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A Methodological Research on the Correlation between the Airborne Part Manufacturing System and Aircraft Maintenance Operations

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Abstract

Aviation is one of the high value-added and well-regulated industry. During the design and manufacturing phase, the aircraft manufacturing companies are focusing on the follow-on-support stage. A commercial aircraft's lifespan is about 35 years depending on the operation conditions. When an airline operation company pays 1 unit to purchase an aircraft, support operations are approximately three times the initial purchase price. In other words, 4 units will be paid totally at the end of the life cycle by the airliner company. In this study, the relationship between the manufacturing and maintenance phase is investigated. It has been found that even a tiny difference that has been done during the manufacturing phase has vital importance on Life Cycle Cost (LCC).

Keywords: Aircraft Maintenance, Intervals, Maintenance Phases, Aircraft Life Cycle, Airborne.

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1 Introduction

Briefly, in this paper, the inter-relation between, designing an aircraft, maintenance activities, and decreasing method of the Direct Operation Cost (DOC) is highlighted.

The process of manufacturing is described as the conversion of the raw material to an end-part that is ready for the market [1]. An aircraft is one of the most complicated manufactured assemblies, which consists of many sub-systems such as Environmental Control System (ECS), avionics systems, propulsion systems, command-control systems, landing gear systems, fuselage, and empennage, etc. As it is shown in Fig. 1. the flap system of an average commercial passenger aircrafts includes actuators, brackets, sheet-metal-formed skin parts, fasteners such as screws, nuts, self-locking nut plates, etc.

Building an aircraft generally requires "engineerity" studies for establishing a chain from parts to components, from components to assemblies, and finally from assemblies to aircraft itself at top assembly.

In the aviation industry, there are some authority organizations such as the ICAO (International Civil Aviation Organization) and IATA (International Air Transport Association). These organizations periodically release reports for enlightening the aviators, academicians, and technical teams. In accordance with the IATA's 2016 Capacity Report, the air traffic has doubled in 15 years since 1977 and it will continue to so. The mobility demand increases dramatically and this demand propels the aviation industry for new technology implementations.

The aviation industry has been expanding its boundaries with the newest and novel technologies. This mobility demand is leveraging the aviation industry and it is the main reason that this industry is called a booming sector against the economic global recessions. Actually, it has to boom because the return-of-investment is very fast comparing with other sectors. Regarding National Academies Press (NAP) reports, the finished value of a commercial aircraft is 60 times bigger than the automotive industry. According to the mentioned report, the automotive industry’s price per pound is $5 while it is $300 in the commercial aircraft manufacturing industry. So it can be easily claimed that there's a loop-cycle in the aviation industry; the income forces the research and development (R&D) activities, and R&D powers the sales.

It should be underlined that every part and component has a different maintenance interval. These intervals are described within the concept of maintainability. Per Raymer et al 1992 [2], the maintainability defines simply the ease with which the aircraft can be fixed. The components and the aircraft's Maintenance, Repair, and Overhaul (MRO) operations must be framed as easy and cheap as possible. It should be considered that the MRO period is unwanted since during the MRO stage aircraft consume money because of Aircraft on the Ground (AOG) operations.

Fig 1. An Aircraft's Flap Assembly Consists of Complicated Sub-Systems and Parts (From Authors' Collection)

2 Material and Method

In this proceeding, methodological literature research has been made and field experience has been reflected in the study in terms of figuring out the correlation between manufacturing and MRO stages of an aircraft. It has been observed that the airline operational companies are focusing on decreasing the MRO operations. Regarding "estimation study", was done by Airbus China that the cost of a grounded A380 is approximately 1.250.000 USD per day [3]. Many collaborations have been established between aircraft maintenance companies and airliners in terms of decreasing the MRO operations. Part 21 G companies also have MRO capabilities depending on the deeply-engineered abilities. Additive manufacturing has a positive impact on Part 21 companies for the MRO activities [4].

The MRO operations are described during the design phase considering lowering the total direct operational cost (DOC). DOC's distribution is provided in Table 1. The MRO operations occupy the 3rd position of the DOC with a percentage of 9,4.

Table 1. The Distribution of Total Direct Operational Cost (DOC) [5]

Case	**%**
Fuel	33,4
Aircraft Ownership	10,6
MRO	*9,4*
General and Administrative	7,3
Flight Deck Crew	6,8
Reservation, Ticketing, Sales and Promotion	6,5
Station and Ground	6,5
Cabin Attendants	5,1
Airport Charges	4,9
Passenger Service	4,2
Air Navigation Charges	4,1
Other	1,2

Albeit, the MRO operations are at the 3rd stage in terms of DOC, during lifespan the cost of MRO operations is 2-3 times higher than ownership prices as it is shown in Fig. 2.

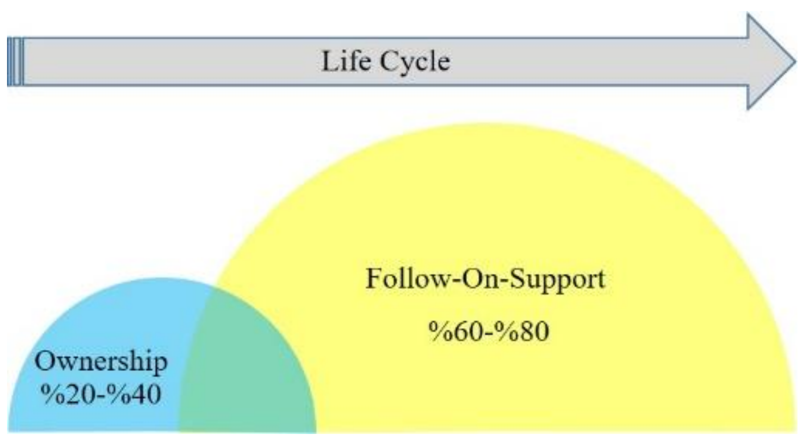

Fig 2. The Ownership and MRO Ratio through the Life Cycle [6]

It is obvious that the aviation-grade materials are highly engineered and comparatively expensive, saving the aviation-grade material has vital importance. So what would be done for manufacturing these high-tech parts and what are the what-to-dos and not-to-dos during the certification process which is executed by the airworthiness authority.

2.1. The Relationship between Airworthy Part Manufacturing and Follow-On-Support Activities

Considering a commercial passenger aircraft's life cycle, the stages are provided in Fig. 3. As it is shown an aircraft's life span is divide into six phases. The MRO documents are created and developed during the first three steps of the life cycle and used during the last three steps.

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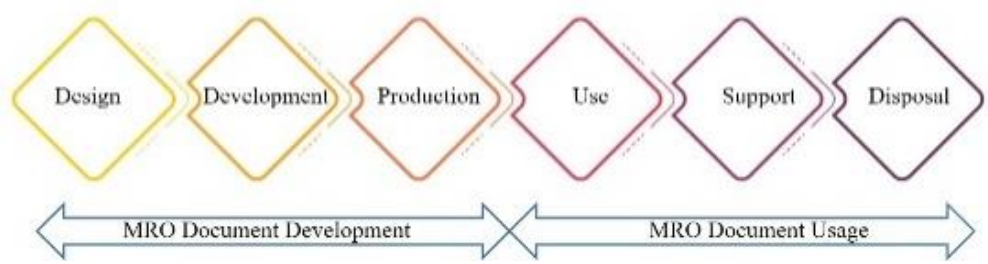

Fig 3. The Life Cycle Steps and MRO Documentation of a Commercial Aircraft [7]

An average commercial passenger aircraft consists of 3-4 million parts that vary by its type. It is noteworthy that, the freighter aircraft would have significantly fewer parts than the full passenger versions. The airworthy parts are manufactured in accordance with the airworthiness authorities' regulations. The airworthiness regulations should be followed independently they are released by local or international airworthiness authorities. In the conclusion, throughout the stages of the lifespan that is shown in Figure 3, all activities should comply with the authorities. While keeping up with the up-to-date documents, the engineers and technical teams should also seek for the manufacturing of the parts that has lower maintenance cost and higher strength.

It should be underlined that the parts are being changed depends on flight hour (FH) and flight cycle (FC) parameters.

The material changes the intervals. The many studies regarding the correlations between rigidity and fatigue damage change in composite structures have concluded that the change in the rigidity of the composite structures helps provide critical information about their structural status [8].

This critical information can be used for the early-determination of fatigue nucleation. It is noteworthy that, the PHM (Prognostics Health Management) and SHM (Structural Health Monitoring) are delivering hopes for early-warning of potential cracks. It is important to evaluate the performance under an expected condition to reduce unexpected failures and plan maintenance activities so they do not disrupt operations [9].

2.2 The Optimization of the Maintenance Operations

In general, aircraft follow-on-support operations are divided into three as scheduled, unscheduled and modification/modernization and life extension program operations. There are sub-categories of the mentioned four divisions as it is shown in Fig. 4.

Fig 4. The Maintenance Operations Categories

It should be highlighted that digitalization is an important issue for the aviation industry, especially for follow-on-support activities like maintenance. Implementation of the new technologies has many benefits such as reducing company overall costs and increasing the revenue. In this manner, the "Digital Transformation Monitor, Industry 4.0 in Aeronautics: IoT Applications" report was released in June 2017 by the European Commission. In accordance with the mentioned report, in the aviation industry, the expected impact of digitalization is - 3.7% in costs and + 2.7% in revenues annually [10].

The aviation industry is famous for its "pioneering feature" for the integration of novel and disruptive technologies. For example, in aviation history, the CAD-CAM and composites were first adopted by the aviation industry. When we put all the pieces of the puzzle it can be easily seen that the aviation industry will adapt the digital transformation before other sectors.

In the legacy aircraft maintenance approach the AMM (Aircraft Maintenance Manual), CMM (Component Maintenance Manual), IPC (Illustrated Part Catalog), and SRM (Structural Repair Manual) are the key-documents for performing the maintenance activities.

3 Discussion

The maintenance documents such as AMM and CMM are used for defining the tasks that would be applied during the operations shown in Figure 4.

Each and every maintenance operation resembles unique tasks for each and every type of aircraft. In other words, the main topics may be the same but as go to details the tasks and sub-tasks should be described with the type of aircraft. Reducing the costs of aircraft is a target since there's a direct correlation between the usage of air Cargo transportation and COTS [11].

In the aviation industry, the amount of passenger and cargo resemble the revenue-generating ratio of a transport operation for airliner companies. While the payload which combines of passenger and cargo reflect the revenue-generating ratio, carrying the airframe, engine, different kind of fluids such as fuel, hydraulic oil, etc, revenue-consuming. In this perspective weight reduction is a key solution for fuel saving.

The "game-changer" materials such as the Carbon Fiber Reinforced Polymers (CFRP), have a direct impact on weight reduction. Also, CFRP based parts feature a variety of benefits on a high strength to weight ratio, improved resistance to corrosion, improved fatigue resistance, and the low cost of maintenance and therefore DOC [12]. The density of steel is about 7.7–8.0 gr/cm3 and aluminum's density is 2.7 gr/cm3 whereas typical CFRP material density is about 1.6 g/cm3[13]. In other words, changing the material from steel to CFRP provides three times lesser weight. This lower density comparing with steel and aluminum while maintaining the same or higher strength makes CFRP a good solution for weight reduction studies. From the optimization side, it is an effective solution. It is reported that Airbus A380 central wing box construction was concluded with weight saving up to 1,5 tons. The upper deck floor beams and the rear pressure bulkhead are the other parts in which materials are converted from aluminum alloys to CFRP [14].

CFRP is also a good solution for reducing the carbon footprint. E.g., for Boeing 747-400 (MTOW is 396.890 kg) with the 1 kg of weight reduction, it is possible to reduce carbon emissions by 0.94 kg. Also, for Airbus A330-300 (MTOW is 242.000 kg) it is possible to reduce carbon emissions by 0.475 kg. Furthermore, a reduction of 1 kg of carbon emissions can also save up to 0.3 kg of aviation fuel [15]. These studies have vital importance because the aviation industry is mainly responsible for Carbon Dioxide (CO2) emissions worldwide with the amount of approximately 2-3% and based on the most current growth forecasts, this figure is expected to double by 2050 [16].

4 Conclusion

In general, in this study it is claimed that;

• There is a direct correlation between design and follow-on-support phases in terms of maintenance operations,

• It is possible to reduce maintenance costs at the beginning of the lifespan of the aircraft,
• Reducing the maintenance cost would power the airliner company against fierce competition since the DOC is lowered,
• With the implementation of the novel technologies into maintenance operations, it is possible to reduce operational while increasing the strength of the part,
• Decreasing the weight of the aircraft has a direct effect on reducing the carbon footprint, so in other words, the weight reduction studies conclude with a positive effect on the environment.

Conflict of Interest

The authors state no conflict of interest

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