SELECTED ASPECTS OF AVIATION EQUIPMENT DISPOSAL ISSUE

Ivan KOBLEN,[*] Libor TALPAŠ,[*] Ján JURČÁK[**]

[*] Faculty of Aeronautics of Technical University, Košice, Slovak Republic , [**] Cadets Company Commander, Armed Forces Academy of General Milan Rastislav Štefánik, Liptovský Mikuláš, Slovak Republic

***Abstract**: The main aim of paper is to inform on importance and selected aspects of aviation equipment disposal issue. The first part of paper describes the system life cycle stages, including disposal stage and its specifics. The authors are focusing on the explanation of the main reasons and possibilities in the disposal aviation equipment area. The paper inform on the aim and mission of the main global aircraft producers effort and initiatives in this area - Aircraft Fleet Recycling Association (AFRA) as a Boeing initiative and PAMELA (Process for Advanced Management of End of Life of Aircraft) project as an Airbus initiative. Due to importance of composite material, which will be the main structure material of future aircraft, the author introduce selected information on aerospace composite recycling issue.*

***Keywords**: life cycle stages, disposal, aviation equipment, dismantling, recycling, composites, projects.*

1. INTRODUCTION

The progress of air transport have brought many advantages and also some disadvantages. Every airliner must have a plan of disposal aircraft from their aircraft's fleet. The age of an aircraft depends on factors including the chronological age, the number of flight cycles, and the number of flight hours. Although the aviation equipment is repaired, each aircraft reaches the point where further maintenance will lead to economic losses, inefficiency and unreliability of the aircraft.

2. LIFE CYCLE STAGES

Every system-of-interest, including aviation system, has a life cycle. The main document regarding the system life cycle issue is the international standard ISO/IEC 15 288 "System Engineering-System Life Cycle Processes". In accordance with this standard the whole system life cycle is dividing into a set of six stages consisting of relevant processes and activities (ISO/IEC 15288):

- Concept;
- Development;
- Production;
- Utilization;
- Support;
- Disposal (Retirement).

Each stage represents one essential period of the life cycle of a system. The partitioning of the system life cycle into stages is based on the practicality of doing the work in small, understandable, timely steps. Stages, in addition, help address uncertainties and risk associated with cost, schedule, general objectives and decisions making. Each stage has a distinct purpose and contribution to the whole life cycle.

The above mentioned stages of system life cycle are valid also for the aviation equipment, but we must take into account the particular specifics towards both the upgrading /modernization process (which would be started during appropriate time of operation (utilization), not closely before end of aircraft technical life) and process of aircraft aging /reaching the aircraft end-of life point limit.

Very frequently the process of aircraft modernization (with aim to meet the new requirements, to replace aging and unreliable equipment and components, to increase aircraft reliability, maintainability and sustainability, to reduce the total life cycle cost a.o.) has been linked with process of technical life extension.

The life cycle thinking from Production stage is shown on Figure 1. The production stage starts when the raw material is extracted and processed to the particular material. Manufacturer of aircraft and aviation equipments continues in the following activities: product design, product manufacture and parts assembling. After production and testing the product is sold to airliner. Airliner starts the Operation (Utilization) and Support stages. The aircraft is used for purposes for which it was designed and manufactured. When the aircraft reaches the end-of life point limit, the Disposal stage is started. Every assigned organization and participant is responsible for the particular life cycle stage and relevant processes and activities during this stage.

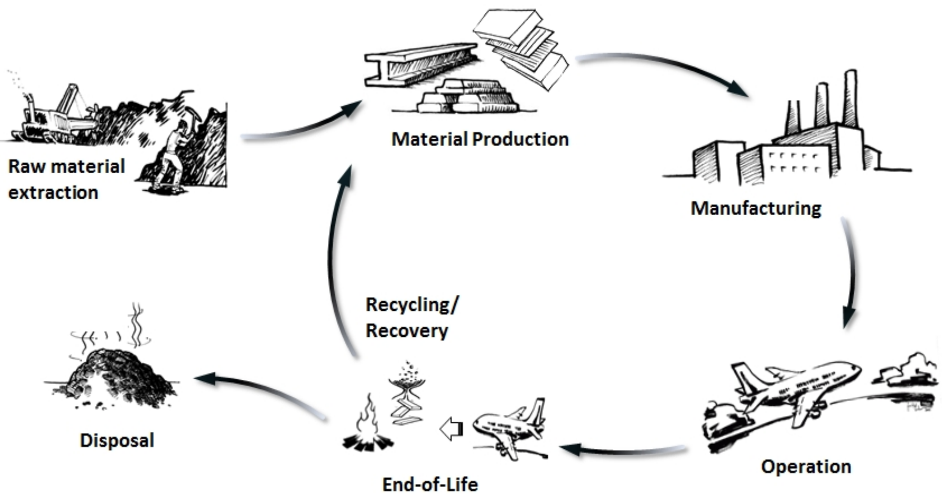

Fig. 1 Life cycle stages from production stage

3. DISPOSAL OF AVIATION EQUIPMENT -THE MAIN REASONS AND POSSIBILITIES

Each product (include aircraft) passes a life cycle. The process of disposal of the aircraft is the final phase of the life cycle. Like all products, civil aircraft come to the end of their useful working lives. The reasons for this may include:

- Increasing maintenance (operating) and repair costs;
- Difficulties to meet new/changed legislative and environmental requirements;
- Difficulties to meet upgrading requirements and expensive technology upgrades;
- Difficulties with the production and procurement of spare parts;
- Increasing content of time or service expired parts;
- Decision to replace the obsolete aircraft or to replace aircraft fleet from other reasons (ineffectiveness of fleet, low demand of air transport, accidents, et cetera).

Currently over 2,000 aircraft are in storage world-wide, and the number of military aircraft in storage is considerably greater. Over the next 20 years, approximately 5,000 commercial airliners are expected to be withdrawn or retired from service at a rate of approximately 250 per year (Towle, 2007).

Current technological development has meant that there is a situation where a moral depreciation is not identical to the physical depreciation. Science and technology plays a major role in determining the end of life value of an aircraft.

As with any product, an aircraft depreciates in value with time. The reduction in value arises from a number of factors including the increased cost of maintenance, repair and upgrading to comply with legislation. At some stage, maintenance, repair and upgrading become uneconomic and at this point the owner will consider taking the aircraft out of service. The term „*End of Life Management Framework*“ has been used and applicable in this specific issue.

When the aircraft reaches the end of technological life, the owner of aircraft in cooperation with aircraft producers has the following possibilities:

- the aircraft is stored at the special parking areas or at the boneyard;
- the aircraft is stored, the usable parts are taken out and then will create a wreck;
- the aircraft is disposal and usable parts are recycling.

Many aircraft owners are trying after reaching the end of aircraft technological life to find a new operator or new owner. If no new operator is found before the aircraft's last service flight, **the aircraft** will often **be stored** somewhere waiting for a new user, sometimes for years. Fact is that the value of the aircraft will decrease over these years, parking fees and maintenance costs have to be paid and the condition of the aircraft worsens. The biggest cost factor, however, is the cost of ownership.

The longer an aircraft is parked, the harder it will be to obtain a good price. Especially when more and more of that type of aircraft are withdrawn from service and are offered on the market. Storing an aircraft is expensive and will often result in selling the aircraft for a value lower than could be reached when disassembled directly after the last flight, especially when the cost of parking, until the aircraft is sold, is incorporated in the financial balance. The largest **boneyards** are in deserts (Figure 2), because the progress of corrosion in hot and dry places is slighter than the places with normal or wet climate. The other benefit or reason why the aircraft are storaged at the boneyards is a visual pollution. These boneyards are usually too far from the cities. The boneyards have been in operation from 1950s.

Fig. 2 Boneyard in Mojave desert, California

The better solution of disposal is salvaging of aircraft. The **ecological disposal, dismantling, recycling and re-using** of aircraft´s parts from global view started in first years of this century.

In the case of dismantling of aircraft it is possible to sell the components under the owner's supervision, directly after aircraft last flight. It might very well be possible that the component value of the (parked) aircraft exceeds its market value as a flyer. The decision between selling and dismantling the aircraft should be primary made on economical drivers.

4. MAJOR GLOBAL AIRCRAFT PRODUCERS PROJECTS IN AVIATION EQUIPMENT DISPOSAL ISSUE

Major global aircraft producers created a special projects focused on aviation equipment disposal issue and take the initiative to establish international organization for dismantling aircraft in an efficient and environmentally-sound manners.

4.1 AFRA. AFRA (Aircraft Fleet Recycling Association) is a Boeing initiative. AFRA comprises a voluntary group of companies and individuals that have agreed to work in a cooperative fashion to provide full aircraft product life cycle capability. AFRA is recognized as the leading global industry association (members of this Association are the global leaders of aircraft recycling, dismantling and reusing) dedicated to pursuing and promoting environmental best practice, regulatory excellence and sustainable developments in aircraft disassembly, as well as the salvaging and recycling of aircraft parts and materials. In this regard the AFRA´s aim is to demonstrate that the 90 to 95 percent of aircraft components are recycled. The AFRA main goal and mission is the sustainable management of end-of-life airframes and engines and to create the conditions for co-operations with industries and governments. This Association collates, consolidates, promotes and publishes the collective experience of its members in its Best Management Practice (BMP) Guides for Management of Used Aircraft Parts and Assemblies. This document is a guide for the AFRA members.

4.2 PAMELA Project. PAMELA (Process for Advanced Management of End of Life of Aircraft) is an Airbus -initiated project to test environmentally-friendly recycling procedures with retired airliners. This initiative is supported by the European Union's LIFE (l'Instrument Financier pour l'Environnement) programme. The objective of the PAMELA project is to ensure that end-of life aircraft do not end up visibly corroding and polluting airfields, degrading the environment and brand image. The project aim is to demonstrate that between 85 and 95 percent of airframe components can be easily recycled, reused or recovered.

Equipment and products such as the electronics system, tyres, batteries, CFC (chlorofluorocarbon) and hydraulic fluids from aircraft have to go through a controlled processing channel. Also serviceable, working spares and components recovered from end of life aircraft will be catalogued and tracked as they are put back into the second hand parts supply chain. PAMELA will also help launch a European network to disseminate information about commercial airframe dismantling at their end of life.

Airbus and its partners had built a dedicated dismantling facility at Tarbes airport in France to undertake the project and plan for this facility to become a centre of excellence for commercial aircraft dismantling and recycling. Figure 3 shows the aircraft disposal process map.

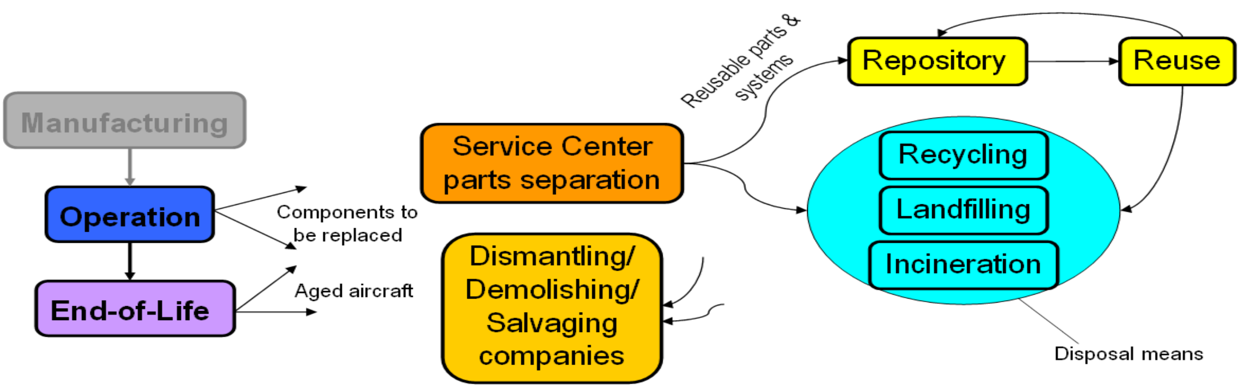

Fig. 3 Aircraft disposal process map

5. COMPOSITE RECYCLING

The importance of aerospace composite recycling is increasingly owing to the rapidly increasing use of these materials in the commercial aerospace sector. Future products from Airbus, Boeing, Embraer, etc are announced to use up to 50 % unladen weight of polymeric based composites in their primary structures. These type of materials currently pose very significant recycling and recovery challenges.

The end of life problems concerned with composites are set to increase and new approaches and technologies to resolve composite end of life problems must start to be developed now. The increased use of composites is driven by weight reduction, reduction in the number of components, reduced maintenance costs and potential improvements in fatigue behaviour. It has been suggested [3] that by 2020, the use of composites will give production aircraft of that date a fuel burn advantage of between 10% and 15 % over their year 2000 counterparts. The A 380 has been manufactured from the **GLARE** (a glass fibre and aluminium composite) material (for the upper fuselage section and horizontal tail section) and widely has been used fibre reinforced plastic (**CFRP**) composite (for the central wing box and in parts of the fuselage). One of the major reasons that GLARE was chosen is its resistance to fatigue crack growth and a density reduction of 10% compared to conventional aluminium alloys.

Figure 4 shows the increasing of using of composites in Airbus aircraft. When the A300 model had less than 5 % composits on total weight, the A380 model has 22 % composits on total weight of aircraft.

The Boeing 787 materials design is based substantially on carbon fibres in an epoxy resin matrix for the fuselage and a composite wing. New production techniques have been developed to produce the composite fuselage, including composite fuselage sections 6.7m long and nearly 6m wide, carbon fibres. Approximately 50 % of total weight are composits. Figure 5 shows the material design of Boeing 787.

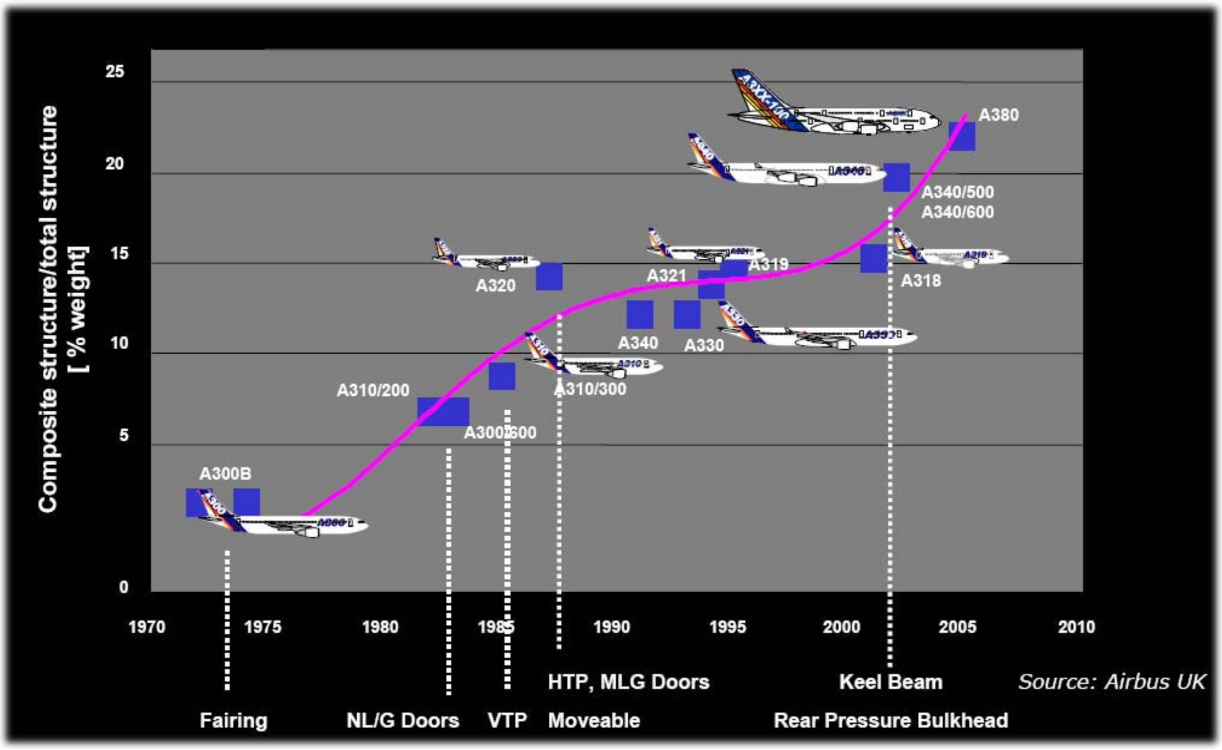

Fig. 4 Increasing use of composites in Airbus aircraft

Fig. 5 Composite use in the Boeing 787

The main advantages of composite materials are high strength, resistance, excellent fatigue properties, low modulus of elasticity and good chemical resistance. Composite materials also offer economic benefits for long-term using. The most advantage for airliners is less resistance to airflow, which means a lower specific fuel consumption. These materials are important not only for manufacturers or airliners, but they are very important for companies, which provide dismantling, disposal and recycling procedures. It is necessary to support development of the composits recycling. The composit´s storaging in a landfill is not a optimal solution.

There are now a lot of European funded research projects, which are looking for develop commercially viable routes to recovering carbon fibres from thermoset composites such as the work undertaken at INASMET Tecnalia in Spain. This work investigated three potential recycling techniques (Towle, 2007):

- a nitric acid treatment to dissolve/remove the thermoset resin;
- thermal pyrolysis;
- an incineration process.

The best technique for composites recycling was determined pyrolysis which provides relatively high quality of recycled composites. Economic efficiency of recycling will increase because the implementation of composits in aviation industry will increase.

Carbon fiber used in the aviation industry has achieved higher quality level in comparison with carbon fiber used in the automotive industry. The processing of 1000 t of waste per year can recycle up to 600 t of carbon fibers. The quality of recycled carbon fiber from aircraft is higher than the new carbon fiber used in the mobile phones, computers or sports equipments´s production and recycled carbon fiber is cheaper.

6. COMPOSITE RECYCLING

The process of disposal of the aviation equipment as the final phase of its life cycle is very important due to several factors and reasons. These factors must be take into account not only during the processes and activities as part of disposal phase, but especially during the concept, development, testing and production phases.

Major global aircraft producers created a special projects focused on aviation equipment disposal issue and take the initiative to establish international organization for dismantling aircraft in an efficient and environmentally-sound manners. Main aim of both AFRA Association and PAMELA project, which are the most reputable in this area, is to increase an efficiency of recycling and re-using of the aviation equipment and both must provide the best environmental and economical solutions resulting to elaboration of Best Management Practice Guides for Management of Used Aircraft Parts and Assemblies.

Current direction of production of civil aircraft has a direct impact on future solutions of aircraft' s disposal. It is very important to solve recycling of composite materials used in the airframe of aircraft and it systems and components.

In conjunction with the technological part of disposal is needed to pay attention also to legislative issue and procedures of aircraft´s disposal on the international and national levels (this issue is not a part of paper). Civil Aviation Authorities has been established the procedures for dismantling and disposal of aircraft. If the aircraft owner intends to dismantle or disposal the aircraft, the owner must notify procedures to the Civil Aviation Authority and inform which organization will perform the dismantling or disposal. The notification of execution of dismantling or disposal must include all needed information and organizations capable for execution of controlled dismantling or disposal must be certified in accordance with relevant aviation regulations.

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