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A Novel Reconfigurable Assembly Jig Based on Stable Agile Joints and Adaptive Positioning-Clamping Bolts

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Abstract

This paper presents a novel reconfigurable assembly jig called Agile Joint Jig (AJJ) which consists of three main parts: framework, locators and auxiliary components. This framework is not a welded one, but is bolted together using three modular construction kits which include stable agile joints, hollow steel beams and adaptive positioning-clamping bolts（PC bolts）. Anti-sheering forces and self-centring provided by PC bolts are keeping the joints and beams in firm position. The modules of this AJJ can be reused to quickly configure other jigs for new products. It can significantly shorten the manufacturing cycle and guarantee the repositioning accuracy of jig. A case study of AJJ has been conducted for a vertical stabilizer assembly and the results demonstrate the advantages of the new reconfigurable assembly jig.

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Keywords: Reconfigurable Assembly System; Agile Joint Jig (AJJ); Agile Joint; Positioning-Clamping Bolts; Stable; Adaptive;

1. Introduction

In aviation industry large workload of the aircraft assembly which accounts for more than 50% of the workload of the entire aircraft manufacturing and high accuracy requirement of the final assembly ask a significant number of assembly jig to be used in the assembly process. According to different assembly stages of the aircraft product, the assembly system can also be divided into three stages: component-level assembly, large component-level assembly and large components alignment and joining.

However, the traditional fixed assembly jig has many disadvantages that include (1) One-to-one: an assembly jig can only apply to the assembly of one aircraft product , not for another one even belonging to the same product family. This leads to high produce cost. (2) Low level of standardization: lots of components of jig need to be customized for a new product. This results in a long cycle of assembly jig design and manufacture. (3) Troublesome storage: because of lack of ability to disassembly, lots of traditional assembly jigs need to have a large space to be stored. (4) Poor structure opening: it is not suitable for the application of advanced automation connection equipment and connection technology [1]. These problems have been attracting significant attentions and then several approaches have been proposed, such as flexible assembly system and reconfigurable assembly system.

Flexible assembly systems which rely on digitalization and automation technology can be quickly adjusted to assemble multiple products. The flexibility is the most fundamental characteristic of them.

Multi-lattice vacuum suction flexible fixture developed by MTorres is kind of flexible assembly system. It can quickly adjust shape of the multiple modular units to generate the uniform distribution lattice to match the profile of the skin panel component. This system uses theoretical data of the digital model to drive the movement of each modular unit. Therefore, theoretical datum of different products can be able to configure different structures to meet assembly requirements. Multi-lattice vacuum suction flexible fixture is usually used for

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the assembly of skin panel component[2][3]. It belongs to component-level assembly system.

Determinant column unit structure flexible assembly fixture consists of multiple column units with the determinant arrangement. Each column unit is independently arranged and equipped with a clamping unit, which generally has the movement adjusting capability of 3 degrees of freedom. This flexible assembly fixture can apply to different aircraft component assemblies by adjusting the arrangement and distribution of clamping units in the column units. It also belongs to component-level assembly system[4][5].

Large component flexible assembly system is mainly used for fuselage large component assembly which consists of four skin panel components. Each skin panel component is mounted on the positioners, and then the positioners are driven by using theoretical datum. AIT and NOVA-TECH Company have developed several of these kinds of flexible assembly systems [6][7].

Aircraft large components alignment and joining system is used to join the large components into a complete aircraft. It has the ability to real-time detect each positioning point and automatically adjust the position and direction. This system can be divided into three types (1) Column structure fixture platform: its ability of weight-bearing is relatively small. (2) Tower structure fixture platform: it has large weight-bearing ability, but its structure is complex (3) Hybrid structure fixture platform: it has good opening, large weight-bearing ability, and flexible adjustment ability [8][9].

Reconfigurable Assembly System (RAS) is also recognized as a promising assembly system for aircraft assembly. It is the perfect solution for the problems which are time-consuming and high cost caused by Dedicated Assembly System [10].

RWTH-Aachen University presents a reconfigurable handling system. The system is capable of being adapted to multiple product variants, because of using multiple robotic arms at several distributed points. The individual robots are very lightweight so that they can be easily moved and switched. Although the high degree of automation could save the labour, its control system is high cost and complicated which are caused by complex procedure of programming cooperating robots with synchronized motion [11][12].

Linkoping University proposed a concept of Affordable Reconfigurable Tooling (ART) based on BoxJoint. The basic principle of this concept is that a assembly fixture is set into CAD-defined positions by means of adjustable supports such as Flexapod 6 and through guidance of external measuring systems. The most benefit is that it enables shorter lead times and concurrent engineering in the tooling development. Late changes of the product resulting in modified coordinates for the pick-up devices can be handled just by setting the adjustable supports into amended positions. Contributing to the shortened lead time in ART is also the fact that the construction parts， to a great extent, can be supplied off-the-shelf as modular standard parts. Another benefit is also the possibility to enable re-configurability within a group of different products. This is especially beneficial in low volume production. The costs of the fixture then are shared between the different projects [13][14].

Compared with the reconfigurable handling system and flexible assembly system, the ART has significant advantages in low manufacturing cost and easy implementation. Therefore, it has become a promising direction in the field of aircraft assembly jig. However, the stability of ART is not very well because this system relies heavily on friction force. If it adopts large size beams or adds supports to enhance the stability. Then this will increase the total weight of tooling and lead to complicated installation process. On the other hand, a BoxJoint usually needs more than two boxes to cooperate connect beams. More joints mean more boxes to be fixed. This will result in increasing set up time and reducing reliability of the joints. Furthermore, there is probably no enough space to torque operate conveniently.

This paper presents a more stable and convenient reconfigurable assembly jig called Agile Joint Jig (AJJ) which is similar to the ART concept, but has a novel connection type based on the proposed stable agile joints and adaptive positioning-clamping bolts (PC bolts). The AJJ system is able to achieve quick rebuilding of a more stable assembly jig which is suited for component-level assembly.

2. Concept of Agile Joint Jig

2.1. Configuration principle based on AJJ

As shown in Figure 1, an Agile Joint Jig is bolted together using modular construction kits that consists of three modules: frameworks, locators and auxiliary components. A framework consists of three modules: agile joints with holes, hollow steel beams with holes and adaptive PC bolts. These three modules can be used to quickly configure a framework as the platform where locators/clamps can be fixed. These locators/clamps are connected with framework easily by using box-joints and expanding mandrels which belong to auxiliary components. These modules of the AJJ system are able to be reused to build another jig for a new product. Especially for a product family, its new requirements can be met by only changing positions and orientations of locators. The AJJ system can shorten the manufacturing cycle of jig and meet the accuracy requirement of the product. Furthermore, this connection type of the AJJ system not only improves the stability of the jig but also shortens the set-up time.

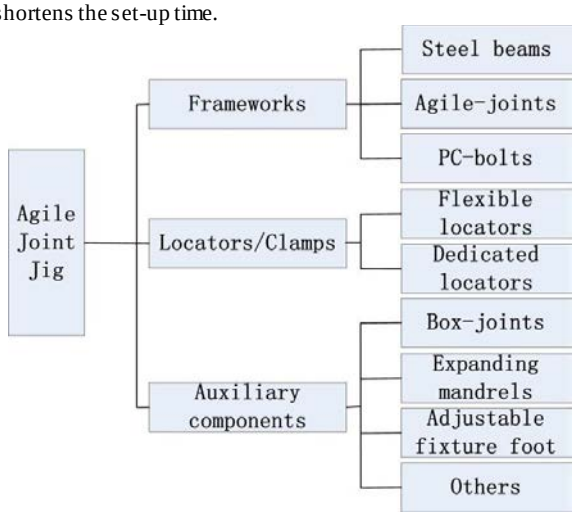

Fig.1.Structure of the Agile Joint Jig (AJJ) system