representation of 3-2-1 principle

IV. HISTORY OF HOLDING DEVICES

In the history of holding device, the different fixtures (or holding device) has been studied that describes the development of work holding devices with the growth of a manufacturing unit. The development of holding devices is necessary because of the complexity of components or parts which has been increasing now-a-days.

A. BASIC HOLDING DEVICE WITH MODIFICATION

The designing and manufacturing of modified bench vice with surface plates embedded on its jaw faces helps to clamp the workpiece as well as to ensure the faces of the workpiece if at 90° or not. It has been observed that the rapid prototyping reduces the time and cost of manufacturing [5]. The increment in the degree of freedom of a bench vice

helped to increase the flexibility and accuracy of production system [6]. Also, the total job flow time of workpiece is reduced because the holding capability of machine vice can assists in performing multiple operations at different angles at a time. It has been described that if the lead screw is replaced with Allen (dowel) pins, the performance of Allen pins based machine vice is superior to lead screw based machine vice. The lead screw based machine vice can undergo wear and tear frequently because of abrasion, as a consequence the jaws cannot grip the workpiece properly. Hence, the working with lead screw based machine vice reduces the accuracy of operation after some time [7]. Pneumatically controlled bench vice (consists of Infrared (IR) sensor, compressor, pneumatic cylinder and microcontroller) holds the workpiece automatically and unclamp the work piece after completion of the operation. The sensor, connected to programming microcontroller, is used to identify the workpiece and send the signal to microcontroller. The pneumatic system receives the signal from the microcontroller and operates the jaw to hold and release the work piece [8]. The pneumatic bench vice with automatic feed mechanism, consists of a pneumatic jack (horizontal and vertical) which is used to hold the work piece as well as to give the automatic feed during operation performed on workpiece [9]. The compressor is used to generate the energy for operating the jack. Also, the compressed air stored in the tank and supplied to move the pneumatic jack which has the primary function to hold and release the work piece

B. INTELLIGENT HOLDING DEVICE

In an intelligent fixturing system, the modular fixturing system based methodologies for part-to-fixture positioning and rapid reconfiguration has been presented. An object-oriented scheme is used in case of reconfiguration approach, to ensure that the fixture can work with several setups without the requirement of modifying the control software. However, the dimensional tolerances was estimated using part-to-fixture positioning methodlogy, which was further utilized for guidance in automated part-fixture positioning [10]. The two methods, namely, contact load distribution and contact region between the fixture and part, have been suggested for designing the fixture. These methods are widely used to analyse the effectiveness region of clamping in workpiece for a particular fixture. The first method indicates the contact load between the workpiece and fixture interface, whereas the second one describes the clamping element position by considering the data from contact load analysis. It has been found that contact load is the function of clamping region [11]. In production systems, the use of new generation clamping devices or intelligent fixtures in place of conventional fixtures are useful. The intelligent fixtures are controlled or operated automatically that helps in reducing the job cycling time and increase the accuracy of operation. The facilities like force measurement, torque measurement or sometime auto reconfiguration are offered by automatic fixtures [12]. Many developments have been reported on new generation fixtures and production machines for flexible manufacturing system. In general, the new generation production system consists of automatic clamping devices, automatic transport device and automatic tool exchange. The automatic devices increased the production facilities, time and performance. The fixture was driven by pneumatic or hydraulic fluids that were operated by two valves on pneumatic or hydraulic actuators respectively [13].

The automatic or flexible device concept has bee employed to fulfill the present demand of accuracy and modularization in operation like cutting, milling and turning etc. of the work piece. The device consisted of sensors or actuators is used to make any alterations in the system as per the shape of the workpiece or processees like milling, turning. The devices have also been presented to clamp the complex shapes and to achieve the required level of dimensional precision. It has been concluded that the characteristics of intelligent devices can be employed to easily adapt the different cutting process [14]. The new fixture system with the capability for automatic jaw exchange was a new concept in intelligent manufacturing system, which has the purpose to enhance the efficiency of production systems. The jaw exchangeable system comprised various sensors that can scan the presence of jaws and workpiece, and also regulate the clamping force. It has also been noticed that small sensors can be used for small pneumatic system which was designed to exchange the jaw automatically according to the shape of the work piece [15].

The customer oriented production system is adapted in some cases due to widening of the product ranges [16]. The study reveals about flexible manufacturing cell type manufacturing system in which fixture designs are decided according to the production system. The low production system requires the simple fixture which are not expensive, but the high production system requires the intelligent fixture system which is very expensive. It was inferred that with the selection of the proper fixture device, the accuracy or quality can be increased in addition to decrease the manufacturing cost and time.

The need of automatic holding and loading of work piece is very important in every operation to reduce the job monitoring cycle. It is also reported that the accuracy of operation is possible if clamping or holding devices will work accurately. It has been concluded that numerical control (NC) clamping and loading is versatile. In some cases NC system are superior because of its fast working and movements. NC devices provide the holding operation to react quickly, according to differing order conditions as compared to manual operations [18].

The accuracy of any operation to be performed on the work piece depends upon the rigidity or accuracy of the fixture. It has been concluded that actuators integrated fixtures aid to overcome the challenges of vibrations, deformations and position optimization of work piece. The finite element analysis and process simulation helps to improve the performance of fixtures. As a result, fixtures have been declared as a powerful tool of modern machining system [19].

The three fingered automatic flexible fixture system consists of two Computer Numerically Controlled (CNC) modules [20]. The first module is an auxiliary mechanism and second is fixturing algorithm. The main motive is to design this kind of fixture for getting the idea about the minimum number of fingers needed to fix an object. The study concluded the reconfigurable fixture has the ability or flexibility to hold the workpieces of different shape and size. CNC

modular system, having eight degrees of freedom and four fingers, consists of multi-finger automated flexible fixture system to locate, support and holding functions [21]. The primary approach was to develop a multi-finger module for achieving the different fixture layout system, which further can be suitable for FMS, and automatic reconfiguration can be achieved without any human intervention.

To design a new fixture or to upgrade a former fixture for a particular operation on specific jobs, this practice is economical for mass production because of the long manufacturing lead time and a high cost, but not suitable for small batch production system. It has been concluded that reconfigurable and flexible fixtures are economical for robotic assembly that provides modularity, automatic configurability, sensory controllability and flexible locating ability. These fixtures consist of Y-guide proximity sensor, light emitter, receiver and reflections for interfacing the workpiece with fixtures [22]. The fixtures (consist of pin-array) is used in a flexible manufacturing system to clamp the workpiece by conforming their shapes. The proposed setup was aimed to either achieve high level rigidity between work piece and fixture or to ensure the stability of pin during holding [23].

V. IMPORTANCE OF WORK HOLDING DEVICE

The basic purpose of every holding device is to provide rigid support as well as proper location as per the tool and holding the work piece against the tool during the operations performed on it. During operation, the rigidity provided by the fixture directly affect the accuracy, the more the rigidity more accuracy and close tolerance will be achieved. In other words, it can be concluded that the close tolerance or interchangeability cannot be achieved without the selection of proper work holding device for specific components, as per the operation to be done and the location where operation to be performed. The rigid fixtures also reduces the vibration during operation, that helps to increase the tool and machine life. The proper clamping device aids to restrict the degree of freedom of the work piece in different axes that helps to control the movement of the workpiece against the tool or machine.

VI. CONCLUSIONS

In this paper, the developments in the work holding devices have been discussed for flexible manufacturing. It has been reported in the literature that the simple bench vice having surface plates on its jaws can measure the surface angle of the workpiece if its 90º or not. The bench vice provided with c-clamp at its base makes the vice flexible to fix on any table. The fixture consists of rapid reconfiguration and part positioning technique is used for holding objects with irregular shapes by reconfiguring itself. The bench vice has also been modified by increasing the degrees of freedom for holding the workpiece at different angles. The fixture system having pin-array on its jaws has been utilized to clamp the work piece by conforming the shape of the workpiece, which provides the better stable equilibrium during machining.

The use of a transducer and sensor in holding devices can be used to monitor the cutting and holding forces during the machining operations. The sensor used in the fixture will make the workholding system more intelligent. There is a huge potential to integrate an intelligent fixture with Internet of things (IoT) for industry 4.0 and the fixture can be integrated with machine learning to hold the work piece by capturing the contour of work piece.

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