Available online at www.sciencedirect.com

ScienceDirect

Procedia CIRP 44 (2016) 233 – 238

www.elsevier.com/locate/procedia

6th CIRP Conference on Assembly Technologies and Systems (CATS)

Development of Automated Flexible Tooling as Enabler in Wing Box Assembly

Ilker Erdem[a]*, Peter Helgosson[b], Henrik Kihlman[b]

[a]*Chalmers University of Technology, Gothenburg 412 96, Sweden*
[b]*Prodtex, Krokslätts Fabriker 3, Gothenburg 431 37, Sweden*

* Corresponding author. Tel.: +46-076-296-1137. *E-mail address:* ilker.erdem@chalmers.se

Abstract

Flexible tooling has been a focal point of investigation for various industries with an emphasis on cost and time effectiveness. Previous research has shown that when combined with the general requirements of tooling such as rigidness and repeatability, the implementation of flexibility can be a very daunting task. Therefore, LOCOMACHS (Low Cost Manufacturing and Assembly of Composite and Hybrid Structures) project has dedicated a work package for the creation of an automated flexible tooling to meet the demands of future aerospace production. The work package focuses on a creation of a tooling technology that can facilitate the process requirements of an automated wing-assembly by using flexible tooling and intelligence support from a force sensor. Hence, this paper aims to present the framework for automated flexible tooling development and results on a hexapod fixture as a case study.

Keywords: Flexible; Tooling; Fixturing; Aerospace; Wing; Assembly

1. Introduction

Along with the evolution of production systems regardless of industry type, several paradigms played a major role in understanding of how to cope with continuously fluctuating customer demands. On a business and networking approach, agile manufacturing created a definition of how all elements of production can be connected in a low cost and flexibility-oriented approach [1]. When reflected on hardware level, the concept of flexibility further found application in flexible and reconfigurable manufacturing paradigms – later called as either flexible (FMS) or reconfigurable (RMS) manufacturing systems respectively [2]. In FMS, production equipment are conceptualized to have a built-in set of functionalities that can handle variations in products and processes in all steps of production [3]. On the other hand, reconfigurable manufacturing systems focus on the limitation of flexibility to reduce the cost and focus on a more modular approach – which is the reconfigurability of hardware and software systems to provide additional functionalities only when needed [4]. Whether aforementioned paradigms concentrate on the either limitation or generalization of flexibility, they stress the importance of using flexibility with low cost and shorter time windows to correspond to changing business paradigms.

Another important aspect of a production paradigm is to create a link between business and manufacturing strategies so that each constituting element coherently responds to uncertainties and shifting demands [5]. An example of such is to evaluate the important drivers behind a business model where each driver is reflected by cost and time so that these drivers can easily be associated to all components of a production system. Therefore, it was evaluated by researchers that this association through drivers can facilitate a framework to evaluate the applicability of manufacturing equipment whether they are process machinery or fixtures [6]. Hence, different strategies regarding this link were assessed [7, 8] and a common conclusion was on the inclusiveness of agile manufacturing paradigm as it creates a networking model spanning from production technologies to enterprise level operations; thus, defining the required structure for the missing link [9]. An example of such is seen in the study conducted by [10] where parameters for a fixturing equipment are quantified in time and cost limits for fixturing design and operations in aerospace wing box assembly procedure. Furthermore, same

doi:10.1016/j.procir.2016.02.065

alignment between business and manufacturing was also reflected on different types of industries. In car manufacturing industry, the study conducted by [6] breaks down the concept of agility drivers by cost and time on both investment and operational level to create a methodology for the implementation of affordable and time effective flexibility in all aspects of production spanning from machining to assembly fixtures. Another example is aerospace industry's efforts to cope with changes in the market with agile manufacturing paradigm as focal point [11]. Particularly, the assembly of wing structures has been investigated with efforts to create a tooling concept that can enable flexibility in terms of modularity, reconfiguration and easy correction of part variations where automation concepts in both design and operation were essential [12-14].

Whether the result of the alignment is towards the concept of customized flexibility as with RMS philosophy or more generalized one as in flexible manufacturing systems, it is often conceptualized for a solution initiated by a business requirement; then, complemented with technical knowledge; and finally, verified by using the same requirements. When this cycle of creating production equipment is reproduced for aerospace industry, a particular element of manufacturing often draws attention in the attempts of various researchers to provide flexibility. Particularly, assembly operations in aerospace industry is often comprised of dedicated and modular tooling components where the nature of the operations is manual labor oriented [15, 16]. Even though these dedicated fixtures provide satisfactory amount of robustness and performance in assembly of wing structures, the same nature of dedication requires excessive amounts of design/procurement times and investment cost both for infrastructure and tooling hardware [17]. Furthermore, the assembly of large scale units, particularly aircraft wings, requires corrections in terms of shimming of the non-rigid materials to secure robust process within tolerance limits. Thus, aerospace industry copes with the variation manually due to the dedicated nature of the conventional tooling. Therefore, there is a certain need for active fixturing solution that is reconfigurable and supported by intelligence to adapt to different products and variations within a workpiece [18].

LOCOMACHS (Low Cost Manufacturing and Assembly of Composite and Hybrid Structures) is European Union project to address the aforementioned problems with a work package for the creation of a flexible tooling concept that has built-in reconfigurable capacity to automate, actively evaluate, and fixate a large scale wing structure within acceptable tolerance limits. Hence, this paper aims to present the methodologic design approach and preliminary results on the development of an automated flexible tooling concept with a Stewart platform as a case study. The organization of the paper is as follows. Section 2 aims to provide a process description. In section 3, the automated flexible tooling (AFT) concept is presented in terms of overall methodology whereas sections 4, 5 and 6 disclose the mechanical, control and intelligence aspects of AFT.

2. Automated Flexible Tooling

Automated Flexible Tooling (AFT) is a methodology developed in order to create a framework that harmonizes agility input generated by business requirements with conventional fixturing design techniques as depicted in [19]. Furthermore, AFT utilizes this input to design the fixture units by selecting the components from various types of fixturing concepts such as modular, reconfigurable and affordable reconfigurable tooling (ART) to complement automated reconfiguration.

The first step of the methodology is to identify agility drivers relevant to the industry type and provide a conversion approach that facilitates meaningful information in fixturing design. As described with a literature review by [20], enterprise level agility drivers are directly defined by enterprise level cost effectiveness, time for design and deployment, and satisfying functionality values. Therefore, AFT methodology inherits a similar approach and uses aforementioned time and cost items to describe the relevant technology. Time relevant inputs are created for limits in design, lead, installation, reconfiguration and workpiece set-up whereas cost relevant limits are drawn for initial investment, maintenance, quality and reusability.

Later, AFT complements the design procedure with general fixturing requirements such as rigidness, accuracy and repeatability as researchers [19, 21] identified. Moreover, the design process for fully automated tooling solutions is first broken down into two categories as from static and dynamic perspectives where static units represent the components that are either fixated or require relatively less flexibility such as framework or base. Dynamic units, on the other hand, represent the fixturing elements that constitute the connection between the workpiece and framework; and these units provide the functionality for reconfiguration, automation and intelligence.

Additionally, agility, product and process inputs are reflected on both dynamic and static units in terms of component design and/or selection. Particularly in this phase, fixturing concepts such as modular, reconfigurable and ART become a key-enabling factor to establish the fixturing design where selection of technological features is investigated. For example, in a case where reconfiguration is required to be conducted on a part family level with a narrower workspace, certain units in the framework and base can be selected or designed to have manual labor intensive modular units. Furthermore, the reconfigurable element of the tooling solution can be somewhat fixated to a certain position on the framework through stronger joint solutions. Also, the automated dynamic components in the reconfigurable tooling can be chosen through standardized products that both fit the fixturing requirements such as rigidness, repeatability and accuracy as well as time and cost limits considering operation and design phases. Therefore, AFT methodology aims to elaborate on conventional approach on fixturing by creating a synergy between a business paradigm and tooling solution; that is not only flexible, cost and time effective but also compliant with operationally effectiveness from labor and hardware perspectives where a summary of this section can be seen in Fig. 1.