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AIRCRAFT MAINTENANCE – NEW TRENDS IN GENERAL AVIATION

ABSTRACT

Maintenance organizations assist in ensuring that all aeronautical products built, operated or maintained under control conform to national and international airworthiness standards. Ensuring that these standards are met involves a vast network of organizations and personnel in general aviation.

Standards and Procedures is responsible for the coordination and management of all regional maintenance and manufacturing activities, other than those related to Licensing and Training. This includes acting as a central coordination and communication point for other Civil Aviation.

KEYWORDS

maintenance, reliability, failure, database, reliability-centred maintenance

1. INTRODUCTION

Since the origin of flight, the main goal of aircraft maintenance has been to efficiently correct defects and prevent failures. Early efforts focused on improving products and maintenance practices through design; recent decades were distinguished by product reliability improvements that extended airworthiness; and current efforts emphasize reducing operating costs and improving competitiveness.

Over the terminate twenty years of the last century, maintenance procedures have changed in general, perhaps more than any other management and technological discipline. The changes are due to a huge increase in the number and variety of physical assets (structural systems, equipment, etc.) which must be maintained at any place in the world, much more complex designs, new maintenance techniques and changing views on maintenance organization and responsibilities.

2. RCM - RELIABILITY-CENTRED MAINTENANCE

Reliability-Centred Maintenance (RCM) is a procedure for determining maintenance strategies based on reliability techniques and it encompasses the well-known analysis methods such as Failure Mode Effects and Criticality Analysis (FMECA). RCM procedures take into account the prime objectives of a maintenance programme:

- Minimise Costs;
- Meet Safety and Environmental Goals;
- Meet Operational Goals.

The RCM process begins with a failure mode and effects analysis which identifies the critical plant failure modes in a systematic and structured manner. The process then requires the examination of each critical failure mode to determine the optimum maintenance policy to reduce the severity of each failure. The chosen maintenance strategy must take into account cost, safety, environmental and operational consequences. The effects of redundancy, spares costs, maintenance crew costs, equipment ageing and repair times must be taken into account along with many other parameters.

Once optimal maintenance policies have been recorded the RCM process provides system performance predictions and costs, expected spares requirements and maintenance crew manning levels. The RCM process may be used to develop a living strategy with the plant model being updated when new data is available or design changes take place.

The principles which define and characterise RCM are:

- focus on the preservation of system function;
- identification of specific failure modes to define loss of function or functional failure;
- prioritisation of the importance of the failure modes, because not all functions or functional failures are equal; and
- identification of effective and applicable preventive maintenance (PM) tasks for the appropriate failure modes. (Applicable means that the task will prevent, mitigate, detect the onset of, or discover, the failure mode. Effective means that among competing candidates the selected PM task is the most cost-effective option.)

These principles, in turn, are implemented in a seven-step process:

1. The objectives of maintenance with respect to any particular item/asset are defined by the functions of the asset and its associated desired performance standards.
2. Functional failure (the inability of an item/asset to meet a desired standard of performance) is identified. This can only be identified after the functions and performance standards of the asset have been defined.
3. Failure modes (which are reasonably likely to cause loss of each function) are identified.
4. Failure effects (describing what will happen if any of the failure modes occur) are documented.
5. Failure consequences are quantified to identify the criticality of failure. (RCM not only recognizes the importance of the failure consequences but also classifies these into four groups: Hidden failure; Safety and environmental; Operational and Non-operational.)
6. Functions, functional failures, failure modes and criticality analysed to identify opportunities for improving performance and/or safety.
7. Preventive tasks are established. These may be one of three main types: scheduled on-condition tasks (which employ condition-based or predictive maintenance); scheduled restoration; and scheduled discard tasks.

Although one of the prime objectives of RCM is to reduce the total costs associated with system failure and downtime, evaluating the returns from an RCM program solely by measuring its impact on costs hides many other less tangible benefits. Typically these additional benefits fall into the following areas:

1. improving system availability;
2. optimising spare parts inventory;
3. identifying component failure significance;
4. identifying hidden failure modes;
5. discovering significant, and previously unknown failure scenarios;
6. providing training opportunities for system engineers and operations personnel;
7. identifying areas for potential design enhancement;
8. providing a detailed review, and improvement where necessary, of plant documentation.

The analysis itself begins with an evaluation of the failure consequences for each type of failure to which the item is exposed. The logic used to organize this problem, leads to categories of failure consequences:

- Safety consequences, which involve possible danger to the equipment and its occupants. Limits for random characteristics are standardised in aviation.
- Operational consequences, which involve indirect economic loss in addition to the cost of repair. Preventive maintenance actions have essential effect on operational costs in aviation.
- No operational consequences, which involve no economic loss other than the cost of repair applying RCM theory to aircraft. These failures have to be registered also, because of potential future missing can be signalised.

In the case of commercial aircraft continuous evolution of the design requirements promulgated by airworthiness authorities and the feedback of hardware information to designers by operating organizations have led to increasing capability for safe and reliable operation. Thus most modern aircraft enter service with design features for certain systems and items that allow easy identification of potential failures. Similarly, various parts of the airplane are designed for easy access when inspection is necessary or for easy removal and replacement of vulnerable items. A host of instruments and other indicators provide for monitoring of systems operation, and in nearly all cases essential functions are protected by some form of redundancy or by backup devices that reduce the consequences of failure to a less serious level.

Complex equipment of the older generations of aircraft that has not benefited from such design practices will have different and less favourable reliability characteristics, and therefore less capability for reliable operation. Since preventive maintenance is limited by the inherent characteristics of the equipment, in many cases RCM analysis can do little more than recommend the design changes that would make effective maintenance feasible.

The role of civil aviation authorities is to work with the operators and manufacturers of aircraft and engines to define and implement a proactive process that includes the following key elements:

- data collection,
- database management,
- risk analysis,
- risk management/action,
- monitoring effectiveness.

Specific tasks should follow the process of RCM creation:

- Manufacturers, with the advice and consent of operators and the appropriate civil aviation authority (CAA) should define data requirements and processes for sharing data. Comprehensive flight operations quality assurance systems should be used as a starting point.
- Operators should provide required data, as agreed upon.
- Manufacturers should solicit data from additional sources, such as International Civil Aviation Orga-

nization and others, to augment the operational database.

- Manufacturers, with oversight from the CAA and the assistance of operators, as required, should collect, organize, and analyze data to identify potential safety problems.
- Manufacturers should recommend corrective action for potential safety problems and seek consensus by operators. The CAA should make sure that actions proposed by manufacturers and operators will be effective, making regulatory changes and mandating compliance as appropriate.
- Manufacturers and operators, with oversight from the CAA, should monitor the effectiveness of corrective action and the safety management process.

The principles of reliability-centred maintenance still apply, and the decision questions are the same. The answers to these questions, however, must reflect the design characteristics of the aircraft.

3. A SUMMARY OF RCM PRINCIPLES

The complexity of modern aircraft generation makes it impossible to predict with any degree of accuracy when each part or each assembly is likely to fail. For this reason it is generally more productive to focus on those reliability characteristics that can be determined from the available information than to attempt to estimate failure behaviour that will not be known until the aircraft enters service. In developing an initial program, therefore, only a modest attempt is made to anticipate the operating reliability of every item. Instead, the governing factor in RCM analysis is the impact of a functional failure at the system level, and tasks are directed at a fairly small number of significant items - those whose failure might have safety or major economic consequences.

These items, along with all the hidden-function items, are subjected to intensive study, first to classify them according to their failure consequences and then to determine whether there is some form of maintenance protection against these consequences.

The first step in this process is to organize the problem by partitioning the aircraft into object categories according to areas of engineering expertise. Within each of these areas the aircraft is further partitioned in decreasing order of complexity to identify significant items (those whose failure may have serious consequences for the aircraft as a whole), items with hidden functions (those whose failure will not be evident and might therefore go undetected), and non-significant items (those whose failure has no impact on operating capability). As this last group encompasses many thousands of items on an aircraft, this procedure focuses the problem of analysis on those items whose functions must be protected to ensure safe and reliable operation.

The next step is a detailed analysis of the failure consequences in each case. Each function of the item under consideration is examined to determine whether its failure will be evident to the operating crew; if not, a scheduled-maintenance task is required to find and correct the hidden failures. Each failure mode of the item is then examined to determine whether it has safety or other serious consequences. If safety is involved, scheduled maintenance is required to avoid the risk of a critical failure. If there is no direct threat to safety, but a second failure in a chain of events would have safety consequences, then the first failure must be corrected at once and therefore has operational consequences. In this case the consequences are economic, but they include the cost of lost operating capability as well as the cost of repair.

Thus scheduled maintenance may be desirable on economic basis, provided that its cost is less than the combined costs of failure. The consequences of a non-operational failure are also economic, but they involve only the direct cost of repair. The classification by failure consequences also establishes the framework for evaluating the proposed maintenance tasks. In the case of critical failures - those with direct safety consequences - a task is considered effective only if it reduces the likelihood of a functional failure to an acceptable level of risk.

Although hidden failures, by definition, have no direct impact on safety or operating capability, the criterion in this case is also risk; a task qualifies as effective only if it ensures adequate protection against the risk of a multiple failure. In case of both operational and non-operational failures task effectiveness is measured in economic terms. Thus a task may be applicable if it reduces the failure rate (and hence the frequency of the economic consequences), but it must also be cost-effective - that is, the total cost of scheduled maintenance should be less than the cost of the failures it prevents.

Whereas the criterion for task effectiveness depends on the failure consequences the task is intended to prevent, the applicability of each form of preventive maintenance depends on the failure characteristics of the item itself. For an on-condition task to be applicable there must be a definable potential failure condition and a reasonably predictable age interval between the point of potential failure and the point of functional failure. For a scheduled rework task to be applicable the reliability of the item must in fact be related to operating age; the age-reliability relationship must show an increase in the conditional probability of failure at some identifiable age (wearout) and most units of the item must survive to that age. The applicability of discard tasks also depends on the age reliability relationship, except that for safe-life items the life limit is set at some fraction of the average age at failure. Failure finding tasks are applicable to all the hidden function items not covered by other tasks.

The process of developing an RCM program consists in determining which of these scheduled tasks, if any, are both applicable and effective for a given item. The fact that failure consequences govern the entire decision process makes it possible to use a structured decision diagram approach, both to establish maintenance requirements and to evaluate the proposed tasks. The binary form of a decision diagram allows a clear focus of engineering judgment on each issue. It also provides the basic structure for a default strategy - the course of action to be taken if there is insufficient information to answer the question or if the study group is unable to reach a consensus. Thus, if there is any uncertainty about whether a particular failure might have safety consequences, the default answer will be yes; similarly, if there is no basis for determining whether a proposed task will prove applicable, the answer, at least in an initial maintenance program, will be yes for on-condition tasks and no for rework tasks.

It is important to realize that the decision structure itself is specifically designed for the need to make decisions even with minimal information. For example, if the default strategy demands redesign and this is not feasible in the given timetable, then one alternative is to seek out more information in order to resolve the problem. However, this is an exception rather than a rule. In most cases the default path leads to non-scheduled maintenance, and the correction, if any, comes naturally as real and applicable data come into being as a result of actual use of the aircraft in service.

The net result of this careful bounding of the decision process is a scheduled maintenance program which is based at every stage on the known reliability characteristics of the aircraft in the operating context in which it is used. In short, reliability-centred maintenance is a well tested answer to the paradox of modern aircraft maintenance - the problem of how to maintain the systems in a safe and economical fashion until we have accumulated enough information to know how to do it.

4. CONCLUSION

RCM will allow one to obtain the full design operating ability of the aircraft. It does not necessarily identify a new series of maintenance tasks. It identifies which tasks are most applicable, which are ineffective and provides a framework for developing an optimal preventive maintenance program.

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ABSTRAKT

ÚDRŽBA LIETADLOVEJ TECHNIKY - NOVÉ MOŽNOSTI APLIKÁCIE V PROSTREDÍ VŠEOBECNÉHO LETECTVA.

Kvalitu systému technickej údržby a opráv ovplyvňuje stupeň využitia technických prostriedkov, spoľahlivosť, bezpečnosť a ekonomickú efektívnosť. Dlhodobým problémom, ktorý neustále vystupuje do popredia je problém hľadania a zavádzania efektívnych programov technickej obsluhy, údržby a opráv lietadlovej techniky a to hlavne u malých prevádzkovateľov. Aktuálnosť tohoto problému vzrástla hlavne za posledné roky. Zber spoľahlivých údajov predstavuje základný kameň tvorby celého procesu manažmentu bezpečnosti. Všetky informácie súvisiace s bezpečnosťou sú podkladovým materiálom analytických postupov, cieľom ktorých je predchádzať nehodám a incidentom.

KĽÚČOVÉ SLOVÁ

Prevádzková spoľahlivosť, zber údajov, udržovateľnosť, životnosť systémov, bezpečnostné analýzy, systém vyhodnocovania dát, informačný systém, manažment bezpečnosti, riadenie kontroly zberu informácií, elektronický poruchový list

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