

Flexible Tooling for Wing Box Rib Clamping and Drilling

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Nirosh Jayaweera , Otto Jan Bakker, Tony Smith, Atanas Popov and Svetan Ratchev
University of Nottingham

Andrew Turnock
Hyde Group Limited

Peter Helgesson
DELFOi

David Tomlinson, Jon Wright and Mark Summers
Airbus

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ABSTRACT

Currently the wing box rib assembly process requires the manual location and temporary fixing of components within product specific jig or fixtures for drilling. After drilling and reaming, parts are separated, cleaned, deburred prior to adding sealant, reclaiming and final bolting, but this may significantly increase cost, manufacturing lead-time, reduces flexibility and cannot usually be economically modified for use on other aircraft types. Due to potential increase in demand for the next generation single isle aircraft, existing tooling solutions have to be improved and new technologies have to be developed. This paper describes the development and testing of flexible tooling to provide clamping and support for drilling wing box ribs to mating rib posts within a restricted environment. Results are presented along with a discussion of the problems that may be encountered during clamping trials.

INTRODUCTION

The Aerospace industry is one of the most technically demanding and requires very tight tolerance in spite of large in size and inherent compliance of the components involved [1, 2]. Due to potential increase in demand for the next generation single isle aircraft, existing manufacturing technologies have to be improved and new technologies have

to be developed. One way of achieving rate, ramp up and cost saving is the development of innovative design and manufacturing techniques. Therefore major aircraft manufacturers have moved towards the composite manufacturing of aircraft parts to reduce weight, fuel consumption and environmental pollution. The manufacture and assembly of composites poses different constraints and challenges compared to traditional aircraft build using metal components [3, 4, and 5]. One of the main challenges of wing box rib assembly is to develop tooling solutions for use within a restricted environment to accommodate tooling frames and clamping and drilling equipment.

Currently the assembly of aircraft components involves product specific tooling and fixtures to locate different components together in the correct relative positions for drilling. After drilling and reaming, parts are separated, cleaned, deburred prior to adding sealant, reclaiming and final bolting, but this may significantly increase cost, manufacturing lead-time, reduces flexibility and cannot usually be economically modified for use on other aircraft types. As the trend towards smaller lot sizes and higher accuracy parts continues, many manufacturers are finding that dedicated work holding systems do not provide required versatility. In spite of these drawbacks, the construction of such aircraft assembly tooling has remained essentially unchanged for almost fifty years. There is thus a significant

need for an aircraft assembly tooling system that is more flexible in design and more economic to produce and use.

One way of achieving this flexibility is to incorporate modular tooling and fixturing for the assembly of aircraft components [6, 7, 8, 9, and 10]. Modular tooling represents the first level of flexibility in aircraft assembly tooling. These devices consist of a standard kit of parts and couplings which make it possible to reuse the parts, as they are not welded. Extruded Aluminum profiles are the most commonly used material and these profiles are screwed together with couplings to build modular tooling. A modular fixture system consists of standard components that can be used to satisfy different fixturing requirements. These fixtures are reusable and this enhances their flexibility and reduces the time and cost of development, especially beneficial in small volume production and new product prototyping. It also offers the benefit of eliminating the need for dedicated tooling fixtures and their associated storage and floor space, rapid response to engineering and production changes, system expandability, and considerable reduction in setup time.

Current wing box is made up of ribs, longitudinal spars and skin panels which are strengthened with rows of stringers attached by thousands of rivets and bolts. These wings are usually built up in the assembly jigs where the ribs and spars are loaded in a set sequence. The skin assemblies are then progressively located and drilled before being bolted to the supporting ribs and spars. This is a labour-intensive process using manual drilling and fastening methods with dedicated jigs and fixtures. The proposed wing box design concept involves integration of the spars with bottom cover with integral rib feet to wing skin to form a single structure before the ribs are progressively located, drilled and bolted. This approach is intended to reduce the number of fasteners and individual parts required in assembly. However, they do increase the manufacturing complexity of the components due to the geometry of the integrated structure and the pitch of the wing box ribs, space is restricted for tooling frames and clamping and drilling equipments.

The work described in this paper is a part of the Next Generation Composite Wing (NGCW) program which is a major new research and development programme that will improve future wing design processes and help to maximise the eco-efficiency of future aircraft designs [11]. Optimising the weight and design of aircraft will improve their efficiency and performance, and burning less fuel will result in lower operating costs and lower gaseous emissions to atmosphere. In order to accommodate the step changes in the aircraft design University of Nottingham has investigated the modular tooling solution to accommodate restrictive access clamping and support for drilling equipment inside the proposed integrated structure. The paper describes the design and development of experimental rig and its application to wing box rib assembly. It further evaluates the usefulness of

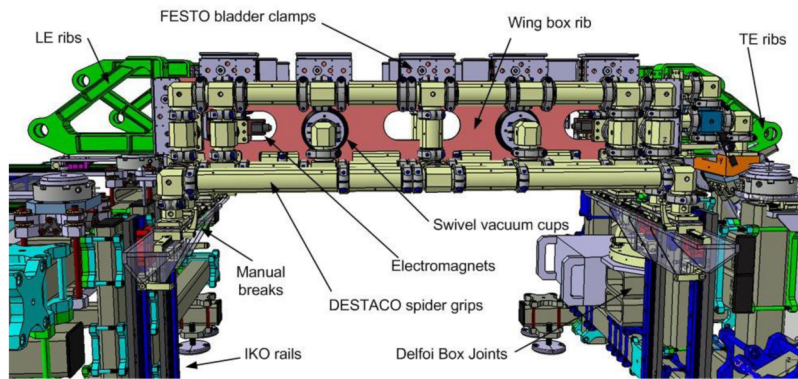
modular tooling and investigates the shape variation of integrated structure during clamping trials.

SYSTEM DESCRIPTION

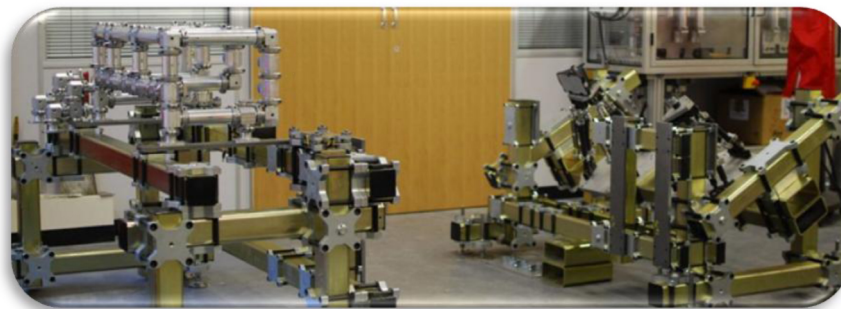
The design of assembly fixture required the development and implementation of a number of key elements includes integrated composite structure (Leading and trailing edge spars + bottom cover), wing box ribs, DESTACO spider grips, Delfoi Box joints, electromagnets, IKO rails and manual breaks, FESTO bladder clamps, and swivel vacuum cups as shown in [Figure 1](#).

DE-STA-CO's Modular parts can be easily configured to meet a variety of aerospace tooling applications. Although made of lightweight aluminum, these parts are more robust than typical systems built using nuts and aluminum square extrusions. All components are made out of high-grade aircraft quality aluminium offers high strength to weight ratios and maintain dimensional accuracy. The lightweight collar and cross-key assembly is the cornerstone of SpiderGrip's modularity. BoxJoint is a standard off-the-shelf box steel component that can be used for modular fixture systems. These steel Beams are joined together using standard plates, bolts and nuts. The bolts are pulled with high torque to give a rigid friction joint, which gives enough stiffness similar to a welded joint.

Bladder clamps can be compared to a bicycle inner tube, which when inflated expands (radially outwards) to fill a void which is contained within the wheel rim and a tyre. Once air is let out of the inner tube the tyre runs flat. Most inflatable seal solutions will end up using a 'standard' profiles. However for some applications a totally bespoke design may be necessary. An electromagnet is a type of magnet whose magnetic field is produced by the flow of electric current. The magnetic field disappears when the current ceases. Unlike a permanent magnet, the strength of an electromagnet can easily be changed by changing the amount of electric current that flows through it. The poles of an electromagnet can even be reversed by reversing the flow of electricity. The Layout of electromagnets consisted of ZN-coated steel housing, coil plastic injected and holding surface grinded. To hold and manipulate wing box rib, vacuum holding systems was attached to the DESTACO structure. Handling of irregular surfaces is easy with vacuum Cup Swivel Joint. To control the degree of swivel, simply tighten the collar nut located on top of the swivel joint to restrict movement. IKO rails include the linear way and linear roller way rail guiding systems, and a ball spline-based shaft guiding system. These are available in range of sizes from the smallest track rail at just 1 mm wide, to a very large version which provides high rigidity and high-load capacity.



(a)



(b)

Figure 1. (a) Cad drawing of Test rig; (b) Test rig without integrated structure and wing box ribs

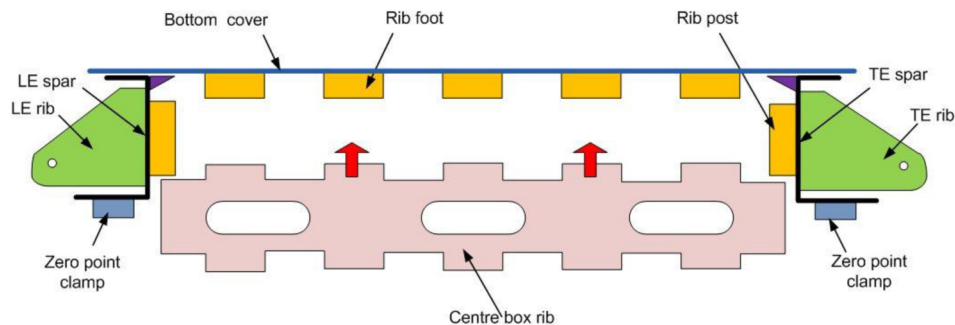


Figure 2. Schematic diagram of wing box rib assembly

SYSTEM EVALUATION

Prior to the wing box rib assembly, the integrated composite structure is placed in its nominal position using zero point clamps as shown in [Figure 2](#). Then load the wing box rib into central modular DE-STA-CO structure 'A' in such a way that the wing rib should be placed on the rib seats which is attached to the structure 'A'. Wing box rib loading side DESTACO structure is called structure 'A' and the opposite side structure is called structure 'B'. Once the wing box rib is in its correct position engage the swivel vacuum cups using the SIEMENS controller. Move the assembly up into the

integrated composite structure until the structure datum on the spar flange (KC of step from spar flange to rib) is achieved. In this position lock-off the manual brake in the four positions to restrict the movement of the structure in the vertical direction.

Move DESTACO structure 'A' so there is contact between the wing box rib and the rib post to give best fit. Then lock the manual brakes in 2 positions to restrict the DESTACO structure 'A' and move the structure 'B' so there is contact with structure 'A' in way of two off electro magnets. Turn the