An innovative method to optimize the maintenance policies in an aircraft: General framework and case study

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Abstract

Maintenance policies applied to aircrafts are governed by a mix of airworthiness authorities' regulations and choices of suppliers and users. This allows airlines to use different strategies to minimize the total costs of maintenance. In this paper, a new approach that integrates the failure and reparation processes, such as modelling, optimization algorithms, and simulation methods, is proposed to define the best maintenance strategies for complex systems.

A case study of an airline carrier is presented. In particular, several critical components for the A320 aircraft family are considered. The impact of the spare parts inventory management is discussed. Different preventive maintenance policies are tested and simulated. With the new policies, the average availability of the aircraft is satisfactory and the total annual cost is reduced to a value of approximately 20% in comparison with the previous policies adopted by the company.

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1. Introduction

Maintenance costs represent on average of 14% of the variable costs incurred by airlines (Sriram and Haghani, 2003; Ferrari et al., 2002). Global competition forces airlines to improve flying hours as well as the availability of their aircrafts with adequate maintenance costs.

An aircraft maintenance program must ensure the realization of the inherent safety and reliability levels of the equipment at a minimum total cost, including maintenance costs and the costs of resulting failures.

The target must be the optimization of the technical total cost of service of an aircraft due to two elements: the maintenance costs (e.g., in terms of labour, spare parts purchase, logistics, etc.) and aircraft downtimes (e.g., in terms of repair and inspection time, waiting time for missing spare parts, etc.). For an aircraft's components, the two cited costs usually have a countetrend, and the goal must be to find the best mix of maintenance policies in agreement with the minimization of the total cost of service. The three-step method proposed pursues this optimization.

Aircraft maintenance is highly regulated. There are various airworthiness authorities around the world (i.e., the European Aviation Safety Agency (EASA), Europe; the Federal Aviation Administration (FAA), the United States; and others). Manufacturers and users (e.g., airlines) of aircrafts are important actors in defining effective maintenance policies after licensing by authorities.

The initial maintenance policies schedule follows the well-known Maintenance Steering Group-3 (MSG-3) process. The MSG-3 process was defined by the participation and combined efforts of the Federal Aviation Administration (FAA), Civil Aviation Authority (CAA/UK), Aircraft Electronics Association (AEA), U.S. and European aircraft and engine manufacturers, U.S. and foreign airlines, and the U.S. Navy.

This process outlines the general organization and decision processes for determining scheduled maintenance requirements initially projected for the life of the aircraft (Life Data Analysis Reference Book, 1993). The initial scheduled maintenance program has been specified in Maintenance Review Board (MRB) Reports. The MRB development process is also discussed in different Advisory Circulars of the FAA (i.e., AC No: 121-22A (1997), 121-22B (2010), 121-22C (2012)).

All of these documents become the basis for the first issue of each airline’s maintenance requirements to govern its initial maintenance policy. Adjustments may be necessary to address...
operational and/or environmental conditions unique to the operator. As operating experience is accumulated, additional adjustments may be made by the operator to maintain an efficient maintenance program. For example, AC 121–22C provides the Statistical Analysis Tasking Optimization (SATO) procedure that describes an original equipment-customized program for the optimization of scheduled maintenance.

The MSG–3 logic was task-oriented, and generally, there are two groups of tasks: scheduled tasks to be accomplished at specified intervals (i.e., Lubrication/Servicing (LU/SV), Operational/Visual Check (OP/VC), Inspection/Functional Check (IN/FC), Restoration (RS), Discard (DS)), and non-scheduled tasks (i.e., corrective measures derived from malfunctions, usually generated by the operating crew reports).

For an aircraft, the inspection/replacement interventions are the most relevant in terms of effort and costs. For this reason, this paper is focused on the optimization of the preventive maintenance policy, in particular considering the on-aircraft repair operations, which are usually out of A/C planned checks.

This study discusses the optimization of maintenance policies. Often, policies are based on a manufacturer’s or maintainer’s experience. The initial MRB for any new aircraft is developed in the absence of actual in-service experience. As a result, the tendency is to be conservative in the decision-making process. However, as service experience is accumulated, task intervals should be adjusted to reflect the results of a professional analysis of actual in-service data. However, intervals of intervention/replacement are often not seriously based on the actual system reliability. This causes maintenance costs to be higher than the optimum. The authors show how it is possible to achieve significant improvements in terms of availability and reduction of maintenance costs using a systematic procedure of data analysis based on RAM (Reliability, Availability, Maintainability) principles. The proposed method is applied in a real case involving an important airline carrier. Different maintenance strategies, including corrective (CM) and preventive (PM) maintenance policies, are compared. The choice of the best maintenance policy has also been linked to a study of inventory management strategies to identify the most effective one from an operational point of view. Both studies are linked to a study of inventory management strategies to identify the most effective one from an operational point of view.

This paper is organized as follows. The next section presents the literature review with regard to the problem. Section 3 explains the new proposed method. An exhaustive case study of an airline carrier is discussed in Section 4. Finally, conclusions are given in Section 5.

2. Literature review

The growing importance of maintenance has generated increasing interest in the development and implementation of
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