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Proposed framework for End-Of-Life aircraft recycling

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Abstract

The recycling of aircraft materials has come into greater focus in recent years, due in large part to the increase in the number of aircraft which are reaching the end of their working life. Aircraft manufacturers estimate that up to 44 percent of the global fleet will reach end-of- life in the next two decades, amounting to more than 13,000 commercial, military and private aircraft. One of the factors that is impeding sustainable end-of-life is the deficiency of knowledge and lack of total management for the aircraft life cycle from cradle to grave. Therefore, developing a conceptual framework for managing the end-of-life aircraft process is essential to achieving true sustainability and then closing the loop. Our review gives an overview of related research and positions end-of-life aircraft as a key strategy for the future. By merging sustainable thinking into traditional end-of-life aircraft process, this review provides a framework for ongoing research, as well as encourages research collaborations among the various communities interested in end-of-life aircraft.

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Keywords: Recycling; aircraft end-of-life; framework.

1. Introduction

Worldwide air transportation will continuously grow. Current forecasts predict that the worldwide passenger traffic will grow by an average of 5.1 % and the cargo traffic will grow by an average 5.6 % per year until 2030. To meet this increasing demand for air transportation, there will be in total about 33 500 aircraft deliveries worldwide over the next 20 years [1]. The worldwide aircraft fleet will almost double [2-1-3].

An aircraft's life cycle consists of the seven phases materials, design, supply chain, manufacturing, transport, aircraft operations and end-of-life as shown in Fig. 1. Usually, an aircraft is designed, developed and produced to be in operations for about 30-40 years.

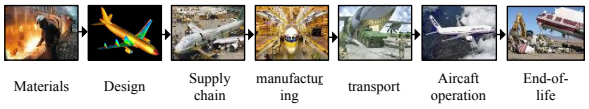

Fig. 1. The aircraft life cycle [4].

At the end of this time span and after millions of flight miles, the aircraft is no longer worthwhile for the operators and is set to retire from service, because it becomes uneconomical to operate the aircraft, e.g. due to high maintenance and overhaul or fuel consumption costs.

As consequence of the predicted development for the next 20 years and the limited aircraft operations time span, about 10 000 passenger aircraft around the world must be replaced and are set to retire from service [2-3]. Fig. 2 illustrates the predicted worldwide passenger aircraft fleet evolution for the next 20 years, subdivided into the aircraft segment of 30-120 seats and the narrow and wide body aircraft segment of more than 120 seats.

The significant growth of the aviation sector will bring considerable economic benefits. It will lead to great adverse social and environmental impacts, too. There is increasing public concern about the impacts of aviation growth on local communities and the environment [5].

Especially, there is growing concern about the aircraft end-of-life by all participants in the aviation industry and society [6]. The end-of-life stage of the aircraft's life cycle was neglected for a long time. The common practice for the final disposal of aircraft was to store them besides airports or in

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deserts around the globe until a few years ago. The number of stored aircraft on landfill sites has even more exacerbated since developing countries such as Indonesia, China and Russia have introduced import restrictions for used aircraft with 10-20 years of age in the recent years [7]. For decades, thousands of retired aircraft have been stored in so-called aircraft graveyards. At the same time, the worldwide demand for raw and secondary materials continues to increase. This seems contradictory, because the discarded aircraft provide a large source of valuable material. Landfilling does not seem to be a suitable long-term solution of handling aircraft at their end-of-life stage any more.

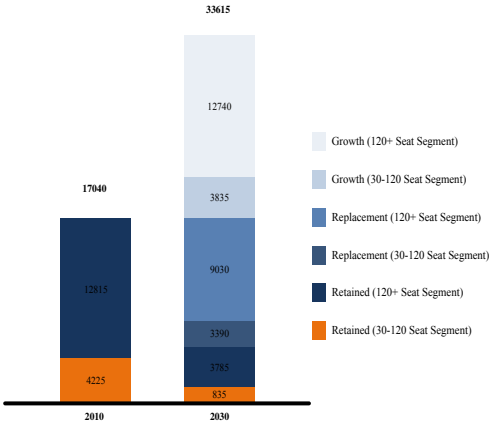

Fig. 2. Worldwide passenger aircraft fleet evolution 2010-2030.

With growing numbers of retired aircraft, growing environmental awareness and growing interest of societies and authorities, the handling of end-of-life aircraft is becoming increasingly important. Primarily the two market leaders Airbus and Boeing carried out first research about the handling of end-of-life aircraft in the recent years beginning in 2005. The handling of end-of-life aircraft has not been legally regulated yet. Facing a prospective legislative regulation, Airbus and Boeing showed general possibilities and limitations of the aircraft end-of-life processes considering the alternatives re-use, recycling and landfilling. Besides the efforts of Airbus and Boeing, the last few years have witnessed a growing realization that applying recycling techniques to aircraft disposal can bring both environmental and economic benefits [8].

1.1 Goal and scope definition

The amount of retired aircraft each year is increasing and landfilling does not seem to be a sustainable end-of-life alternative. Therefore, alternative options to landfill should be taken into account, e.g. re-use, material recycling and thermal recycling. The handling of end-of-life aircraft is a relatively young research topic and little knowledge about the aircraft end-of-life process is available. There is a lack of quantitative, transparent models about handling aircraft at the end of their lives.

Each aircraft end-of-life alternative has its own consequences on the criteria of sustainability, namely economic, environmental and social criteria. One alternative can be better than another with respect to one criterion, but worse regarding another criterion. Furthermore, handling aircraft at the end of their lives affects many participants from the aviation and salvaging industry, and also affects legislators and society. Each participant has his own goals and preferences regarding these criteria.

Research on the decision between the different end-of-life alternatives is little represented in the literature review. Existing research has its origin mostly in the electronics and automotive industry, where regulations forced the manufacturers to improve their treatment of end-of-life products in the last years. The majority of existing recommendations regarding the end-of-life decision for aircraft is based on suggestions which lack a quantitative foundation. There is no model to support concerning the aircraft end-of-life process considering all criteria of sustainability. A systematic, complete and qualitative framework to assist a process in taking a proper aircraft end-of-life is urgently needed.

2. Existing approaches handling end-of-life aircraft

Until a few years ago, end-of-life aircraft were abandoned to landfills around the globe. Beginning in the 2000s, the two largest aircraft manufacturers Airbus and Boeing began to develop alternative approaches of how to handle aircraft at their life's end. Airbus started the so-called PAMELA project (Process for Advanced Management of End-of-Life Aircraft), while Boeing founded the industry association AFRA (Aircraft Fleet Recycling Association) together with several aviation and salvaging companies. Also, an aircraft dismantling industry emerged. In this section, the PAMELA project will be described in detail.

2.1 Process for Advanced Management of End-of-Life of Aircraft (PAMELA) and technology recycling

Parallel to the efforts of Boeing to deal with end-of-life aircraft, Europe's leading aircraft manufacturer Airbus launched the project "Process for Advanced Management of End-of-Life of Aircraft" (PAMELA) in 2005. The project was initiated by Airbus, EADS, the French recycling company Suez-Sita, and the working group LIFE, France (French: l'Instrument Financier pours l'Environnement). The project was also supported by the European Commission. The main goal of the PAMELA project, which was completed after 32 months in 2007, was to demonstrate during a full-scale experiment on an Airbus A300 that 85% of an aircraft's weight can be recycled, re-used or recovered. In addition to this primary goal, a further goal was to set up a new standard for a safe and environmentally responsible management of end-of-life aircraft. To run the project according to the local environmental legislation and current technical recycling knowledge, Airbus needed to found an complementary partnership with the recycling company Suez-Sita [9].

Furthermore, in the project Airbus wanted to support a fully integrated lifecycle approach to aircraft design and

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