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Assessment of Aero Engine Assemblability during Preliminary Design

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Abstract

Unabated growth of air traffic interacting with increasing competition between the airlines continuously raises the economic pressure in the aerospace supply chain. New products, such as aircrafts and aero engines, have to be designed to match the resulting requirements. Hence it is important to assess production cost as well as producibility of aero engines already at an early stage during preliminary design. Assessing the assemblability is a vital task in this context. The level of design detail which is required to realize such an assessment has been investigated using a low pressure turbine module as an example. It turns out that the level of detail currently offered by many preliminary design tools will have to be increased moderately.

Keywords: Preliminary Design; Aero Engines; Assemblablity

1. Introduction

The paradigms of the aviation industry are changing continuously. During the last decades a change was made from technologically possible towards economically feasible solutions [10]. Reasons for this paradigm shift were decreasing ticket prices, rising crude oil prices as well as the volatility of the industry itself. This resulted in a decreasing passenger yield, as displayed in Fig.1.

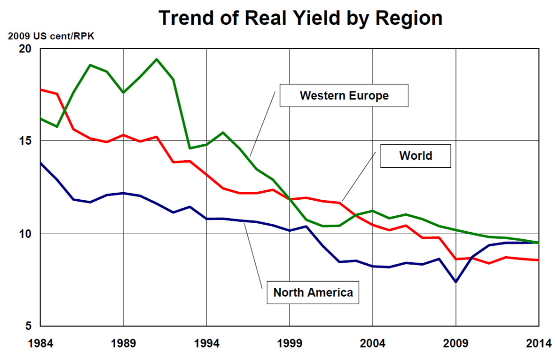

Fig. 1. Historical Passenger Yield [13]

Despite the continuing economic pressure and the volatility of the aviation transport market the global industry grows 5 % annually, a trend that will continue for at least two more decades [5]. Raising ecological requirements and the efforts to lower direct operating cost drive the need for new airplanes. Compared to today's fleet composition, by 2032 the global fleet will consist of 85% new airplanes with respectively new engine technologies [5,21]. This trend is exaggerated by currently low key interest rates, as indicated by Fig.2.

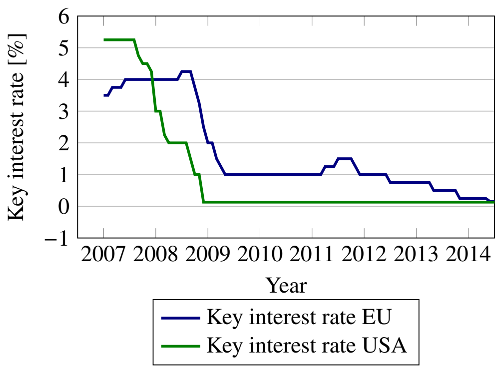

Fig. 2. Key interest rates of the EU and USA [9]

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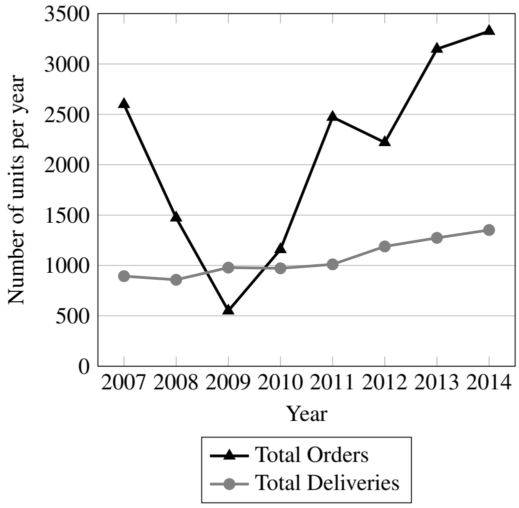

Fig. 3. Combined orders and deliveries of Airbus and Boeing [1,6]

In this context, the struggle of the aircraft industry to deliver the products according to the order books leads to an increasing production backlog (see Fig.3). Long delivery times potentially results in significant order cancellations.

Taking the aforementioned aspects into consideration, an additional paradigm shift in aviation industry is inevitable. Products that were previously considered to be economically feasible need to be industrially producible in the future. In pursuance of this goal a systematic evaluation of assemblability during preliminary design is essential. It is an integral part for the holistic life cycle cost analysis of future aero engine concepts.

2. Preliminary Design Optimization

Future generations of aircrafts and aero engines need to fulfill high requirements regarding emissions [19,23,24]. This goal applies significant pressure on the technology development along the aircraft supply chain. In order to optimize the system "aircraft" with all its sub systems, life cycle cost of aircrafts and engines were closely analyzed to find an optimum operating strategy in the global market [10].

The development process of modern aero engines is capital-intensive and set up in distinct stages [14,15]. Major architectural decisions are made during the preliminary design phase. Thus, the largest potential for life cycle cost optimizations is implied in this stage [3,11]. Furthermore, preliminary design decisions strongly influence the methods of manufacturing and the methods of assembly.

Current work in the context of preliminary design comprises evaluations of the engine architecture, design, performance and emission optimizations as well as weight estimations along with the respective effects on life cycle costs [2,7,11,15,16,23]. Additionally, different aspects of manufacturing were analyzed to assess and optimize the cost of parts and the complete product [2,3,14].

The optimization of aero engine assembly is another major milestone in the quest to increase productivity and reduce life cycle cost. The modularity of modern aero engines has to be the foundation of such investigations. It leads to the fact that final assembly of aero engines is being set up in a takted assembly line. The methods used to optimize aero engine assembly so far are based on commonly known lean principles [8,22]. A feedback of assembly experience into the preliminary design has not been reported as of today.

3. Assessment of Assemblability during Aero Engine Preliminary Design

The challenges of assessing the assemblability during preliminary design are elaborated using the low pressure turbine module of a civil aero engine as an example. A cross section of such a module is shown in Fig. 4.

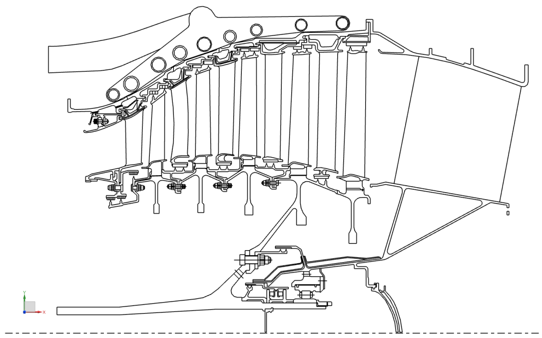

Fig. 4. Low pressure turbine module of a civil aero engine [4]

Typically, such a module consists of about 1,500 single parts. A-Parts such as discs, blades and vanes as well as casings determine the overall architecture of the module. In case of the considered module, they constitute about 70 % of mass as well as 95 % of the cost [2]. Because of their dominant role these parts are represented in state of the art design tools. However, in preliminary design tools A-Parts are represented using a generic geometry [7]. Fig. 5 highlights the A-Parts of the low pressure turbine module.

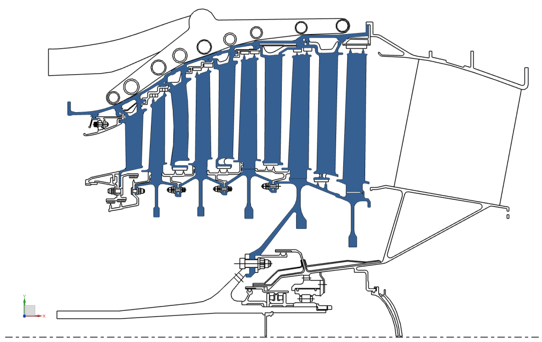

Fig. 5. A-Parts (blue) of the considered low pressure turbine module