The Manufacturing and Qualification Methodology of the Aviation-Grade Parts

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Abstract

The aviation industry still attracting the academicians and technical teams with its unique structure. National Academies Press (NAP) declares that the added value of an airworthy part is sixty times more than its equivalent in the automotive industry. In another meaning, a screw that is used on an aircraft has sixty times more price of the same one in a car. On the other hand, aviation is an industry that has stiff regulations since it is worldwide and has a precise process. Since the aviation industry adheres to rigid requirements, the qualification of an aviation-grade part is very important. In this study, the information regarding the manufacturing techniques and qualification methodology of the aviation-grade part will be provided.

1. Introduction

The aviation industry is a well-framed and well-regulated industry that is governed by the International Civil Aviation Organization (ICAO) under the United Nations (UN). As it is shown in Figure 1., there are some regional authority bodies such as the Federal Aviation Administration (FAA) that is originated in the USA and European Aviation Safety Agency (EASA) that is originated in Europe.

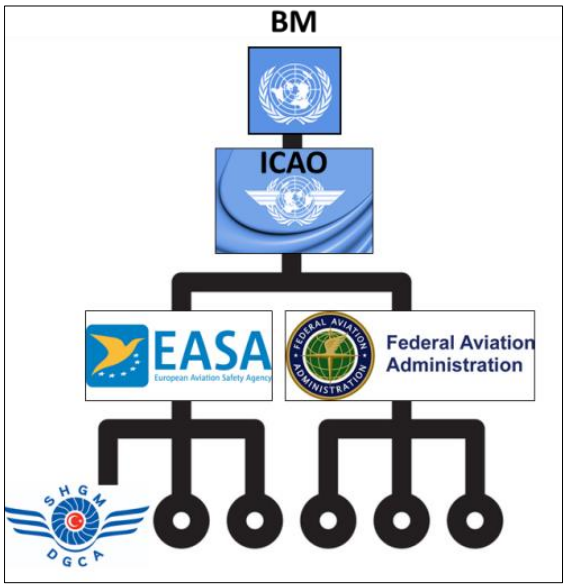

Figure 1. Hierarchical Depiction of Airworthiness Authorities (Saraçyakupoğlu, 2020)

Additionally, every country has its own local airworthiness authority to ensure aviation safety. These local airworthiness authorities are called as Country Airworthiness Authority (CAA). For ensuring aviation safety, both international authorities and local authorities put stiff regulations to define manufacturing, maintenance, and training activities. These regulations include certification and production approval, airworthiness of aircraft, certification of aircraft personnel, facility, and other safety-related matters.

For the approval of a company, some audits are executed by authorities. As these audits are satisfactorily completed, the candidate company may gain the privilege of manufacturing a part on the aircraft.

A part on the aircraft may be called as;

- Aviation grade part,
- Airworthy part,
- Airborne part,
- Ready-to-take-off part,
- Flight-ready part,
- Flight-grade part,
- Aviation-grade part.

2. Work and Methods

2.1. System Audits Executed By Airworthiness Authorities

After initial approval, it is a must for the manufacturer company to pass the periodic continuing audits successfully. As it was mentioned before, any major failure may result in the interruption of the mass production line. For example, after two fatal accidents of Boeing 737 Max aircraft killing 346 people in total, EASA, FAA, and many CAA's stopped all the operations of Boeing 737 Max. Many aircraft have been waited as Aircraft on the Ground (AOG) status with the force of authorities. The investigation reports showed that the problem was originated from the Maneuvering Characteristics Augmentation System (MCAS) which was newly designed and implemented to Boeing 737-Max aircraft against excessive Angle of Attack (AoA) trend that causes the vertical instability (Saraçyakupoğlu, 2020).

ICAO makes safety studies and expresses some warnings that the new technology and new concepts may impact aviation safety negatively unless they are not matured enough.

2.2. Manufacturing Technologies Used in the Aviation Industry

The manufacturing can be described as the conversion of the raw material to an end-part that is ready to market. There are many manufacturing techniques while five of them are the most commonly used ones (Esmailian, Behdad, & Wang, 2016). These are;

- Joining Technologies:

The parts are produced with joining techniques such as welding, riveting, etc. A welded surface of a vehicle can be a good example of this technology.

- Cutting Technologies

The parts are divided into smaller parts with the saw machines, waterjet machines, etc. A cut aircraft composite skin part can be an example of this technique. Abrasive Water Jet (AWJ), provides more sensitive surfaces when it is compared with other cutting techniques (Saraçyakupoğlu, 2019). It is noteworthy that, Boeing uses 5-axis AWJ machines as standard ones since, Abrasive Water Jet (AWJ) has the prevention capability of delamination, splitting, and edge scratches (Shengxiong & others, 2017).

- Chip-Away Technologies:

Milling machines, turning machines (Lathe), and drills are the machines used for chip away techniques. A bulkhead that is manufactured with a 5-axis milling machine can be an example of a chip-away manufacturing technique.

- Form Changing Technologies:

Sheet metal forming, forging, or casting processes are used for form changing manufacturing techniques. In this technique, there's no chip so the raw materials weight and the final product’s weight are almost the same.

- Additive Manufacturing Technologies:

This technique is a newly developed technology that has been used for almost three decades. In this technique, parts are produced layer by layer. It can be thought of as the opposite of the chip-away technique.

Additive Manufacturing is a quite new technology that is defined as a disruptive one. With its novel structure, additive manufacturing changes the paradigm of production techniques. It is based on the conversion of three-dimensional geometries into simple two-dimensional layers hence it provides opportunities for the production of complex parts. The open literature documents give clues that, additive manufacturing is taking place of conventional subtractive techniques.

As a novel and disruptive technology additive manufacturing is an approach that provides opportunities for reducing the weight while maintaining the same mechanical features. Sometimes modern technologies require materials that have unusual combinations of properties that cannot be provided solely by metals, polymers or ceramics (Yasa & Kivilcim, 2018).

2.3. The Part, Component, Assembly, and Top-Assembly Relation

For manufacturing methodology, the chain of part, component, assembly, and top-assembly relation should be understood. A standard commercial aircraft consists of 3-4 million parts depending on its type. It should be underlined that the freighter aircraft would have significantly fewer parts than the full passenger versions. The components are made of parts and the assemblies are made up of components. As it is shown in Figure 2, the aircraft, itself is the top assembly which consists of;

1. Structural Parts (Longeron, Spar, Rib, Bulkhead, etc.)

2. Standard Parts (MS Fasteners, NAS Fasteners, screws, nuts, self-locking nut plates, etc.)

3. Consumables (Tyres, fluids such as hydraulic and hydrazine, etc.),

4. Commercial-Off-The-Shelf (COTS), (Actuators, CVR, FDR, upholstery items, yoke, etc.)

5. Loose-items (Such as plugs and software etc.)

Figure 2. The Consisting of an Aircraft

2.4. The Break-Down Structure of a Landing Gear

In a landing gear system which is shown in Figure 3., the shock-strut and other load-carrying parts are the structural parts. The screws, nuts, and other fasteners are the standard parts used on the landing gear. The hydraulic fluid that transfers the force is a consumable. The actuators and customized switches are the COTS parts and finally, the plugs on the pipes and hoses are the loose items. From the manufacturing pyramid point of view, the piston and piston pins are the parts, actuators are the sub-assembly, and the landing gear system is an assembly. Finally, the aircraft is the top assembly.

Figure 3. The Landing Gear of a Commercial Passenger Aircraft

3. Results and Discussion

3.1. Manufacturing Pyramid in the Aviation Industry

From bottom to top the manufacturing of an aviation-grade part has its own unique flow. The parts are at the bottom while the top assembly is the aircraft itself as was mentioned previously. It is noteworthy that there are some similarities between common manufacturing lines and airborne part manufacturing lines in terms of the plant-layout and lean-manufacturing line. Before providing information about aviation-grade parts manufacturing the manufacturing pyramid of the top assembly is an essential issue.

3.2. Design Organization Approval (Part21-J) and Product Organization Approval (Part 21-G)

Basically, the life cycle of a part is divided into six phases. At it is shown in Figure 4, these phases are:

- Design
- Production
- Development
- Operation
- Follow-on-Support
- Disposal

Figure 4. The Phases of a Product Life Cycle (Szabo, Koblen, & Vajdová, 2017)

In the aviation industry, for a company that designs the aircraft part, there are some requirements that must be met. This certification process is called Design Organization Approval (DOA).

Similarly, the airworthiness authority makes audits for certification for manufacturing. This certification process is called Product Organization Approval (POA).

4. Conclusion

The airworthiness authority executes the system audits and inspections if the company has the capability of designing the aviation-grade part. To understand this, airworthiness authority makes detailed inspections on organizational structure, working environment, accreditation of management personnel, control of tool and equipment, Certificate Release Staff (CRS) validation, facility requirements, Protection of design and manufacturing data.

As a result, a company that is a candidate for designing and manufacturing aviation-grade part should follow the stiff regulations of national and international airworthiness authorities.

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