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Computer aided fixture design: Recent research and trends

Hui Wang [a,*], Yiming (Kevin) Rong [a,b], Hua Li [b], Price Shaun [b]

[a] Department of Precision Instruments and Mechanology, Tsinghua University, Beijing, 100084, China
[b] Computer Aided Manufacturing Laboratory, Worcester Polytechnic Institute, MA, 01609, USA

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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 of computer aided fixture design (CAFD) and many achievements in this field have been reported.

In this paper, a literature survey of computer aided 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 CAFD field, including their approaches, requirements and working principles are discussed. Finally, some prospective research trends are also discussed.

1. Introduction

A fixture is a mechanism used in manufacturing to hold a workpiece, position it correctly with respect to a machine tool, and support it during machining. 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 [1]. Approximately 40% of rejected parts are due to dimensioning errors that are attributed to poor fixturing design [2]. Fixture design work is also tedious and time-consuming. It often heavily relies on fixture design engineers' experience/knowledge and usually requires over 10 years manufacturing practice to design quality fixtures [3]. 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 to bring new products to the market, there is an strong desire for the upgrading of fixture design methodology with the hope of making sound fixture design more efficiently and at a lower cost. The development of computer-aided fixture design (CAFD) technology over the past decades can be attributed to the fulfilling of this goal.

As an important field in manufacturing, research and applications of fixture design has been paid much attention over past decades [4,5]. Many academic and applications papers have been published in this area. In this paper, we will focus on an investigation of computer aided fixture design research in the past decade. The following sections will give a survey on the state of the art of these researches. Some conclusions on research trends are also discussed.

2. Fixtures in manufacturing

A fixture is designed to position and hold one or more workpiece(s) within some specifications. It is widely used in manufacturing, e.g. machining (including turning, milling, grinding, drilling, etc), welding, assembly, inspection and testing. The following Figs. 1–9, are some real fixture design cases in manufacturing. Fixtures can be classified with different principles. However, compared with the publications of CAFD research in machining fixture field, only a few [6–16] have been focused on other important manufacturing fields, for instance, assembly fixtures and welding fixtures.

2.1. Welding fixtures

Welding is essential to a high dollar volume of manufacturing processes, including national defense industries. According to *Economic Impact and Productivity of Welding, Heavy Manufacturing Industries Report*, by American Welding Society and Edison Welding Institute on June 2001, "The contribution of welding to the US economy in 1999 via these industries was no less than $7.85 billion. This figure represented 7% of total expenditures by these firms in 1999" [17,18]. So there are significant technical and commercial

* Corresponding author.
E-mail address: wanghuisx@gmail.com (H. Wang).

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Fig. 1. Machining fixtures (*IMAO corp.*) [19].

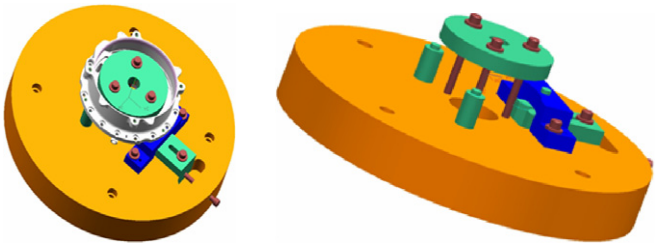


Fig. 2. Machining fixtures of aircraft-used bearing housing.

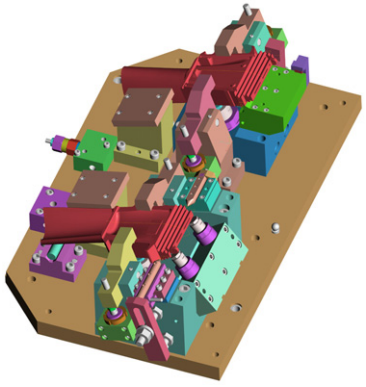


Fig. 3. Grind fixture for turbine blades (*aerocad design, inc.*) [20].

advantages in the development and deployment of welding fixture design systems.

There are obvious differences between machining fixture design and welding fixture design. As in the following:

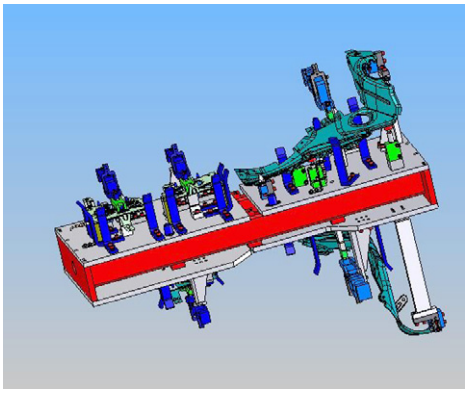


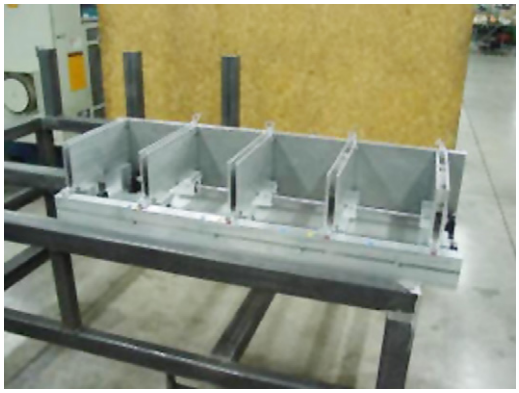
Fig. 5. Automotive stud weld fixtures on a trunion frame, (*DBM innovation inc.*) [22].

- The workpiece in a welding process is usually an assembly of several parts, while workpieces undergoing a machining process contain only one part.
- Usually, the accuracy requirement in a welding process is less than in machining.
- Fixing forces and machining forces in a welding process commonly are smaller than in machining.
- Thermal reactions in welding should be seriously considered.

Furthermore, these factors also should be paid some attention in welding fixture design cases:

- Electrical conductivity is critical for arc welding stability.
- In addition to thermal conductivity, when selecting fixture material thermal expansion properties also should be considered.
- Refined welding waveforms require an optimized welding circuit to maintain short arc lengths while reducing spatter, stubbing, arc flare, and arc outages to maximize travel speeds.
- More complex applications may require a dedicated fixture. The design and installation of a dedicated fixture frequently involves installing and routing wiring and pneumatic or hydraulic lines.

In the past decade, only very limited CAFD research and applications have been reported in the welding sector. In this field, due to the importance of welding for sheet metal assembly in automobile and aerospace industries, the assembly and welding of sheet metal has received some special attention. A weld fixture is often developed to reduce the deformation of each workpiece due to heat and residual stress in the welding process and, hence, to reduce the dimensional variation of the assembly. Therefore, some methods of offline or online deformation analysis were developed to enhance the fixtures' ability on deformation controlling [8,9]. In



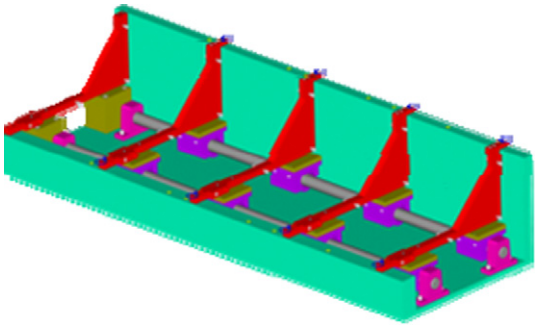


Fig. 4. Assembly fixture to locate shelves for assembly of cabinets (*pioneer industrial systems LLC.*) [21].