THE IMPLEMENTATION OF ADDITIVE MANUFACTURING TECHNOLOGIES IN AIRCRAFT MAINTENANCE, REPAIR, AND OVERHAUL (MRO) OPERATIONS

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ABSTRACT

Chip-away technologies are traditional manufacturing methods based on the principle of taking-out particles from a large workpiece employing cutting tools. Its origins date back centuries. On the other hand, Additive Manufacturing (AM) technologies, the first patent of which was obtained in the 1980s, are based on the principle of manufacturing the final part in layer-by-layer philosophy by fusing or melting the particles, exactly the opposite of the working principle of machining methods. In this study, information is given about the use of AM technologies in aircraft Maintenance, Repair, and Overhaul (MRO) operations. The life cycle of an aircraft consists of design, manufacture, development, operation, MRO, and retirement. The activities in lifespan are mainly Design Organization Approval (DOA/Part 21-J), Production Organization Approval (POA/Part 21-G) or Approved Maintenance Organization (AMO/Part 145), approved by national and/or international airworthiness authorities. In general, the cost spent in the MRO process of an aircraft corresponds to approximately three times the amount of the design and production process. Aviation-grade materials are expensive materials that require high technology both as a material and as a final product. In this manner, “Buy-to-Flight” ratio concept may be underlined. It is a key indicator of the benefit-cost analysis in the aircraft manufacturing industry. It can be defined as the weight ratio between the raw material used for a part and the weight of the end-part itself. With the implementation of additive manufacturing technologies, the buy-to-flight ratio can be as low as 1:1 while it can be as high as 33:1 in some cases with legacy chip-away methods. In other words, it is possible to obtain the final product in the weight of the raw material placed in additive manufacturing. In this study, information will be given on the use of additive manufacturing technologies in the "Just-In-Time Maintenance” process within the scope of MRO activities.

INTRODUCTION

Additive manufacturing technologies are allowing the manufacturers to go from CAD file to end-part. While using AM techniques, the core of the whole process is creating a CAD model. The CAD model initiates the whole process as shown in Figure 1.

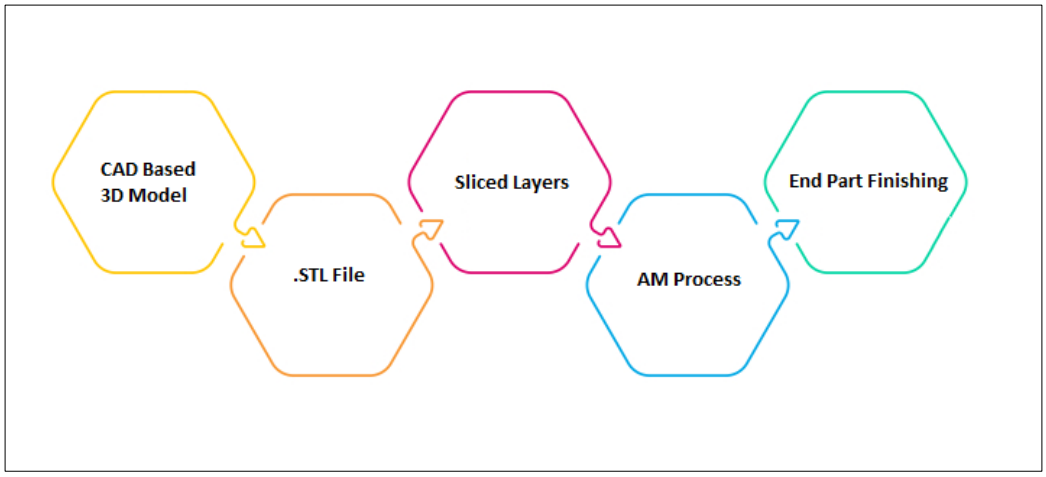

Figure 1. Process Steps of Additive Manufacturing

This model is considered as a digital copy of the original version of the part planned to be produced. A CAD model is a file structure that can always be modified more precisely. In order for the part to be produced with the additive manufacturing method, the CAD model is generally converted to Standard Triangle Language (STL) format. The ".STL" format, converts the CAD model into the most optimized structure in standard triangles. Then the data in the STL file is converted into layers. This step is called slicing. The purpose is based on the principle of additive manufacturing, which makes manufacturing in layerwise philosophy. After slicing, the processing of the piece on the additive manufacturing machine is started. EU processes are used extensively in the aviation industry, especially in the manufacturing stages.

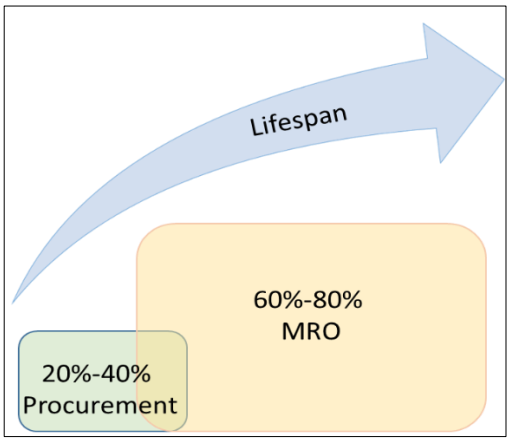

Figure 2. Procurement and MRO Portions During Lifespan

MRO activities have a cost of approximately 3-4 times higher than the cost of procurement in an aircraft's lifespan [1]. It is accepted that the average life cycle of a commercial passenger aircraft is approximately 35 years depending on operational Conditions [2]. It is noteworthy that, not only commercial airlines but also the military aviation industry is under constant pressure to accelerate aircraft MRO activities, to reduce costs, and get the aircraft ready to return to the skies as quickly as possible. It is considered that the reason for this pressure is the need for sortie generation.

3. MRO ACTIVITIES

In general, the scheduled maintenance activities can be categorized into four groups. These are, scheduled, unscheduled, modernization, and life extension programs. It is obvious that these activities vary depending on the type of aircraft. It is worthy to note that unscheduled maintenance activities are generally based on the sudden malfunctions encountered during operations.

Unscheduled maintenance is the unforeseen maintenance that occurs in the air, during taxi, or pre-flight maintenance (Walk-Around Check, Quick Check, etc.). The materials needed in these maintenances are generally calculated based on the Failure Frequency (Mean Time Between Failure-MTBF) data. However, in some cases, it is possible to encounter malfunctions that are not included in the data. Lastly, the modernization and life extension programs are subject to high-level decision-making.

3.1. A-Level Maintenance / Line Level Maintenance (A-Check)

It is the most basic maintenance activity. There is no need to take the aircraft to the hangar during this maintenance period. It is the maintenance that can be done while the aircraft is in the parking area. For this reason, it is called line-level maintenance.

3.2. B and C - Level Maintenance / Base Level Maintenance (B and C Check)

It covers the basic and detailed maintenance operations performed at the base level. It includes more extensive maintenance operations than the line level. In the level, it is also possible to carry out the operations of the back shops such as landing gear, hydraulic, propeller, etc. where the units are maintained on a component basis.

3.3. D - Level Maintenance / Depot Level Maintenance (D-Check)

It is the maintenance phase where maintenance operations are carried out beyond the line and base maintenance. At this phase, the most detailed maintenance of the aircraft is performed. It is generally considered as the maintenance period in which aircraft manufacturers are directly involved.

In the open literature, it is stated that planned maintenance is carried out in three main categories, as many maintenance operations in B-level maintenance are transferred to A and C-level maintenance operations [3].

3.4. The Technologies Used During MRO

It is obvious that the airplanes and their components are designed for extraordinary conditions that require the integration of novel manufacturing technologies. These challenging features need overall technical development, that's why the aviation industry generally determines the technological level of the countries [4]. Besides, the mentioned extraordinary conditions lead the aviation industry as a pioneer for the implementation of the water jet cutting process, CAD-CAM technology, composite-based structural parts, additive manufacturing [5,6,7]. Conventionally, machining processes have been used widely in the aviation

industry. In other words, replacing additive manufacturing with conventional chip-away techniques will take a significant time.

4. THE IMPLEMENTATION OF ADDITIVE MANUFACTURING TECHNOLOGIES IN AIRCRAFT MRO OPERATIONS

As mentioned earlier, if an aircraft is subject to unplanned maintenance, it is usually not possible to keep the spare part in the warehouse. In some cases, the lead-time of the needed spare part takes too long and the AOG process of the aircraft is prolonged. The prolongation of the Aircraft on the Ground (AOG) is considered as the delay of the aircraft from the operation in a sense, and the financial figure of this situation is generally high.

In this context, it is considered that additive manufacturing is very useful in terms of minimizing the lead time of the part production and reducing the AOG time. For example, Etihad Airways Engineering approved maintenance organization and EOS company, which is the manufacturer of additive manufacturing machines and produces parts with these machines as an approved organization, cooperate by signing a strategic agreement [8]. Similarly, a cooperation agreement was signed between Emirates Engineering Maintenance and 3D Systems Inc. an EU-based company to reduce maintenance costs of Emirates. Moreover, the monitor frames of Airbus and Boeing aircraft in the fleet of Emirates Airlines are produced and assembled with flame-resistant nylon-12 thermoplastic material by 3D Systems Inc. [9]. At the same time, Airbus and Belgium-based EU manufacturer Materialize made an agreement with Singapore-based SIA Engineering Company (SIAEC) for the production of aircraft with EU [10,11]. In addition, Airbus has signed an agreement with the Israeli company Stratasys for the production of many parts of the A350 XWB model aircraft [12]. In the military field, flaperon spars of F-35 aircraft were produced by the Electron-Beam Direct Melting (EBDM) method, one of the additive manufacturing methods, between Lockheed Martin company and Sciaky company. With this study, it is predicted that US$ 100 million will be saved throughout the life cycle of the F-35 aircraft [13]. Eventually it can be claimed that the additive manufacturing technology will be a game changer in the MRO field.

As presented in Figure 3, it is observed that cost-effective solutions have emerged thanks to the cooperation of aircraft maintenance and production units.

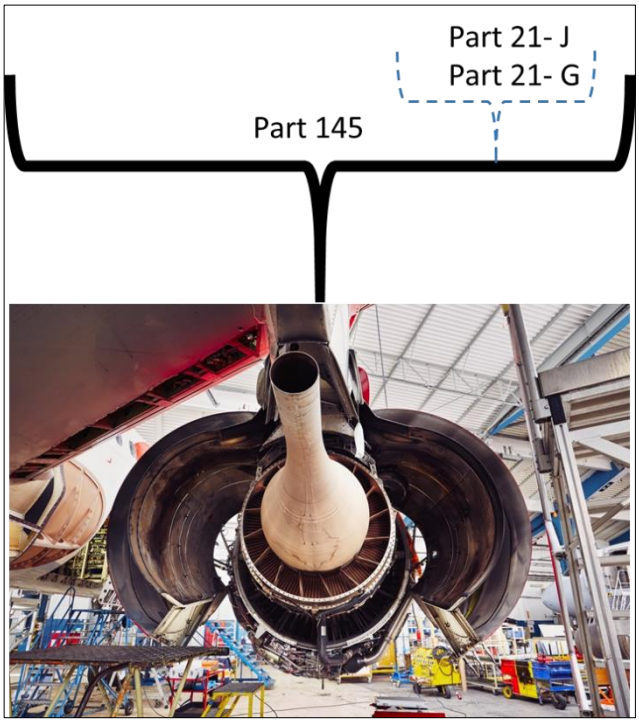

Figure 3. The Cooperation Between Part 145 and Part 21 Organizations

5. CONCLUSION

EU technologies are rapidly replacing traditional production methods. It is observed that the companies producing in the field of aviation have evolved their processes to the additive manufacturing method. The Direct Operational Cost (DOC) is an important role player in an airliner company's income. The fuel consumption, the initial price of the aircraft, and MRO are the three top drivers of DOC. In this manner, reducing the maintenance cost will propel the airliner company against its competitors in the fierce competition market.

"Just-In-Time Maintenance" can be described as taking a piece of part and equipment off-line for maintenance services when it needs it, rather than obtaining a huge warehouse. The additive manufacturing capability – when it is registered by national and/or international airworthiness authorities- will be very beneficial for manufacturing the parts needed "Just-In-Time Maintenance" concept. In this context, it is foreseen that there will be more cooperation by aircraft part manufacturers and aircraft maintenance organizations in the future.

CONFLICT OF INTEREST

The authors state no conflict of interest

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