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An Advanced Exploration on Fixture Design

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ABSTRACT
Widely used in manufacturing, fixtures have a direct impact upon product manufacturing quality, productivity and cost, so much attention has already been paid to the research fixture design and many achievements in this field have been reported. In this paper, a literature survey of fixture design and automation over the past decade is proposed. First, an introduction is given on the fixture applications in industry. Then, significant works done in the design field, including their approaches, requirements and working principles are discussed. Finally, some prospective research trends are also discussed.
Key Words: Fixture design, manufacturing considerations, need of automation of fixture.

I. Introduction

A fixture is a mechanism used in manufacturing to hold a work piece, position it correctly with respect to a machine tool, and support it during machining. Fixture is a device for locating, holding and supporting a work piece during a manufacturing operation. Fixtures are essential elements of production processes as they are required in most of the automated manufacturing, inspection, and assembly operations.

Fixtures must correctly locate a work piece in a given orientation with respect to a cutting tool or measuring device.They are normally designed for a definite operation to process a specific work piece and are designed and manufactured individually. Widely used in manufacturing, fixtures have a direct impact upon product quality, productivity and cost.

Generally, the costs associated with fixture design and manufacture can account for 10%–20% of the total cost of a manufacturing system. Approximately 40% of rejected parts are due to dimensioning errors that are attributed to poor fixture design. Fixture design work is also tedious and time-consuming.

Traditionally, the design and manufacture of a fixture can take several days or even longer to complete when human experience in fixture design is utilized. And a good fixture design is often based on the designer's experience, his understanding of the products, and a try-and-error process. Therefore, with the increasingly intense global competition which pushes every manufacturer in industry to make the best effort to sharpen its competitiveness by enhancing the product's quality, squeezing the production costs and reducing the lead time.

There is a strong desire for the upgrading of fixture design with the hope of making sound fixture design more efficiently and at a lower cost. Many academic and applications papers have been published in this area. In this paper, we will focus on afixture design research.The following sections will give a survey on the state of the art ofthese researches. Some conclusions on research trends are also discussed.

1.1 Elements of Fixtures

Generally, all fixtures consist of the following elements:

1.1.1 Locators

A locator is usually a fixed component of a fixture. It is used to establish and maintain the position of a part in the fixture by constraining the movement of the part. For work pieces of greater variability in shapes and surface conditions, a locator can also be adjustable.

1.1.2 Clamps

A clamp is a force-actuating mechanism of a fixture. The forces exerted by the clamps hold a part securely in the fixture against all other external forces acting on to the component.

1.1.3 Supports

A support is a fixed or adjustable element of a fixture. When severe part displacement/ deflection is expected under the action of imposed clamping and processing forces, supports are added and placed below the work piece so
as to prevent or constrain deformation. Supports in excess of what is required for the determination of the location of the part should be compatible with the locators and clamps.

II. General Requirements of a Fixture

In order to maintain the work piece stability during a machining process, an operational fixture has to satisfy several requirements to fully perform its functions as a work holding device. The following constraints must be observed while designing a viable fixture.

1.2 Geometric constraint

Geometric constraintguarantees that all fixture elements have an access to the datum surface. They also assure that the fixture components do not interfere with cutting tools during a machining operation. In addition to these requirements, a fixture design should have desirable characteristics such as quick loading and unloading, minimum number of components, accessibility, design for multiple cutting operations, portability, low cost, etc.

1.3 Contained deflection

Work piece deformation is unavoidable due to its elastic/plastic nature, and the external forces impacted by the clamping actuation and machining operations. Deformation has to be limited to an acceptable magnitude in order to achieve the tolerance specifications.

1.4 Deterministic location

The work piece is constrained by locators so that it is presentable for the machining operation. Locating errors due to locators and locating surfaces of the work piece should be minimized so as to accurately position the work piece within the machine coordinate frame.

2.2 Fixture Design Fundamentals

Fixture design consists of a number of distinct activities: fixture planning, fixture layout design, fixture element design, tool body design, etc. They are listed in their natural sequence, although they may be developed in parallel and not necessarily as a series of isolated activities in actual execution.

2.3 Fixture Design

Fixture planning is to conceptualize basicfixture 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. The following outputs are included in the fixture plan:

i. Fixture type and complexity
ii. Number of work pieces per fixture
iii. Orientation of work piece within fixture
iv. Clamping surfaces and Support surfaces, if any

The following design criteria must be observed during the procedure of fixture design:

- Design specifications
- Factory standards
- Ease of use and safety
- Economy

A typical Fixture ofcomponent for milling operation is as shown in fig 1. The clamping system should be strong enough to withstand forces developed during operation. At the same time, the clamping force should not dent or damage the workpiece. Speed of operation, operator fatigue and strategic positioning are other important considerations for contriving a clamping system.

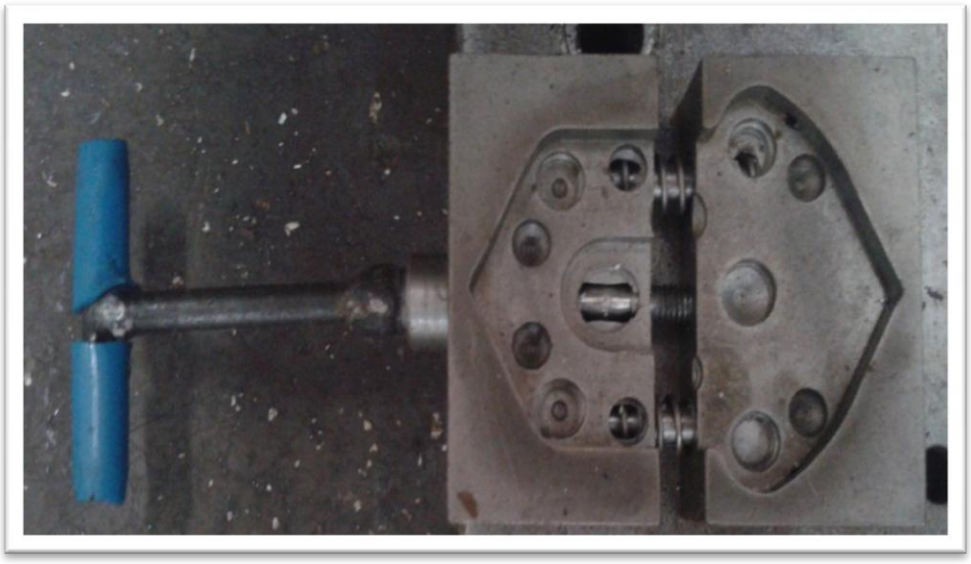

Figure no.1 Fixture of component for milling operation

III. Fixture Design Procedure

In the design of a fixture, a definite sequence of design stages is involved. They can be grouped into three broad stages of design development.

- Stage one deals with information gathering and analysis, which includes study of the component which includes the shape of the component, size of the component, geometrical shape required, locatingfaces and clamping faces. Determination of setupwork piece orientation and position.
- Stage two involves product analysis such as the study of design specifications, process planning, examining the processing equipment's and considering operators safety and ease of use. Determination of clamping and locating position. In this stage all critical dimensions and feasible datum areas are examined indetail and layout of fixture is done.
- Stage three involves design of fixture elements such as structure of the fixture body frame, locators, baseplate,clamping and tool guiding arrangement.
- Stage four deals with final design and verification, assembly of the fixture elements, evaluation of the design, incorporating the design changes if any required and completion of design.

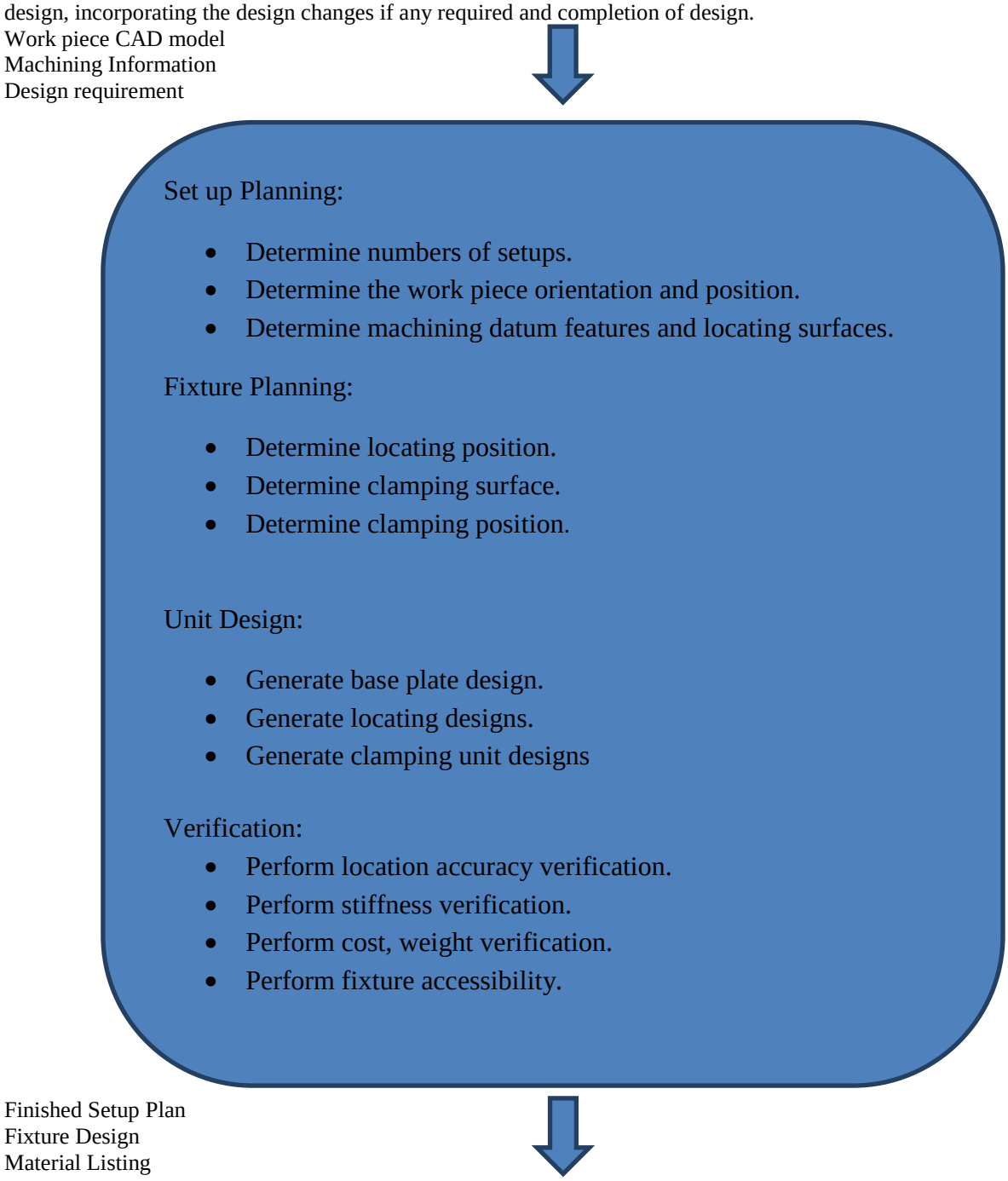

Figure no 2: Basic Elements for Fixture Design

3.1Restrictions on the Degrees of Freedom of aWork piece

A work piece, just like any free solid body, has six degrees of freedom (some researchershave referred this to the twelve degrees of freedom by considering the +I-movements in each category)

- Three rectilinear displacements along themutually orthogonal co-ordinate axes.
- Three angular displacements with respect tothe same axes.

During a set-up, it is necessary to restrict certain degrees of freedom so as to locate and orient the active surfaces with respect to the cutting tools. Since supporting or restricting surfaces may vary from the true geometrical shape, especially on rough machined surfaces or cast blanks, it is desirable that the work piece be located with respect to the point supports. Locating using point supports in the form of hemispherical rest buttons would considerably reduce the influence of geometrical variations of locating surfaces on the locating accuracy.

For prismatic parts, the general principle of 3-2-1 location is most commonly employed. For achieving greatest stability, the first three points of location on the primary surface should be as far apart as possible, or the area enclosed by the three points as large as possible.

For cylindrical work pieces, three-point location cannot be obtained because of the non-existence of plane surfaces, V-locators and close-fitting bushes are often used instead.

For circular laminae, location can be achieved with the aid of a slot support. When a work piece is required to be located with respect to an inside hole or bore, a plug is used for locating the work piece. Locating from two holes typically uses a full and a diamond plug combination, with the latter inserted in the larger of the two holes.

IV. Automation in fixture Design

With the advent of VMC machining technology and the capability of multi-axis machines to perform several operations and reduce the number of set-ups, fixture design task has been somewhat simplified in terms of the number of fixtures. The rapid development through the computer aided fixture design (CAFD) in manufacturing of modified fixture design has an immense role for to reduce the designing time and application of Flexible Manufacturing System (FMS) has added to the requirement for more flexible and cost-effective fixtures. Traditional fixtures (dedicated fixtures) which have been used for many years are not able to meet the requirements of modern manufacturing due to the lack of flexibility and low reusability.

The replacement of dedicated fixtures by modular and flexible fixtures is eminent in automated manufacturing systems. Fixtures are constructed from standard fixtureelements such as base-plates, locators, supports, clamps, etc. These elements can be assembled together without the need of additional machining operations and are designed for reuse after disassembly. The main advantages of using modular fixtures are their flexibility and the reduction of time and cost required for the intended manufacturing operations. Automation in fixture design is largely based on the concept of modular fixtures, especially the grid-hole-based system.

V. Conclusion

Traditionally, fixture design is a manual process and demands an expert's Knowledge and skilled engineering. . In this paper, a literature survey of fixture design and automation over the past decade is proposed with the introduction on the fixture applications in industry and the significant works done in the design field, including their approaches, requirements and working principles are discussed. Finally, some prospective research trends are also discussed.

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