AN INTEGRATED METHODOLOGY TO FIXTURING TECHNOLOGY

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Abstract

Whether in traditional machining fields or modern flexible manufacturing systems, the work piece-holding is the first issue of the machining operation to be confronted. To ensure the machining accuracy of specific dimensions, it is necessary to correctly determine the position of the work piece related to the cutting tool and immobilize this correct position during entire machining operation. In this paper, a new machining dimension-based fixture design approach is developed for the first time and partitioned into two main parts for the study. Firstly, based on the velocity composition law of particle movement, locating correctness is proposed to properly constrain the work piece DOFs so that the work piece can capture the correct position. Secondly, based on the engineering mechanics and linear programming technology, machining stability is formulated to maintain the work piece equilibrium. Finally, a detail discussion is made about how to use the proposed method to plan locator and clamp points.

Keywords: *Fixture design, Fixture planning, Fixture configuration*

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1. INTRODUCTION

Fixture design can be classified as a part of process planning. The task wise description of process planning specifically states that "'fixture design for each work piece set-up is an integral planning task. However, the automation of fixture design has been overlooked in most research into automated process planning. In this paper, a wide range of fixture-design literature is studied in order to reveal the progress in the field and the significant contributions to it. Established fixturing techniques and methodology include the supporting and locating principles and the clamping principles. The principles are considered systematically, according to the geometric types of the workpieces (e.g. prismatic or cylindrical parts) for which they are applied.

2. FIXTURE DESIGN PRINCIPLE

The fundamental principles of basic fixture design, which have been actually used in manual fixture design, are reviewed in this section. These principles can be categorised into two major types- the supporting and locating (or vertical and horizontal locating) principles, and the clamping principles. Discussion of each of these is further organized according to its applications to different workpiece geometries.

2.1 Supporting and Locating Principles

The main purpose of this section is to describe the "'fixturing criteria" that ensure the precise locating and rigid supporting of the workpiece under various circumstances. There is a total of 12 (2 • 3 x 2) linear and rotational movements along the x-, y- and z-axes, including both positive and negative directions (see Fig. 1). Usually, supporters and locators restrict at [east nine movements, with the remaining three possible movements constrained by clamps [4].

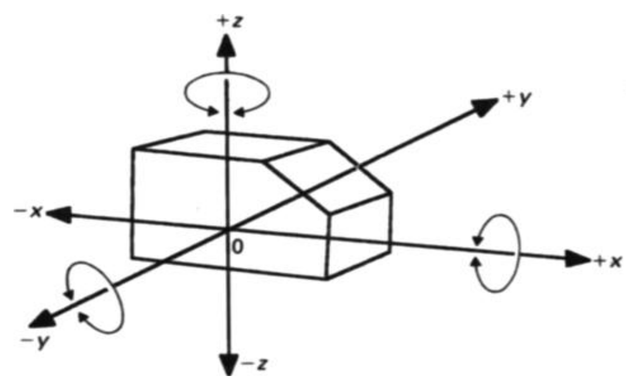

Fig -1: 12 degrees of moment: six linear moment (+x,+y,+z,-x,-y,-z) and six rotational moments(clockwise or anticlockwise around each of the three axis)

2.2 Prismatic Parts without an Existing Hole

According to the ANSI dimensioning and tolerance standard, a "datum reference frame" of a part can be defined by three perpendicular datum planes(see Fig.2).For a prismatic workpiece, the datum planes are sequentially related to the defined datum features of the part. The 3-2-1 locating principle can be used to configure the external locating points[4,6]which can relate the part to the datum reference frame as shown in the Fig.3.First,the three points supporting principle is used to assign the three supporting points on the first datum plane; three shall be located as far as possible to increase the workpiece stability. Five moments will be restricted by following the three point support principle. Second two points are assigned on the second datum plane and restrict three possible moments. Third, one point has to be assigned on the third datum plane and can restrict one more moment. Totally nine moments are bound according to this principles. However, the 3-2-1 principle can only be applied to prismatic workpiece fixturing.

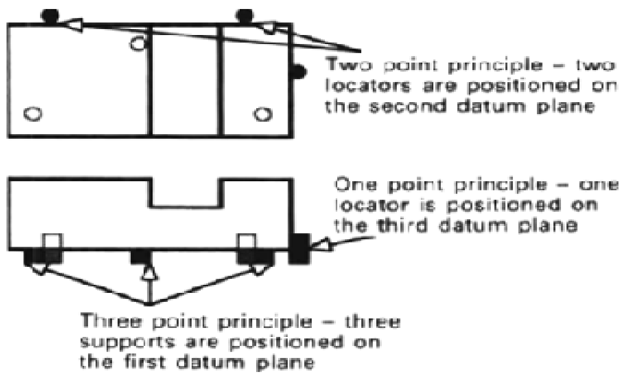

Fig -2: The 3-2-1 Supporting and locating principle for a prismatic workpiece.

2.3 General Parts with Existing Holes(S)

Nine moments at once: this is the most efficient way of locating the workpiece. If there is a another hole in the part that can also be used for internal locating, eleven moments are restricted.

2.4 Nonprismatic Parts

Here, external locating principles have to be applied to restrict the possible moments of the workpiece. Several components may be considered for properly supporting and locating the workpiece by following the external locating principles. They are V-Blocks for locating and supporting externally cylindrical parts. Adjustable supports (e.g. threaded type).The fixturing technique for nonprismatic 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.[4]

Fig -3: .Non prismatic part.

3. CLAMPING PRINCIPLES

Clamping is used to restrict the possible moment of a workpiece that is not bound by supports or locators. The basic requirements are,
1. To provide a suitable locking for achieving the stability of location,
2. To produce sufficient frictional effects for the above purpose but without causing any undesirable effects to the work piece such as distortion or surface damage.
It is also essential that the idle time involving loading, locking, unlocking and unloading of work pieces should be minimized as much as possible to reduce the overall set-up and non-machining time. Certain additional requirements are therefore to be fulfilled with respect to clamping devices:
1. The clamping devices must be easy to manipulate manually or otherwise,
2. These devices must be quick-acting so as to reduce time for setting the clamping and simultaneous locating,
3. They must be low-cost so that their application in small lot sizes is economical.

4. KNOWLEDGE BASE

The knowledge base is used for acquisition and storage of procedural, declarative, heuristic, and meta-knowledge from the fixture design domain. Knowledge is represented through a set of syntax and semantic rules which allow formal description of fixture elements. Knowledge representation means coding and formalization of knowledge into a format which is suitable for computer processing. The knowledge is organized in such a manner which allows the software to directly use it in the process of fixture design. The systems which store their knowledge in the form of rules are often called rule-based systems. The rules can be understood as elements of knowledge, that is, knowledge quantum from a particular area of fixture design.[1]

5. INPUT INFORMATION

Input information can be broken down into two principal groups: information on workpiece, and manufacturing information. In general, input information comprises information based on; 1) Type of machining (turning, drilling, milling, grinding and so on); 2) Main machine tool group (lathes, drilling machines, milling machines, grinders and so on); 3) Machine tool sub-group (universal lathe, copy lathe, revolver lathe, single-spindle pillar drilling machine, horizontal single-spindle boring machine, multi-spindle drill head machines, aggregate drilling machines, horizontal milling machine, vertical milling machine, universal milling machine, copy milling machine, surface grinding machine, universal grinding machine, copy grinding machine, round grinding machine and so on); 4) Type of machine tool (conventional, CNC); 5) Specific machine tool which is selected for machining (work table surface info, info on the dimensions of work table grooves); 6) Number of work pieces being machined at the same time (one, two, three, and so on); 7) Number of tools (single tool, more identical tools, more various tools); 8) Number of machining surfaces (single surface, more identical surfaces in linear displacement, more identical surfaces in circular displacement); 9) Method of connecting fixture with machine tool (spindle, work table); 10) Method of arresting fixture during machining (by fixture elements, manually); 11) Batch size; 12) Work piece shape (prismatic, rotational, irregular); 13) Overall workpiece dimensions (length, height, width); 14) Number of degrees of freedom arrested with locating elements (3, 4, 5, 6); 15) Workpiece locating method (3-2-1, 4-1-1); 16) Basic fixture characteristic (locating and clamping on external surfaces, locating and clamping on internal surfaces, locating and clamping on internal and external surfaces); 16) Forces and moments acting during machining process; 17) Shape of locating surfaces (external flat, internal flat, external cylindrical, internal cylindrical, external conical, internal conical, external spherical, internal spherical and so on; 18) Integrality of locating surfaces (continuous, step-like); 19) Quality of locating surfaces (ISO tolerance grade - IT); 20) Type of locating surfaces (ring, triangle, quadrilateral, rhomb, trapeze); 21) Characteristic dimensions of locating surfaces; 22) Position of primary locating surfaces relative to machine tool work table (horizontal, vertical, angled); 23) number of clamping force directions; 24) Shape of clamping surfaces; 25) Clamping scheme in particular directions (clamping force is parallel to the plane of cutting moment, clamping force is orthogonal to the plane of cutting moment, clamping force is at an angle relative to the plane of cutting moment); 26) Clamping drive in particular directions (manual, pneumatic, hydraulic, electrical, combined); 27) Direction of clamping force relative to locating surface in particular directions (parallel, orthogonal); 28) Intensity of clamping force in particular directions; 29) Types of clamping surfaces by particular directions; 30) Characteristic dimensions of clamping surfaces.[3]

6. SELECTION OF FIXTURE ELEMENTS

Within this system module, all required fixture elements which belong to various functional groups are selected. In order to allow efficient system operation, the following functional groups of fixture elements were identified:

1. Locating elements - Uniquely define workpiece location in a fixture, bring workpiece into correct and final orientation in a fixture, arrest degrees of workpiece motion, in order to allow proper machining;
2. Clamping elements - Provide stable contact with locating elements; prevent workpiece movement during machining due to acting forces;
3. Fixture body elements - Provide platform for all other elements and receive loads which act upon workpiece during machining;
4. Tool guiding elements - Used with conventional machine tools to guide the cutting tool relative to the workpiece;
5. Tool aligning elements - Used with conventional machine tools to locate the cutting tool position relative to the workpiece;
6. Connecting elements - Connect fixture elements with each other;
7. Add-on elements/elements for bridging height and length distances - Bridge the distances in required directions in order to provide fixture integrity;
8. Add-on elements for fixture manipulation -Allow fixture manipulation during mounting/dismounting, transport, and similar;
9. Add-on elements/elements for fixture positioning on machine tool - Uniquely define position of fixture on machine tool table;
10. Add-on elements/elements for attaching fixtures to machine tool - Attach fixture to machine tool table;
11. Add-on elements /securing elements - Allow workpiece to be set in a proper position in fixture;
12. Add-on elements/translating elements - Translate workpiece in order to bring it, in one clamping, into a new working position, relative to the tool;
13. Add-on elements/rotating elements - Rotate workpiece in order to bring it, in one clamping, into a new working position, relative to the tool.

7. FIXTURE ASSEMBLY, ANALYSIS OF SOLUTION AND DEFINITION ON OUTPUT SOLUTION.

Input into the last segment of the system is previously generated data on fixture elements. In the first step, fixture is assembled using the database, that is, the file with all the fixture elements. The required elements are entered into the assembly one-by-one, for better clarity and to avoid collisions. Workpiece is entered first, then the locating elements, clamping elements, followed by the remaining fixture elements. Once the fixture is assembled, the design solution is analyzed. This analysis comprises detection and removal of possible collisions. There are three types of collisions which can be identified [5]

1. The collision between immovable fixture elements can prevent successful fixture assembly. The same holds for the collision between adjustable and exchangeable fixture elements, which is often the case in group technology.
2. The collision between fixture elements and workpiece can directly influence machining process requirements, hindering the set-up and take-out of workpiece from the fixture. Also, workpiece can often be setup into fixture in more than one variant. This can cause various errors in locations of the machined features.
3. The collision between fixture elements and the cutting tool can occur in cases when placing fixture elements along the tool path during the machining. This can damage the tool or fixture elements and in some cases can result in tool and fixture elements failure, damaging the machine and other parts

of machining system or even injuring workers. After the final fixture solution is formed, the required output information are generated–fixture drawings, and bill of materials. Should any additional information be required, they can be generated within this system module.

8. CONCLUSIONS

The aim of this review paper has been to express the contribution of previous research and to emphasize the need for further research in fixture-design automation. The overview reveals that a general and comprehensive automatic fixture-design system has not been completely developed. The rule-of-thumb expert-system approach for fixture design is limited by the application domain owing to the case-oriented expert-rule structure. In order to run the system in reality, a huge rule base has to be constructed to cover a sufficient domain in the expert system. One way to generalize the research domain is to develop the theoretical base by analyzing the general and basic principles of the workpiece-fixturing relationship. Furthermore, the development of AFD system software and the fixture-hardware design must be studied together to enhance the overall automation of fixture design.

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