

Handling of Large Components for Aircraft Assembly Using an Adaptable Network of Different Kinematic Units

Rainer Mueller and Matthias Vette
ZeMA

ABSTRACT

Today's assembly devices used for large-volume components in the aerospace industry are characterized by their inflexibility. This inflexibility is evident by the common use of custom designed rigid structures and specially adapted solutions for a single task. This paper describes an approach for a flexible assembly device, using the example of an aircraft section assembly, capable of integrating and exchanging different kinematic units making it highly adaptable to a variety of assembly tasks and product types. This reconfigurable assembly device uses an integrated measuring system enabling it to handle and assemble different large components with high tolerance requirements.

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INTRODUCTION

Industrial production companies face new challenges from fluctuating demands in quantity, increasing requests for custom built designs, and a growing push for advancements in production technology [1] [2]. In order to respond to these challenges, more flexible production systems are required. This trend is not only visible in the larger consumer goods and automotive production, but also in the aircraft production [3].

In contrast to the production of other industries, the aircraft production is characterized mainly by small quantities and long production life cycles of several decades. Therefore, new assembly systems for aircraft are not continuously developed, whereby new production and assembly technologies are not integrated into production systems until the introduction of a new aircraft type [4]. When considering different types of aircraft, many similarities in the aircraft structure can be seen. In general, the aircraft fuselage consists of several sections as shown in [Figure 1](#). The sections 11/12 consist of the cockpit of the aircraft. Attached to it are sections 13/14, followed by section 15 which includes the Wingbox. The rear of the plane is made up of sections 16-18 and the tail is formed by the section 19 which includes the vertical and horizontal tail surfaces [5]. These sections are constructed with layers of shells, where the number of layers depends on the type of aircraft.

The A320, for example, a three-shell division is used, whereas in the A330/340 and A350 a four shell subdivision is used. The individual shells are joined in an assembly station with longitudinal seams on a fuselage section. To reduce the number of elements to be joined, initial concepts using very long shells with sub divisions were developed. Despite this seemingly similar shell based structure format, assembly systems are designed only for a specific section, and its product variants, of a particular aircraft, and is then used for several decades without major structural changes. To build the first aircraft, for example, when introducing a new model, all production facilities have to be built at the beginning, which requires a very high initial investment. The introduction of new technologies and materials are especially subject to high risk, as these concepts can only be tested in advance to a limited extent. Subsequent modifications and conversions are very complicated and expensive. Another problem is the fluctuation in demand, making planning challenging since it is unknown when and how many aircraft need to be built and which variations will be requested. In addition, it is often unclear whether or not to respond to a growing demand with a scaling of the production facilities and at what point it is worth investing in additional equipment. Due to these problems the aircraft manufacturers are increasingly outsourcing production and assembly work. The trend is towards global suppliers for individual components such as clips, joists and stringers which will grow to include shells and sections in the foreseeable future.

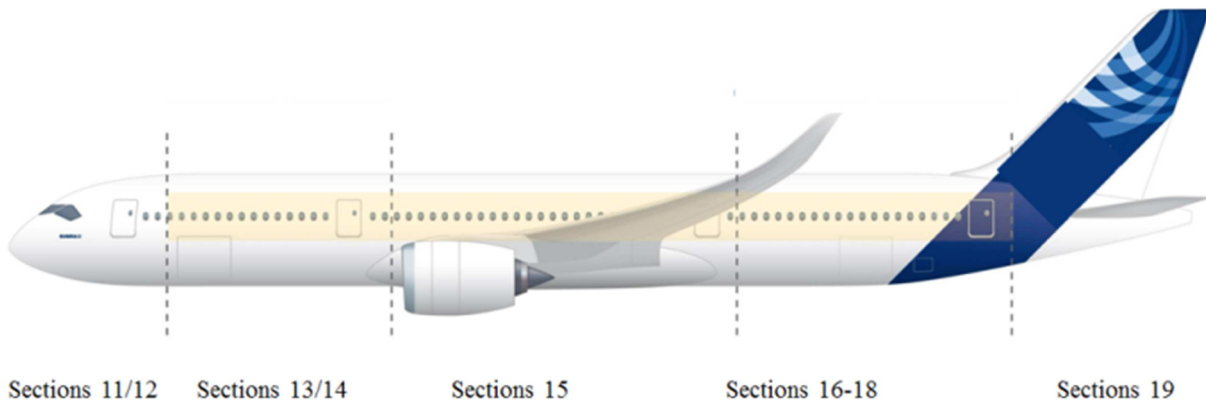


Figure 1. Construction of an Airbus aircraft (similar to Premium AEROTEC)

Due to this development, suppliers will be faced with the challenge to produce preferably short-term, cost effective components at the required quality for different types of aircraft. Due to the large variety of aircraft models, the risk of assembly system downtime is also reduced, since fluctuations in demand of components may be offset by production of another model's components. In addition, by merging different models to a single assembly system, the production volume and the plant efficiency could increase. Therefore, there are similar to the automotive industry - efforts to build up plants that can be chained to a single line system. One advantage of the line is that the advancement of production and the improvements to procedures and processes will be simpler and more transparent. This is expected to result in shorter throughput times and higher quality products, but this line system requires novel adaptability to handle the variations in the aircraft assembly.

ANALYSIS OF THE HANDLING TASK

For aircraft assembly, the scope of work and the joining technologies for the different sections are similar, but the size and shape as well as the number of seams, rivets and rivet types can be quite different [5]. [Figure 2](#) shows a simplified illustration of different types of aircraft with their respective shell subdivisions (three or four sections of the division) and the different dimensions of the individual shells. This can be seen in the A350, whose diameter within an aircraft type is uniform. However, the length of the plane section varies between 10 and 20 m. The transparent sections of the shells show the maximum extension length while the shaded sections correspond to the shortest variants of a type section (see [Figure 2](#)). Not only does the length vary, but also the opening angle of the shell varies, i.e., the proportion of the shell in the perimeter of the section. For example, the opening angle of the bottom shell of the A330/340 in section 14 is almost three times as large as the opening angle of section 17 (see [Figure 2](#)). Today, large rigid devices which support specific areas of the component geometry with the aid of component templates (see [Figure 3 a](#)) are used for the

positioning of the fuselage shells when joining an aircraft section. In order to meet the required tolerances, the devices have to possess a high stiffness and dimensional accuracy that can only be achieved through a massive construction technique. This construction has the effect that the devices are large, heavy and correspondingly expensive to procure. In addition, a device must be designed and deployed for each component. Besides these rigid devices, manually convertible devices and programmable devices (see [Figure 3 b](#)) exist, which can be adjusted automatically. The accuracy of these programmable devices is not replaced by rigid and exact shape elements, but rather by several handling devices, and one or more measurement systems. The measurement system regulates the handling devices and their component fixing equipment continuously in an iterative process until the position of the shell is in the required tolerance. In a variant change, the device can be adjusted accordingly to its process path. Although a certain product type mix can be realized by the previous solutions in system engineering, the existing technology imposes limits to a product model mix, since the individual structural elements of the different planes differ too greatly in shape, size and installation position. Therefore, these flexible devices are not universally applicable. If for example all sections of the A330/340 are to be installed in a plant, the different opening angles (see [Figure 2](#)), and thus the different positions of the gripping points on the component immediately stick out. Despite the same division of four shells per section, the gripping points of the shells are located differently because of the different opening angles so that the handling devices in the current assembly station cannot grip and handle the shell. When considering the A320 model, the difference becomes even more obvious, because the threefold division of the shell, the joined seams are moved. Even a simple conveyance of the shells to the handling devices is no longer possible.

There is a structure of bottom, top and side shells as in the A330/340 and A350, but rather combined lateral and under or upper shells. Customizing the system by only prolonging the traversing axes is no longer sufficient. Instead, the arrangement and grouping of the handling units have to be

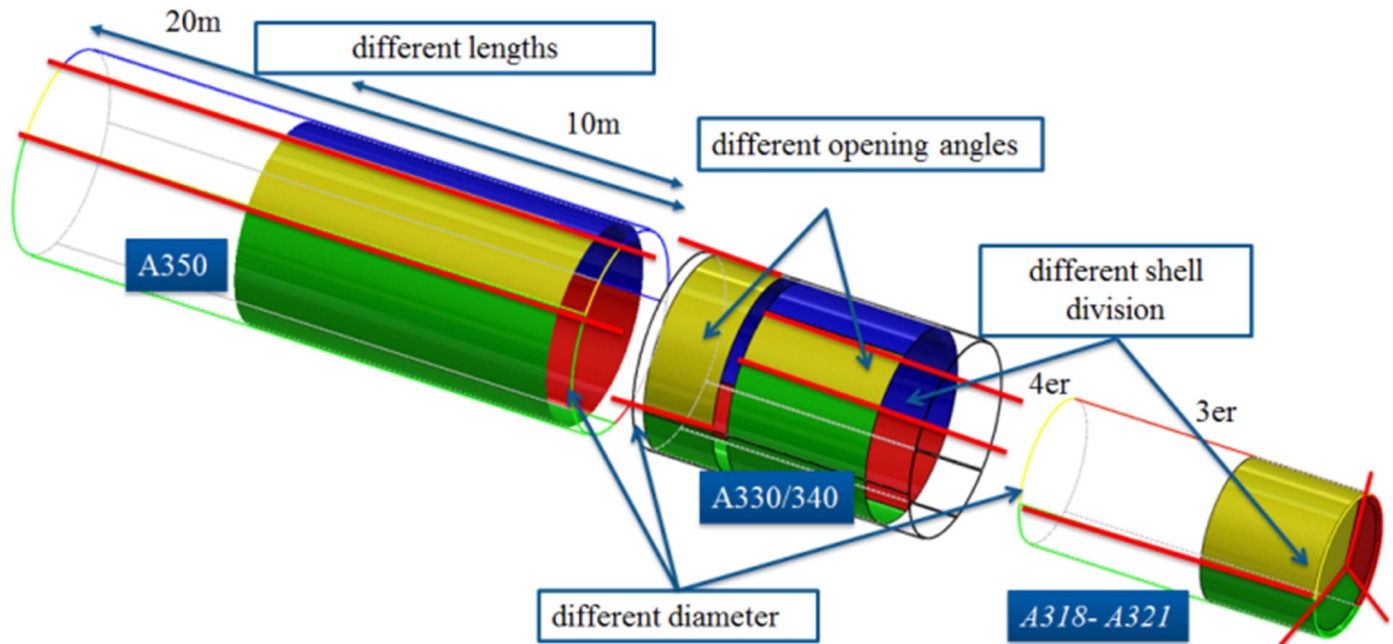
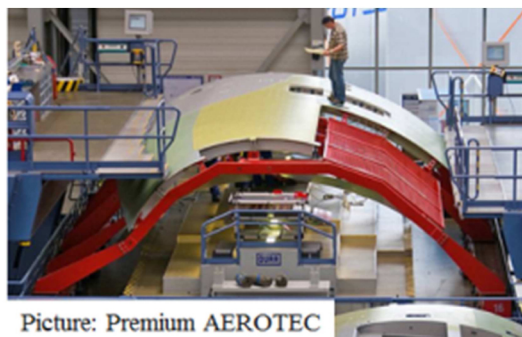
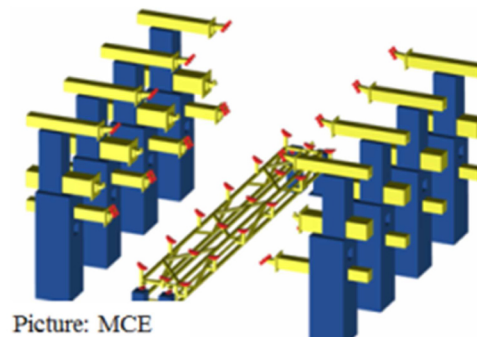


Figure 2. Dimensions of the sections for A318-A321 A330/340 and A350



a) Rigid devices



b) Programmable device

Figure 3. Devices for the handling of large components

changed. From a controlling technology point of view, the handling units are put into groups for the respective shell so that these units can synchronously move a shell together. In an arrangement for a foursome shell division such a rearrangement to a three shell division is not possible because additional passive handling equipment is used for the upper and lower shells. Due to the large component and application spectrum a device is needed that can be extended and adapted according to the task is required. The device has to be scalable and universally usable in order to respond to changing economic and technological influences. Reconfigurable devices that can be equipped to specific tasks are an economical solution. Two different such devices are shown in Figure 4. On the right side the shells are conventionally held and positioned externally by passive or active handling units. In contrast to the programmable

devices, the units can be freely configured on the tower structures and positioned. The ports are designed in a way that the apparatus can be adapted as required for the new task. With the use of rope kinematics to hold and roughly position the shells on the left side, a different approach becomes evident. Ropes hold the main weight of the shell, whereas small handling modules inside the aircraft position the shells exactly. This type of plant does not only handle one type mix, it can also be reconfigured to allow a model mix. It can combine different handling modules with different kinematics in order to realize the required assembly tasks and functions. Thus it is possible to assemble even small quantities and different models economically.