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An Investigation into the Interrelationship between Aircraft Systems and Final Assembly Process Design

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Abstract

Modern aircraft are more integrated with advanced systems functionalities, which result in ever-increasing aircraft complexity, further development difficulties and development delays. These system complexities are mostly in the form of system interactions that make it difficult to understand the overall system characteristics. At the early stages of final assembly line (FAL) design, one of the most important objectives is to arrange the installation and test tasks from components to sub-systems and systems in the proper sequence to meet the designed functions and prevent hazards from the integration process. Improper sequencing of the final assembly process will cause rework, time delays, cost and potential safety risk in development. In the field of final assembly line design, previous research has mostly focused on assembly line balancing or supply chain design based on structural parts assembly. However, these approaches do not consider the early final assembly line definition or test allocation for system functions. In this paper, the research proposes a method based on a systems engineering view and integrated computer aided design (CAD) to help better understand system interactions and generate viable final assembly process sequencing. This research aims to develop a concept of unified master data for final assembly design, which contains 3D geometrical CAD, system functions and interaction characteristics. The paper will present the methodology framework, key concepts and associated industrial software packages for implementation. The paper concludes with further discussion of an initial case study.

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Keywords: Aircraft Systems Integration, Final Assembly Process Design, Integrated CAD

1. Introduction

Aviation industries are making great efforts all the time to develop more comfortable, efficient, reliable, intelligent and low cost aircraft. The development of aircraft systems makes a significant contribution to many of the high-level requirements which are related to advanced functions. As aircraft systems are a typical example of complex system[1,2], the highly integrated system architecture and interactions raise product complexities and cause issues in both design and manufacturing. Thus, systems engineering (SE) is introduced to deal with these complexities and issues. However, Systems Engineering principles and guidelines, for example SAE ARP4754A Guidelines for Development of Civil Aircraft and Systems[3], are mostly covered and applied to systems integration in aircraft system design but not at the manufacturing stage.

In the aircraft system development process, final assembly is recognised as a particular and important development stage. It is the time that individual components are assembled together to build the product from sub-systems, systems to complete aircraft. Therefore, the design and industrialization of modern advanced aircraft is a complex system integration process. There are two main concerns involved in this integration process: firstly, bringing aircraft system design requirements and specifications into the roll-out aircraft through assembly process; secondly, bringing manufacturing strategies, tooling, process capacity and related resources together to balance the cost, time and quality in the form of documented assembly plans. In this field, many previous researchers concentrate on the latter one, assuming that there is a designed final assembly process ready to be used[4]. Some researches try to use knowledge-based solutions embedded into 3D CAD system to improve the process of

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early final assembly line design [5,6]. In addition, the design for manufacture and assembly (DFMA) principle is widely used in assembly system design. Some researchers combine DFMA with digital modelling and simulation to generate assembly sequencing and validate assembly line alternatives[7]. In these researches, the initial FAL process and station allocation are determined mostly by major structural sections join-up processes[8] or directly following the product breakdown structure (PBS)[9]. The relationship between structures and systems, and their relationship to different integration activities in FAL are not fully recognized. Although the importance of FAL design at an early stage is acknowledged, and most previous research applies digital design technologies to improve FAL design quality, they seldom comment on final assembly process design issues from the perspective of system complexities, which are the basis for later development. A method is required to help FAL engineers better understand aircraft system complexities and generate a feasible FAL process at an early stage in the design process.

This paper is structured as follows: Section 2 explains the integrated nature of aircraft final assembly. Then section 3 proposes a design framework based on integrated CAD system, followed by the benefits and challenges in section 4. Section 5 makes conclusions and states future work in brief.

2. Aircraft Systems Integration at Final Assembly Stage

This section describes the complexities of aircraft systems, and how systems are integrated through FAL process, which is the basis for the development of proposed method.

2.1. Aircraft final assembly

The scope of final assembly varies from company to company and from one aircraft to another. This is mainly due to different marketing strategies, manufacturing capacities and aircraft technological specifications. Examples can be found on modern civil and military projects where major section assemblies arrive at FAL with some systems installed by subcontractors or provider[10]. But generally, the main activities and tasks in final assembly can be concluded as: joining major structure sections, installing systems which are not suitable for earlier stage and testing the developing and complete aircraft[11,12]. To limit the scope, this paper assumes that most of system components that can be accessed after structure joining are integrated in final assembly stage. In the FAL design process, tasks are designed and allocated to assembly stations in the early FAL design stage.

Figure 1 shows two main FAL layouts implemented in industry, which are bench layout and flow line [13]. Sometimes bench layout is also known as fixed-position or slant assembly[14], while the flow line layout consists of pulsed-line and continuous moving line. Since the flow line layout is easier for waste reduction and mass production, it is widely used in FAL today.

The layout in Figure 1(b) is a typical pulsed-line organized by stations and normally named with countdown numbers. As each station has an equal takt time, a continuous moving line can be treated as a pulsed-line that includes many stations of short takt time.

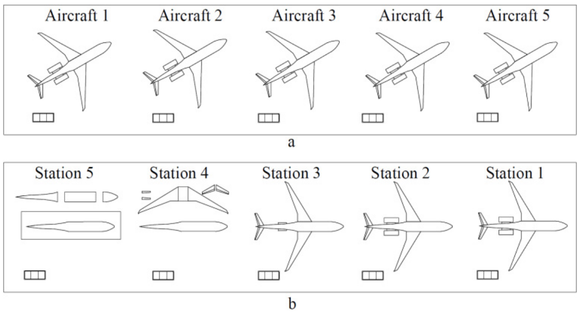

Fig. 1. (a) Bench layout (b) Flow line layout

In final assembly design process, the assembly layout and FAL task allocation are designed in the early development stage, which are concurrent with the product design process in current engineering. If the aircraft itself is treated as a top level complex system, aircraft structure can be considered as one of the sub-system which is the basis for later systems integration. Thus, the main activities of FAL task allocation are to decide the interface between stations. The previous approach that uses structure join-up processes to determine stations is not suitable for a continuous moving line with many stations, because structure join-ups are only a small part of the overall process. A profound understanding of aircraft functions and systems is of importance for FAL design. However, this heavily depends on personal experience because the FAL engineer must fully understand system complexities, and combine systems functions and interactions with assembly processes to determine the best integration sequence for the system components.

2.2. Characteristics of aircraft system integration

An aircraft is a system of systems that can be represented in a hierarchy. In most commercial and military aircraft, the top level sub-systems are defined as structure, vehicle systems, avionic systems and mission systems. Two types of integration characteristics, physical and information based, are found in these sub-systems[15]. Table 1 shows a comparison of integration characteristics for these sub-systems of modern advanced aircraft.

Table 1. Characteristics of integration in modern advanced aircraft[15]

System	Physical integration	Information based integration
Structure	Strong	N/A
Vehicle systems	Strong	Medium to strong
Avionic systems	Weak	Strong
Mission systems	Weak	Strong

It is noticed that vehicle systems show both strong physical and information based integration. This is because vehicle systems like fuel system and propulsion system have strong physical interactions with the structure. Furthermore,