Power Plant Health Monitoring - The Human Factor

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ABSTRACT/OVERVIEW

There are numerous publications of technical papers describing how the authors set up and ran condition monitoring systems for just about anything from single pieces of machinery to vast chemical plants or whole fleets of aircraft. Even a quick glance at all this work reveals a bewildering array of techniques, ranging from a man with a pencil, note pad and graph paper reading existing dials on a control panel to specially designed and built computer systems that automatically gather, store and process data from dedicated instrumentation, before presenting reports on equipment health to the operators. Each worker in the field of condition monitoring claims his approach to be the most effective and trumpets the successes he appears to have achieved while, one suspects, playing down the difficulties and failures.

The bemused observer of all this frenzied activity is bound to wonder what's in it for him and the equipment he is operating: he feels, subjectively at least, that monitoring should be able to help him because it will increase his knowledge about the way his equipment is working, but is unsure whether the benefits that may be achieved justify the costs and time put into setting up and running a condition monitoring system. What level of system should he go for? A man with pencil and paper where all the interpretation of results is a human process, or a sophisticated computer system where the interpretation is handled by the machine? With the cost of human resource continually rising and the cost of computer systems falling, where do you draw the line? Technology versus human intervention? What are the cost/benefit trade-offs? and what are the human factors involved? This paper looks at the various types of Engine Condition Monitoring (ECM) systems that have been employed in gas turbine aero engines from the perspective of one engine manufacturer and comments on the efficiency and dependability of these systems as well as looking at proposals for the future. Also examined are the particular facets of the human interface with such systems.

REASONS FOR/BENEFITS OF CONDITION MONITORING

One of the major reasons why so much interest has been shown in condition monitoring in recent years is due to the continually rising costs involved in operation of an airline. As the costs of buying and running plant and equipment have risen, so requirements have emerged for reducing the costs of operations and maintenance. Figure 1 shows the cost breakdown of an "average" airline, based on ICAO statistics for 1989. While, obviously all of the cost categories could benefit from some form of monitoring, ECM systems have been designed to help reduce costs in the first two (separated) categories: aircraft fuel

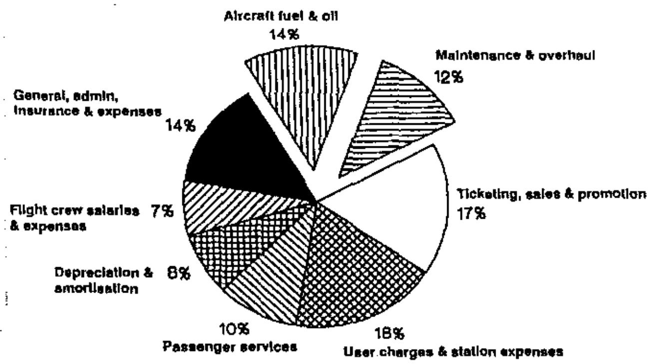


Fig. 1 Average airline cost breakdown

and oil costs, and maintenance and overhaul. These cost categories depend more than any others on equipment health and are therefore the traditional areas where condition monitoring techniques are applied.

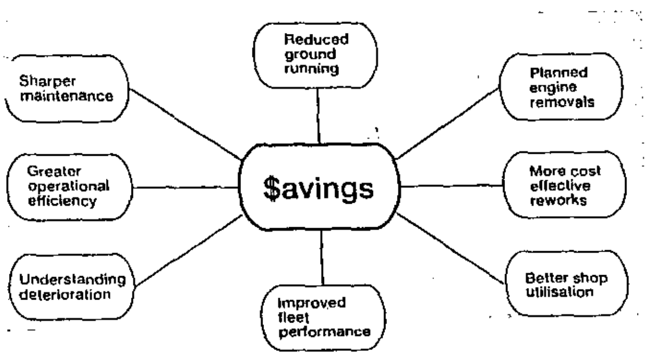


Fig. 2 The benefits of engine condition monitoring

Between them, they add up to over 25% of the total running costs of a typical airline.

Figure 2 summarises the potential benefits of ECM which can help to reduce the above costs in many ways:

a) By reducing the amount of fuel and other consumables used, ensuring that the equipment is running as efficiently as possible.
This can be achieved by:
   i) enabling on-wing adjustments of variable stator vanes, bleed valves, fan trim balance, etc. to be made without dedicated ground runs: this clearly has operational advantages, as well as saving fuel and mechanics time.
   ii) enabling a better standard of engine rework to be achieved, by correlating rework activity (such as blade polishing) with fuel burn improvements.
   iii) indicating when engine washing may be required.

b) By reducing the possibility of failures of the equipment and hence reducing the associated repair and dislocation costs, and such intangible effects as loss of customer confidence, loss of quality and loss of operator reputation (often underestimated).

c) By optimising the maintenance of the equipment, to achieve the correct balance between too little maintenance (leading to breakdowns) and too much (leading to unnecessary labour and parts costs).

Clearly, reducing fuel and consumable usage leads to easily quantifiable savings: however, it is becoming widely recognised that equipment down-time due to repair and maintenance represents lost opportunities for making profits, which, while less easy to quantify, can be very significant indeed.

The current levels of gas turbine reliability have changed the rework

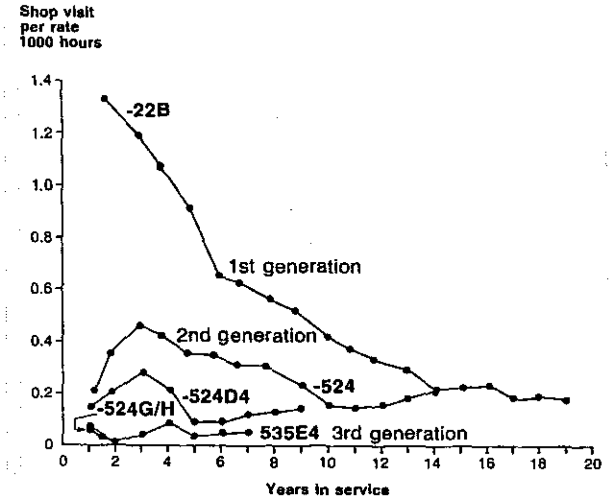


Fig. 3 RB211 derivative reliability improvements

criteria more towards performance related issues rather than those of mechanical failure.

Figure 3 gives a diagrammatic representation of the shop visit rate for the RB211 family. This shows how the derivative approach has improved the basic reliability from generation to generation to a level where third generation engines have a shop visit rate of less than 0.1 per thousand hours, ie. the engines are consistently taying on-wing for more than 10,000 hours.

The twin requirements of health monitoring therefore become:

a) the ability to schedule maintenance to allow the most cost effective rework.

b) the need to protect against disruptive unscheduled removals.

The cost involved in scheduled maintenance and overhaul can be reduced by:

a) focusing attention on the items of equipment that actually require maintenance: airframe, APU, engine and (with the correct instrumentation fitted) module deterioration can be diagnosed, enabling maintenance and overhaul activity to be concentrated on the areas that require it.

b) allowing the operator to plan shop workload ahead of time, based on the health of all the engines in the fleet. Maintenance and overhaul "peaks" could be evened out, leading to better shop utilisation.

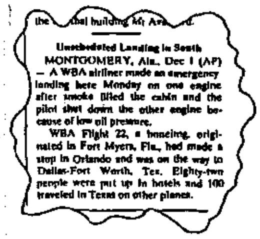
c) allowing the operator to simulate the effects of maintenance action, allowing trade-offs to be carried out between the costs of component efficiency improvements due to rework and the resulting operational benefits.

ECM can provide a great deal of information on which to base decisions on scheduled maintenance and overhaul action. Depending on the instrumentation available, information about problems requiring maintenance action can be produced down to module level (for engines) or individual control surface level (for airframes), with attendant cost savings. Such a level of understanding can also help to reduce spare parts holdings. Indeed, the implementation of such concepts as Maintenance Programme Design, Resource/Activity Matching ("Rightsizing") and Just-in-Time Inventory Systems can be highly dependant on having access to the information that ECM can provide.

The cost involved in unscheduled maintenance and overhaul can be reduced by:

a) providing warnings of impending failures, thus reducing the possibilities of operational disruption (remote engine removals, inflight shutdowns, aborts, delays, diversions and cancellations): these events can be very costly indeed, both financially and in terms of loss of passenger confidence, as illustrated in the actual example shown in Figure 4.

Event: IFSD and diversion with remote site engine removal



Unscheduled Landing in South

MONTGOMERY, Ala., Dec 1 (AP) — A WBA airliner made an emergency landing here Monday on one engine after smoke filled the cabin and the pilot shut down the other engine because of low oil pressure.

WBA Flight 22, a boeing, originated in Fort Myers, Fla., had made a stop in Orlando and was on the way to Dallas-Fort Worth, Tex. Eighty-two people were put up in hotels and 100 traveled in Texas on other planes.

Likely hidden costs incurred (not including shop visit costs):

Lost revenue	—	passengers transferred to other airlines	$10 000
Fuel	—	extra fuel used	$3000
Overnight costs	—	hotel accomodation, passengers and crew	$6000
Knock-on effect	—	aircraft out of position causes cancellations down the line	$22 000
Engine removal	—	removal at remote site, trucking and labour	$15 000
Passenger concern	—	future revenue loss	$12 000
Others	—	Crew costs, landing fees, tyres/brakes, etc	$2000
			$70 000

Worth 3% of aircraft annual fuel burn

Fig. 4 An example of hidden costs

b) reducing secondary damage, by indicating the need for maintenance and overhaul in time.

As well as making a contribution to cost savings in the above areas, ECM can also help in fleet management, by:

.) allowing the operator to match aircraft to particular route requirements (such as hot engines on cool routes, high performance aircraft on longer routes).

b) providing statistics to aid fleet planning and utilisation studies.

Beyond enhancing the operational reliability, utilisation and safety of operation, Engine Condition Monitoring helps to reduce the burden that today's aircraft place on the environment. Simply because engines which get the best possible maintenance have the best performance and consequently use less fuel.

Condition monitoring may be defined as a system (or series of systems) that gather, store and process data from an operator's equipment in order to assist in making decisions about the operation and maintenance of such equipment. It is the key element that enables the operator to change from a strategy of reaction to unplanned events (such as excessive fuel usage, breakdowns, etc.) to one of pre-emptive action to foreseen events. All in a timescale which aids management, improves efficiency, reduces disruption and increases the profitability of the equipment being used.

TECHNIQUES USED IN CONDITION MONITORING

Clearly, man has been monitoring machinery for centuries, if only by listening to it! "Funny noises" in anything from ancient watermills to modern motor cars have always been a signal for the alert operator to get things checked over: "It sounds different, so something must be wrong".

With aircraft engine maintenance, (up until the late 1960's), it was common practice to overhaul an engine after a predefined number of flight hours or cycles whether it needed it or not, but with the increasing maturity of jet engines it has been recognised that it is the "condition" that counts.

In the early days, condition monitoring mainly consisted of monitoring mechanical parameters such as oil system filter condition, oil pressure, temperature, engine vibration and magnetic chip detector (MCD) debris. This type of data was manually recorded and analysis of MCD debris required the assistance of a qualified inspector

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