

Operational Simulation Modeling in Legacy Engine Maintenance

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Abstract

This paper presents a conceptual design decision making approach through operational modeling through the eyes of the airline. It put more emphasis on the engine maintenance, repair and overhaul, since engine maintenance is about 13% of the total cash cost.

A key element of the research is a simulation program through Operation Simulation Modelling OSM, that has been built by the others to create an operational modelling environment to see the impact of different design technologies, or concepts, or compare different type of engines operation on a real environment through the eyes of the customer (i.e. the airline engineers and mechanics). The Rolls Royce engine (RB211-524D4) for a specific airline has been chosen to be the case study and validate the code in case of man-hours.

Finally, it was found that OSM gives outcome for the baseline maintenance hours, and man hours needed give an difference 2.7% and 0.8% respectively.

Keywords: Simulation; Modeling; Engine maintenance

Introduction

The nature of this paper in the field of engine conceptual decision making design is exploring areas considerably outside the traditional design space.

Since engine maintenance is about 13% of the total cash cost [1], and since design has shifted from design for performance at any cost to design for affordability, also engine maintenance is about 6% of DOC [1], moreover it is important for the airlines that their aircraft fly most of the time with less maintenance time spend for their aircraft and engines, so the time for the engine to be maintained is important.

Since this study deals with fleet engines performance in maintenance, man hour spend it was one of the most challenging tasks to validate the data output. Fortunately an airline helped by supplying data for their Rolls Royce engines which includes the man hours needed and time for maintaining an engine, and most important the steps and phases that the engine goes through in an overhaul job, which include the different shops and tasks taken for the main parts.

The objective of this paper is to focus on the operational aspects of the implementation of a given engine design to airline maintenance shops capability to fully evaluate its impact through the eyes of the operators. For example a particular engine might improve s.f.c. but due to the additional maintenance requirements does not save time or money overall.

To facilitate this objective it will be necessary to develop a program Operation Simulation OSM code that enables the designer to evaluate the effect of different design decisions in the full operational context [2].

An important element of this work is to develop an understanding of the different stages that the engine undergoes in its maintenance phases which includes removal from the aircraft, sending to overhaul shop, engine reception and inspection, engine disassembly, engine assembly, balancing, engine dispatch, land test, air test, install to aircraft, then operation. While the different shops when the engine disassembled are Unit disassembly, cleaning, inspection, repair, welding X-Ray, heat treatment, painting, process control laboratory, fuel rig testing, and an assembly unit. How they interact with each other, and the construction

of the program architecture and logic. The enabling step is then to evaluate a given engine.

The engine in general is build up with seven modules, each module represent part of the engine. As shown in the Tables 1 and 2.

Simulation Program Architecture and Logic

This section describes a generic approach to the analysis of event driven simulation. The application is to the simulation of the operating environment for civil transport aircraft including aircraft flight, maintenance, and all aspects of relating to the airlines business operations, applying it in the engine maintenance operation.

Philosophy

The first consideration is to produce an architecture that is sufficiently flexible to permit modeling over a wide range of fidelity models. The approach should also permit the code to be further developed and extended at some future date.

Module	
1	Fan module
2	LP compressor
3	Intermediate compressor
4	HP (Compressor, Turbine)
5	LP/IP Turbine
6	Gear Box
7	Fan case module

Table 1: Module type description for the RB211.

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Engine type
Engine #
Stage #
Fault type
Module 1 *
Module 2
Module 3
Module 4
Shops # **
Ready

The number in the box represents the part number in module 1

** The number in the box represents the shop number at which the part is being worked at

Table 2: Event prediction Model.

The approach should also be sufficiently generic to permit its application to a wide range of similar problems.

Main Datasets

The structure of the program centers about a number of key datasets. These may be retained in memory (for speed) and / or written to disk for post-processing (e.g. log files).

Entity Status

The basis of the method is the tracking of the progress of a number of ‘entities’ that constitute the ‘model world’. The current state of any one entity is defined by a number of parameters contained in its status dataset. There is one status dataset for each entity. All entities are treated in a consistent manner throughout the program this is key to ensuring the generic nature of the program. Examples of entities could be an aircraft or a maintenance facility.

Event Prediction

The ‘world’ evolves as a function of time through the occurrence and action of a flow of events. The event prediction data determines when events should occur. Each entity has a series of events associated with it and the logic that defines when they should occur. The events will be driven primarily by reference to the ‘master clock’. Events will also be a function of an entity’s status and that of other entities. This data need only be stored for each different class of entity.

Event Stack

Whenever an event is predicted to occur it is placed into the event stack and will subsequently be processed. When an event has been processed, it is removed from the stack. There can be one event stack for each entity.

Program Flow

Having defined the structure of the code the program flow becomes as follows in Figure 1.

Importance of OSM

The main importance of OSM is that the programme is written in a way that it has the following features:

1. Different steps of any action on the life cycle of the engine or aircraft can be added in as much or little level of detail through status, type of event, and the protocol associated with it.
2. No need to have knowledge of a programme language.

3. Different people that have different experience can participate in OSM.
4. The programme can be build up -ability to grow-.

This would be important to capture actions during the life cycle of the engines

The ‘knock –on’ effect of random event, such as faults and delays can be modelled to determine the overall impact on such parameters as costs and required resources.

Assumption for OSM

In order to model the maintenance engine operation in OSM a set of assumptions was set with the help of the airline

1. All maintenance operations are performed in the base airline hanger.
2. The High Speed External Gearbox is simulated in the operation gearbox There are at all times at least one aircraft should be at stand by for any cancelled flight

Results and Discussion

OSM code was written in a Visual Basic [3,4], it was used to generate data for over hall engine maintenance man hours, by running OSM for a single engine from its removal to its Installation in the aircraft, generating maintenance time in min, and man – hours needed, with a difference of 2.7% and 0.8% respectively compared with data provided from the airline. OSM provide a useful tool to compare the impact of each technology applied to the baseline engine or to compare between two engines. These data can be used by a Project Manager, Fleet Planner or an engine Designer, to decided on which type of engine to go with, and which technology would provide the best benefit or best results during operation in time for the time, and money spent in case of the fleet planner, and for the designer that would also provide him with the best decision making for the customer and best engine selection, through the eyes of the airlines.

Table 3 summarize the out put data generate from OSM

This paper helped the authors in many ways in which to learn more about the operation of engine not just the theory, to understand the airlines concerns and issues which would be important to the designer. The authors encountered numerous problems throughout the paper,

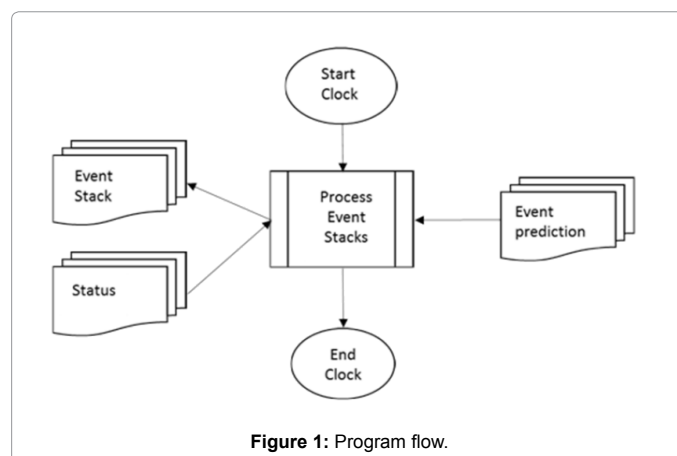


Figure 1: Program flow.

	Total time needed [min]	Total man-hours [man-hr]
OSM	10350	129
Airline Data	10080	128
% Difference	2.7	0.8

Table 3: OSM results output vs. airline data.

most concerning the issues of time, on which airlines are reluctant to give out information on their data. Also problems resulted from the mapping of the effect of different operations and shops action or concepts to different parameters, as well as their different protocol steps, also the integration of the different parts of the engine hanger. Given that each status has its different protocols for inspection repair and even delays.

Conclusion

From the study we could include the following

1. Engines maintenance time is very important for airline operation.
2. OSM has acceptable results in predicting the Total man-hours for engine maintenance.

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