A Review and Future Direction on Computer Aided Fixture Design
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Abstract— At the time of manufacturing operations, assembling operations and various other types of operations workpiece need to be located and supported properly for well performance and to increase the efficiency of operation. The device needed for this purpose is called fixture. Fixture are used for locating, clamping and holding workpiece properly according to desired need for performing the machining operation well. Various methods of fixture designs are available of which computer aided fixture design is one of efficient method among them. This paper reviews the work and techniques of various authors used in the field of fixture design. Finally, the reached conclusions are presented with the expected directions for future researches.

Key words: Computer Aided Fixture Design, Clamping, Productivity

I. INTRODUCTION
Fixtures are mechanical component that are designed for holding, locating and to support work pieces during manufacturing operations. Fixture design consists of a number of distinct activities: fixture layout design, fixture-planning and fixture element design. Fixture planning is the process of conceptualizing a basic fixture configuration through analyzing all the available information regarding the material and geometry of the work piece, operations required, processing equipment for the operations, and the operator. Fixture layout consists of basic drawing of the concepts of fixture containing the primary needs of the fixture. Fixture element design is about the complete details of the locators, clamps and supports. An output of fixture element design step involves detail design of clamps, locators and supports.

II. FIXTURE-DESIGN PRINCIPLES
These principles can be categorized into two different major types- the supporting-locating principles, and the clamping principles.

A. Supporting -Locating Principles:
There are total of 12 (2 x 3 x 2) linear and rotational movements along the x -axis, y- axis and z-axis, including both positive and negative directions. Usually, Locators and supporters restrict at Least nine movements, with the remaining three possible movements constrained by clamps

Fig. 1: There is a total of 12 degrees of movement: six linear movements (+x, +y, +z, -x, -y and -z) and six rotational movements (clockwise or counterclockwise around each of the axes).

1) Prismatic Parts without an Existing Hole:
According to the ANSI dimensioning and tolerancing standard, a “datum reference frame” of a part can be defined by 3 perpendicular datum planes. The datum planes are sequentially related to the defined datum features of the part for a prismatic workpiece,. The 3-2-1 locating principles can be used to configure the external locating points which can relate the part to the datum reference frame. First, the three-point supporting principle is used to assign three supporting points on the first datum plane; these shall be located as far apart as possible to increase the workpiece stability. By following the three-point supporting principle five movements will be restricted. Second, two points are assigned on the second datum plane and can restrict three possible movements. Third, one point has to be assigned on the third datum plane and can restrict one more movement. Totally, nine movements are bound according to the principles. However, the 3-2-1 principles can only be applied for prismatic-workpiece fixturing, and the three perpendicular datum planes and corresponding features must be well define.

2) General Parts with Existing Hole(s):
For a general part that are having an existing hole, a single internal locator and three supports may be applied to restrict nine movements at once, which is the most efficient way of locating the workpiece. Certain criteria have to be met, for example:

The existence of the first datum plane for three-point supporting as described in the previous paragraph The hole used for internal locating should be perpendicular to the first datum plane and open towards the datum plane .The hole in the workpiece must be of a suitable diameter to contain an existing internal locator.

Fig. 2: The three datum planes are related to the primary, secondary and tertiary datum features of the part.
Fig. 3: The 3-2-1 supporting and locating principles for a prismatic-workpiece

Otherwise, the internal locating principles cannot be used, and the workpiece is treated as a regular prismatic part applying the 3-2-1 principles for fixture design. Eleven movements are restricted if there is another existing hole in the part that can also be used for internal locating.

Fig. 4: Using an Internal locator to locate a general part with an existing hole

Fig. 5: Using two internal locators on a general workpiece with two or more existing holes

3) Non-Prismatic Parts:
In this type of parts to restrict the possible movements of the workpiece, external locating principles have to be applied. Several components may be considered for properly locating and supporting the workpiece by following the external locating principles. They are: V-blocks for locating or supporting externally cylindrical parts, adjustable supports (e.g. threaded type) and locators for supporting and locating non planar or rough surfaces the fixturing techniques for non-prismatic parts are often dependent on the workpiece shape. Because of the complex nature of workpiece geometry, there are no generalized fixture-design principles for non-prismatic parts, especially since multiple choices of design are often available.

B. Clamping Principles:
Clamps are used in restricting the possible movement of a workpiece that are not bound by locators and supports. According to the clamping direction with respect to the workpiece set-up the general clamping principles are reviewed below.

1) Horizontal Clamping:
On the “horizontal clamping face” a horizontal clamp is applied which has not been used as the locating face. Also, in order to counteract the locating force the clamp is located on the side of the workpiece that is opposite to the second or third datum face. Multiple horizontal clamps can be applied on one face to ensure the restriction of the movement when the horizontal clamping faces are nonplanar faces.

2) Vertical Clamping:
On the "vertical clamping face" vertical clamps are applied, which is a face that is the top surface of the workpiece and is on the opposite side of the workpiece to the first datum plane. The most rigid area is used as the clamping position to prevent bending or cracking during the machining process. Therefore, locating the vertical clamp on the area directly above a vertical support is the most secure vertical clamping configuration. If that is impossible, the vertical clamp can be located inside the "vertical clamping zone", which is a projective polygon with its vertices defined by the three supporting points. These locating, supporting and clamping principles can be coded as a knowledge base to help decide the proper locating, supporting, clamping configurations and the corresponding faces and positions. To help make the configuration decision the knowledge of fixture-design principles has to be embedded into the fixture-design system.

Fig. 6: Horizontal clamps arc placed on the opposite sides of the workpiece to their counteracting Locators

Fig. 7: The polygonal region for vertical clamping
Different clamps types
- Strap Clamp
- Heel Clamp
- Bridge Clamp
- Edge Clamp or Side Clamp
- Screw Clamp
- Latch Clamp

III. LITERATURE REVIEW

Hargrove S et al [1] recognizes four general requirements of a fixture
- Non-machining interference.
- Limited amount of deformation of the workpiece.
- During machining operation total restraint of the workpiece.
- Accurate location of the workpiece

A. Approaches Based On Expert Systems:
The use of as expert system Applications as well as artificial intelligence (AI) approaches, in fixture design have long been identified by researchers that the importance of developing computer-automated fixture design (CAFD) approaches, in which the supports, clamps and locators design attributes are generated automatically for different part designs.

Nee et al. [2] used an expert system approach to perform the fixture design task where a heuristic based rule was applied to generate a list of fixturing recommendations Including base and locating elements for the fixture. For the task of fixture design the input used was CAD model of a given product design. For primary locating face, the face on the workpiece consisting the largest cross-sectional area was chosen. The secondary location face was identified as being perpendicular to the primary location face.

Anglerot.G et al [3] suggested that the fixture design support system is developed on the basis of an expert system shell. The author showed the use of that kind of tool in determining reactivity factor in the fixture designing process. The work of author focuses of the development of fixture designer’s support. He presented an expression of the trade rules and structuring of the design method in the expert system formalism. He has developed SEACMU (System Expert d’Aide il la Conception des Montages d’Usinage for expert system for fixture design) using industrial expertise. It is basically a fixture designer’s supported expert system. SEACMU is based on a fitted part modeling to the fixture design.

The correspondent model is defined using RI rules from CAD/CAM data part. The necessary link between the part CAD/CAM and the future design expert system are RI rules. A simultaneous development of the fixture design, the manufacturing schedule establishment and the NC programmed design is then allowed

B. Fixture Layout:
Fixture layout is the initial work of the fixture design. Fixture designing is a practical problem in product manufacturing. It is necessary to support, immobilize, and locate the workpiece, during the manufacturing processes, which is also known as work holding. The work of fixture layout is to determine the type, number and location of the work holding elements. Secondary task is concerned with avoidance of interference and collision between the fixture and machining tool and preparing fixture setup. Basic Fixture Components is support, locator and clamps. Basic functional requirements of fixture are: (a) accurate localization (b) stable resting (c) stable clamping (d) Support reinforcement, (e) quality performance (f) total restraint. Zhuang,Y et al [4] focuses on efficient numerical techniques and effective fixture modeling for automatically generating, optimizing and analyzing fixture layout designs for any 3D work pieces having complex-shape.

C. Clamping Approach:
The work of Chou [5] focused on the clamping aspects of fixture design. A fixture clamping procedure was developed based on the twin criteria of work piece stability and total restraint requirement. The total restraint requirement was ensured by restricting the degree of freedom of a given workpiece using clamps and balancing the cutting forces. Over the past decade, much focus has been put on intelligent methods for computer aided fixture design to seek a technical breakthrough in embedding more design knowledge into semiautomatic or automatic CAFD systems. J. Cecil [6] suggested an innovative clamping design approach in the context of fixture design activities. The clamping design approach involves recognizing clamping points and surfaces on a given workpiece. This approach can be used in conjunction with a locator design approach to
support and hold the workpiece during machining operation with reference to the cutting tool.

D. Fixture Design System:

Computer Aided Fixture Design

The design of fixture by manual means is traditionally a time consuming task in manufacturing and the designer’s experience plays a key role in fixture design. The jig and fixture parts and component are divided into following categories : (a) Clamping mechanisms (b) Locating components (c) Support components (d) Tool Guiding components (e) Fixing components for fixture (f) Body of fixture (g) Auxiliary mechanisms (h) Power mechanisms (i) Operating elements (j) Miscellaneous components.

Markus [8] performed the work in which the locator and clamp positions were not determined automatically. The approach adopted was interactive where the user specified the clamping, locating, and support points, and then selected the appropriate fixturing components in the desired positions. He developed an expert system which configures clamps about a part using design specifications and rules related to geometrical constraints. This work did not address the issue of automating the fixture design task. However, it attempted the development of a semi-automated methodology to aid in the generation of fixture design for a given part design.

Hui Wang et al. [9] fixture design includes the identification of clamps, locators, and support points, and the selection of the corresponding fixture elements for their respective functions. There are four main stages within a fixture design process—setup planning, fixture planning, fixture unit design and verification. Setup planning determines the number of setups required to perform all the manufacturing processes, the task for each setup, e.g., the ongoing manufacturing process and workpiece, orientation and position of the workpiece in each setup. A setup represents the combination of processes that can be performed on the workpiece by a single machine tool without having to change the position and orientation of the workpiece manually. During fixture planning, the surfaces, upon which the locators and clamps must act, as well as the actual positions of the locating and clamping points on the workpiece, are identified. The number and position of locating points must be such that the workpiece is adequately constrained during the manufacturing process. In the third stage of fixture design, suitable units, (i.e., the locating and clamping units, together with the base plate), are generated.

IV. Conclusion

As an optimal fixture solution is a combination of many different considerations such as stiffness configuration, machining process, tolerance configuration etc. It can be easily achieved by Computer aided fixture design which provides various advantages over other method as higher production efficiency, shorter lead cycle, lower cost and easily automated. The only problem associated with CAFD is functions of automated fixture design systems are limited and it required human interaction therefore further development of interactive CAFD (I-CAFD) is valuable for industrial application.

For the assurance of significant improvement modern CAE and CAD are used in designing the system as the reliability and efficiency of fixture has enhanced by the system. Optimum design approach can be used to full fill high performance and multifunctional fixturing need and to determine compression analysis. To minimize the deformation most effectively the optimal fixture layout based on dynamic clamping forces optimization method and fixture layout can be used most effectively. The production target and efficiency are fulfilled by proposed fixture work.

REFERENCES