ADDRESSING TECHNICAL AND REGULATORY REQUIREMENTS TO DEPLOY STRUCTURAL HEALTH MONITORING SYSTEMS ON COMMERCIAL AIRCRAFT

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Abstract

Multi-site fatigue damage, hidden cracks in hard-to-reach locations, disbonded joints, erosion, impact, and corrosion are among the major flaws encountered in today's extensive fleet of aging aircraft. The use of in-situ sensors for real-time health monitoring of aircraft structures, coupled with remote interrogation, provides a viable option to overcome inspection impediments stemming from accessibility limitations, complex geometries, and the location and depth of hidden damage. Reliable, Structural Health Monitoring (SHM) systems can automatically process data, assess structural condition, and signal the need for human intervention. Prevention of unexpected flaw growth and structural failure can be improved if on-board health monitoring systems are used to continuously assess structural integrity. Such systems can detect incipient damage before catastrophic failures occurs. Other advantages of on-board distributed sensor systems are that they can eliminate costly and potentially damaging disassembly, improve sensitivity by producing optimum placement of sensors and decrease maintenance costs by eliminating more time-consuming manual inspections.

This paper presents the results from successful SHM technology validation efforts that established the performance of sensor systems for aircraft fatigue crack detection. Validation tasks were designed to address the SHM equipment, the health monitoring task, the resolution required, the sensor interrogation procedures, the conditions under which the monitoring will occur, and the potential inspector population. All factors that affect SHM sensitivity were included in this program including flaw size, shape, orientation and location relative to the sensors, operational and environmental variables and issues related to the presence of multiple flaws within a sensor network. This paper will also present the formal certification tasks including formal adoption of SHM systems into aircraft manuals and the release of an Alternate Means of Compliance and a modified Service Bulletin to allow for routine use of SHM sensors on commercial aircraft. This program also established a regulatory approval process that includes FAR Part 25 (Transport Category Aircraft) and shows compliance with 25.571 (fatigue) and 25.1529 (Instructions for Continued Airworthiness).

1 Introduction

The costs associated with the maintenance and surveillance needs of aging aircraft are rising at an unexpected rate. Aircraft maintenance and repairs represent about a quarter of a commercial fleet's operating costs. The application of distributed sensor systems may reduce these costs by allowing condition-based maintenance practices to be substituted for the current time-based maintenance approach. The evolution of on-board sensor systems makes it possible to quickly, routinely, and remotely monitor the integrity of a structure in service. A series of expected maintenance functions will already be defined; however, they will only be carried out as their need is established by the health monitoring system. Figure 1 depicts a sensor network deployed on an aircraft to monitor critical sites over the entire structure.

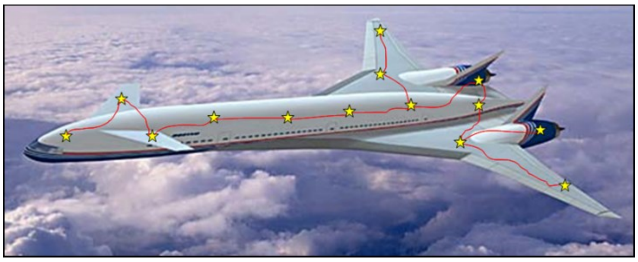

Fig. 1. Depiction of distributed network of sensors to monitor structural health.

The Airworthiness Assurance Center (AANC) at Sandia Labs, in conjunction with aircraft manufacturers, airlines, regulators and sensor development companies has conducted a wide array of programs to develop SHM solutions and establish certification processes for their deployment. These extensive SHM studies highlighted the ability of various sensors to detect common flaws found in composite and metal structures with sensitivities that meet or exceed current flaw detection requirements. By conducting a focused assessment of particular aircraft applications, the full spectrum of issues ranging from design to performance and continued airworthiness were addressed. These programs established an optimum aircraft manufacturer-airline-regulator process and determined how to safely validate and adopt SHM solutions. Comprehensive probability of flaw detection assessments were coupled with durability and on-aircraft flight tests to study the performance, deployment, and long-term operation of SHM sensors on aircraft. Statistical methods using One-Sided Tolerance Intervals and Log Regression Analysis were employed to derive Probability of Detection (POD) levels for SHM sensors. The test specimens were chosen to represent an array of applications on commercial aircraft. These programs also established a regulatory approval process that includes FAR Part 25 (Transport Category Aircraft) and shows compliance with 25.571 (fatigue) and 25.1529 (Instructions for Continued Airworthiness).

Global SHM, achieved using sensor networks, can be used to assess overall operation (or deviations from optimum performance) of aircraft. The ease of monitoring an entire network of distributed sensors means that structural health assessments can occur more often, allowing operators to be even more vigilant with respect to flaw onset. The activities conducted in these programs facilitated the evolution of an SHM certification process including the development of regulatory guidelines and advisory materials for the implementation of SHM systems via reliable certification programs. Formal SHM validation is allowing the aviation industry to confidently make informed decisions about the proper utilization of SHM solutions. An important element in developing SHM validation processes is a clear understanding of the regulatory measures needed to adopt SHM solutions along with the knowledge of the structural and maintenance characteristics that may impact the operational performance of an SHM system.

1.1 Effect of SHM on Operator's Programs

The aerospace industry is striving to reduce the unit acquisition and operating costs to their customers while maintaining required safety levels. To obtain this goal, manufacturers are promoting new technologies such as SHM to reduce long-term maintenance costs and increase aircraft availability and weight savings [1]. Innovative deployment methods must be developed to overcome a myriad of inspection impediments stemming from accessibility limitations, complex geometries, and the location and depth of hidden flaws. Self-sufficient SHM systems use embedded networks of integrated sensors to detect structural damage while reducing human error. In principle, SHM in commercial airplane applications has the potential to detect structural discrepancies, determine the extent of damage, determine effects of structural usage, and eventually determine the impact on structural integrity and continued airworthiness. Parameters to be monitored could indicate flaws directly or could be physical properties such as load, strain, pressure, vibration, or temperature from which damage, malfunction, mechanical problems, or the need for additional investigation can be inferred. The key element in an SHM system is a calibration of sensor responses so that damage signatures can be clearly delineated from sensor data produced by undamaged structures.

The potential benefits that SHM offers regarding airplane maintenance and operation are [1-4]: reduction of inspection time, early flaw detection to enhance safety and allow for less drastic and less costly repairs, minimized human factors concerns due to automated use of SHM sensors, and the elimination of costly disassembly processes that are needed to gain access to inspection regions and which provide the opportunity to damage the structure. However, the commercial implementation of SHM needs to be proven through statistically-viable lab performance data and successful field operations.

2 Overview of FAA Regulatory Guidance and Aircraft Certification Process

Before SHM systems can be accepted for routine use on commercial aircraft, they must demonstrate: satisfactory and proven performance (improved or equivalent safety) and the ability to meet FAA validation requirements. The FAA has established regulations and guidance to ensure the safety of commercial aircraft operations. The introduction of SHM can be fostered through the addition of SHM solutions in FAA and OEM documents. These documents include: Federal Aviation Regulations (FARs), Advisory Circulars (ACs), Airworthiness Directives (ADs), Advisory and Rulemaking Committee Orders, Continued Operational Safety (COS) documents, Special Airworthiness Information Bulletins (SAIB), and other technical orders [5-6].

For transport category aircraft, FARs related to design and airworthiness include Part 21 which addresses certification procedures for components, Part 25 which addresses airworthiness standards for aircraft and Part 121 which discusses operating requirements. Items specifically related to SHM systems include: airworthiness, equipment, maintenance, alterations and operating limitations. ADs describe required inspections or other maintenance actions that are derived from service experience or other assessments that identify safety concerns. An operator may request to use SHM in lieu of an AD required inspection and this can receive formal approval from the FAA via an Alternate Means of Compliance (AMOC). Information contained in ACs is intended to aid aircraft maintenance processes, suggest standards, and clarify FAA programs relative to aircraft operations. Supplemental Structural Inspection Documents (SSID) are issued by the OEMs for the specific purpose of notifying owners and operators regarding modifications and inspections believed necessary to maintain structural integrity of their aircraft.

FAA Certification is an evaluation process that results in the issuance of a standard Airworthiness Certificate for each aircraft type. The process includes an assessment of aircraft design (type certificate), manufacture (production approval), operation and maintenance (continued airworthiness). An initial Type Certification (TC) is issued by the FAA to approve new products while a Supplemental Type Certificate (STC) addresses design modifications to a certified product. Any aircraft modifications must be accompanied by an airworthiness assessment and a continued maintenance assessment. Validation requirements are normally established through joint agreements between the FAA and the applicant. In the case of STCs, OEM input may also be solicited. The adoption of new SHM systems on aircraft could involve the issuance of an STC. With this FAA Aircraft Certification process in mind, Figure 2 provides a flowchart showing how the integration of an SHM system might be approved through the FAA STC process.

3 Validation of Structural Health Monitoring Systems

The validation and certification process begins with the declared application intent, and a determination of the resultant criticality. The declared intent should specify whether this application is for credit (replaces required task or leads to changes in the requirements for a task) and if it adds to, replaces, or intervenes in maintenance practices or flight operations. When the declared intent is for credit, the end-to-end criticality for such an application should be determined and used as an input to establish the validation criteria. If the declared intent is for noncredit (provides additional data above and beyond required tasks), it may be certified if it can be shown that the installation of the equipment will not result in a hazard to the aircraft. Therefore, criticality describes the severity of the result of an SHM application failure or malfunction.

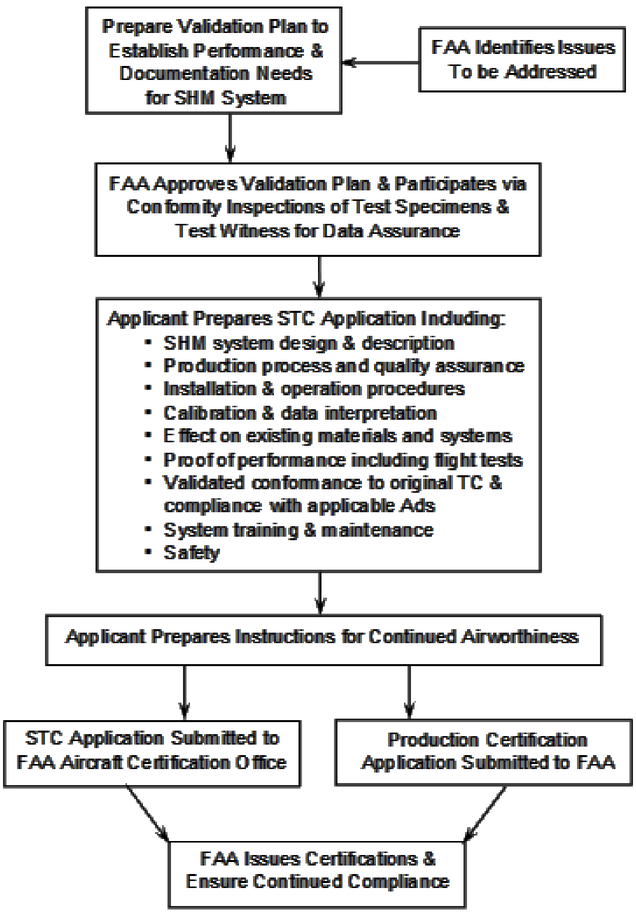

Fig. 2. Possible flow of an SHM system through the supplemental type certificate process.

The objective of any SHM technology validation exercise is to provide quantifiable evidence that a particular inspection or maintenance methodology (equipment plus its operation) can achieve a satisfactory result. The validation process must consider the numerous factors that affect the reliability of an inspection methodology including the individual inspector/operator, his equipment, his procedures and the environment in which he is working. It also accounts for the viability of the SHM approach within the aircraft's maintenance program. The approach is based on the use of real-life Validation Assemblies which are full-scale structural assemblies containing known, realistic defects or other operational malfunctions which the SHM system is intended to monitor [7-9].

The validation process should: 1) provide a vehicle in which skills, automation of instrumentation and human error can be evaluated in an objective and quantitative manner, 2) produce a comprehensive, quantitative performance assessment of the SHM system and utilization procedure in a systematic manner, 3) provide an independent comparison between SHM solutions and alternate maintenance and monitoring methodologies, 4) optimize SHM utilization methodologies through a systematic evaluation of results obtained in laboratory and field test beds, 5) produce the necessary teaming between the airlines, aircraft manufacturers, regulators, and related SHM development and research agencies to ensure that all airworthiness concerns have been properly addressed.

The process of validating SHM techniques involves the specification of a structure with defects or containing the appropriate boundary conditions and features to allow for the assessment of whatever physical parameter the SHM system is monitoring. The validation process may involve the production of full size sections of airframes or appropriate laboratory test samples which contain natural, fully characterized defects or realistic, engineered defects. Inspection or monitoring of these Validation Assemblies must occur under conditions identical to those of the day-to-day inspection environment. The validation process is a full-scale, realistic mockup of the daily activities of the maintenance personnel involved in the proposed SHM application. The tests performed are then independently assessed against industry standards in terms of personnel and instrument performance. In this regard, independence and objectivity are essential. Some validation efforts may include the use of airline maintenance personnel who will perform the monitoring tasks using normal working practices and under normal working conditions (lighting, heating, noise, work shifts, etc.).

A key element in evaluating SHM methods is a criteria with which to "score" systems and compare them with competing NDI or other SHM techniques. While specific systems and inspections will have their own individual features of interest, there are some basic evaluation criteria which are of fundamental importance for any SHM system. There are basic generic features which should be considered when conducting Validation Experiments. Also, special, unique features, over and above the "basic" ones, must be evaluated on a case-by-case basis. A summary of these evaluation criteria is provided in Table 1.

SUMMARY OF POTENTIAL EVALUATION CRITERIA			
RANK	**CRITERIA**	**DESCRIPTION**	**MEASURE**
*	Accuracy	Correct flaw locating/ High probability of detection Low probability of false indications	no. of flaws detections / no. of actual flaws >X% no. of false calls / no. of total calls <Y%
*	Sensitivity	Capability to detect small flaws and provide location, type, and degree of damage	Types or severity of corrosion/ debonds detected Length of cracks detected Detect 10% reduction in skin thickness due to corrosion
*	Analysis Capability	Clarity of results and time required to obtain them	Real-time presentation Provides rework decision Ease of flaw location ID Measures peripheral factors and removes subjectivity
*	Human Factors	Ease of use	Evaluation of man-machine interface (MIL-STD-1472) Compatible with existing equipment and current inspection demands
*	Versatility	Detect flaws in a variety of locations on the aircraft, under different circumstances and structural configurations	Number of recalibrations required for different circumstances Capability to inspect through paint Detect flaws at different levels of various multi-layered structures
*	Portability	Ease of shipping and handling	Can be moved around hangar to meet inspection demands
*	Scan Rate	Rapid and precise set-up	Area inspected per unit of time
*	Availability	Off-the-shelf or available to meet near-term inspection requirements	Lead time for vendor to produce operational system
*	Cost	Cost-benefit analysis	Operational and fixed costs vs. other NDI or SHM methods

* Determine a suitable rating system (e.g. High, Med, Low; assign numeric values from 1 to 10)

Table 1. Summary of potential SHM evaluation criteria.

Following are some issues to consider when developing an evaluation scheme for individual validation experiments. As always, the state of maturity of the SHM technique, along with the specific needs and views of the end-user, will determine the type of assessment performed.

1. Are the results subjective and difficult to interpret? Is there a clear difference between meaningful indications and noise in the results? Would the use of calibration samples aid the interpretation of results?
2. Was the hardware and software robust? Were there frequent shutdowns or reinspection of the same areas to get adequate results?
3. Instrument Details - How is the technique implemented (equipment description and comparison to other versions of similar or competing techniques)? What is the systems history and current phase of development?
4. Aircraft Inspection Requirements Addressed - What type of structures are inspected and for what type of flaws? How easily can the SHM system be integrated into normal aircraft maintenance activities?
5. Deployment - Manpower needs, training needs, time to set-up and gather data, inconveniences, problems associated with different environments (e.g. staging, lighting, noise, temperature, movement of airplane, other simultaneous work).
6. Specific Experiments - Results of planned experiments and success using specimens with known flaw profiles. Comparisons with results from similar NDI or SHM methods or different but competing methods.

4 Establishing SHM Probability of Detection Using One-Sided Tolerance Intervals

The quantification of SHM performance – in the lab and in the field - must be completed to prove that the resulting aircraft maintenance meets the desired safety standards. Statistical performance assessments of flaw detection sensors that are permanently mounted in a fixed position must be handled differently than similar studies using hand-held or other deployed NDI transducers. Such NDI transducers are moved along the structure being inspected. In the case of in-situ SHM sensors, the flaw of interest originates within or propagates into the region being monitored by the SHM sensor. Performance analyses then consider the response of the sensor or flaw detection and correlate this response with the size of the flaw when detected. For example, a crack in the material beneath or near an SHM sensor will allow for detection. The Probability of Detection (POD) data could then consist of fatigue cracks that were propagated in various metal specimens with the direction of growth aligned with the mounted sensors. The data captured is that of the flaw length at the time for which the SHM sensor provided sustainable detection. With these assumptions there exists a distribution on the flaw lengths at which detection is first made. In this context, the probability of detection for a given flaw length is just the proportion of the flaws that have a detectable length less than that given length. That is, the reliability analysis becomes one of characterizing the distribution of flaw lengths and the resulting cumulative distribution function is analogous to a POD curve. If the distribution of flaws is such that the logarithm of the lengths has a Gaussian distribution, it is possible to calculate a one-sided tolerance bound for various percentile flaw sizes. To do this, it is necessary to find factors $K_{n,\gamma,\alpha}$ to determine the probability γ such that at least a proportion (1-α) of the distribution will be less than $X - K_{n,\gamma,\alpha}$ where X and S are estimators of the mean and the standard deviation computed from a random sample of size n. The data captured is the crack length at sensor detection. From the reliability analysis a cumulative distribution function is produced to provide the maximum likelihood estimation (POD). This stems from the one-sided tolerance bound for the flaw of interest using the equation:

$$A_{(90,\,95)} = X + (K_{n,0.95,\alpha})(S) \qquad (1)$$

Where:

A = Crack length for 90% POD, 95% confidence

X = Mean of detection lengths

K = Probability factor (function of sample size, confidence level desired and detection POD desired)

γ = Confidence level (normally chosen as 95%)

S = Standard deviation of detection lengths

n = Sample size

1- α = Detection level

Using equation (1), it is possible to quantify the 90% POD level (e.g. crack length) for a sensor with a desired confidence level. The probability factor, K, can be found in statistical tables. The value for K is proportional to the number of samples tested and the range in detection levels observed. Thus, the performance is penalized – and the resulting POD increases - if the results are obtained with only a few samples and/or if there is a high degree of variability in the results.

5 Sample SHM Validation Activities for Aircraft Applications

The AANC at Sandia Labs, in conjunction with Boeing, Northwest Airlines, Delta Airlines, Bombardier, Structural Monitoring Systems and the FAA, completed validation testing on the Comparative Vacuum Monitoring (CVM) system to adopt CVM as a standard SHM practice [10]. Fatigue tests were conducted on simulated aircraft panels to grow cracks in riveted specimens while the vacuum pressure within the various sensor galleries was simultaneously recorded. The fatigue crack was propagated until it engaged one of the vacuum galleries such that crack detection was achieved (sensor indicates the presence of a crack by its inability to maintain a vacuum). In order to properly consider the effects of crack closure in an unloaded condition (i.e. during sensor monitoring), a crack was deemed to be detected when a permanent CVM alarm was produced even if the fatigue stress was reduced to zero. Figure 3 shows a sample CVM sensor mounted on aircraft structure as part of a performance validation effort.

The test program produced a statistically-relevant set of crack detection levels for 0.040", 0.070" and 0.100" thick panels in both the bare and primed configurations. Table 2 lists some of the crack detection/sensitivity results for the CVM sensors. Note that there were no false calls produced by the CVM sensors in any of the tests. The crack detection values listed in Table 2 must be added to any sensor placement error adjacent to the rivet and any detection delays caused by coatings, such as primers, to arrive at the length that a crack must grow before it is detected with the CVM system on an aircraft.

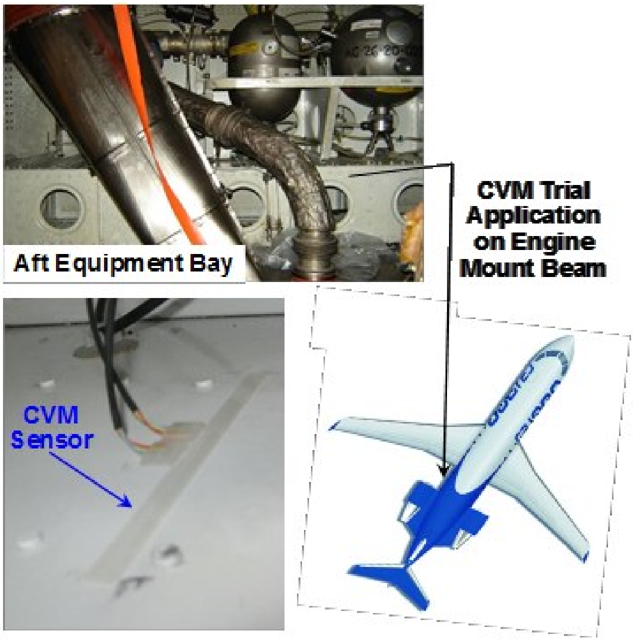

Fig. 3. Crack detection via CVM system and aircraft Test installations of sensors.

Material	Plate Thickness (mm)	Coating	90% POD for Crack Detection (mm)
2024-T3	1.02	Bare	1.24
2024-T3	1.02	Primer	0.53
2024-T3	1.80	Primer	1.07
2024-T3	2.54	Bare	6.91
2024-T3	2.54	Primer	2.29
7075-T6	1.02	Primer	0.66
7075-T6	1.8	Primer	0.84
7075-T6	2.54	Primer	0.58

Table 2: Summary of crack POD levels for CVM deployed on different materials, surface coatings, and plate thicknesses.

The 90% POD levels for crack detection on aluminum structures of various thicknesses and surface conditions were calculated using equation (1). A sample POD curve is plotted in Figure 4. As the number of data points increases, the K value will decrease and the POD numbers could also decrease. In this instance, it was desired to achieve crack detection before the crack reached 0.10” in length so this goal was achieved.

To study CVM sensor performance in aircraft operating environments, 26 sensors were also mounted on structures in four different DC-9, 757, and 767 aircraft in the Northwest Airlines and Delta Air Lines fleet (see Figure 5). Periodic testing was used to study the long-term operation of the sensors in actual operating environments. The sensors functioned successfully during over 7 years of flight test monitoring.

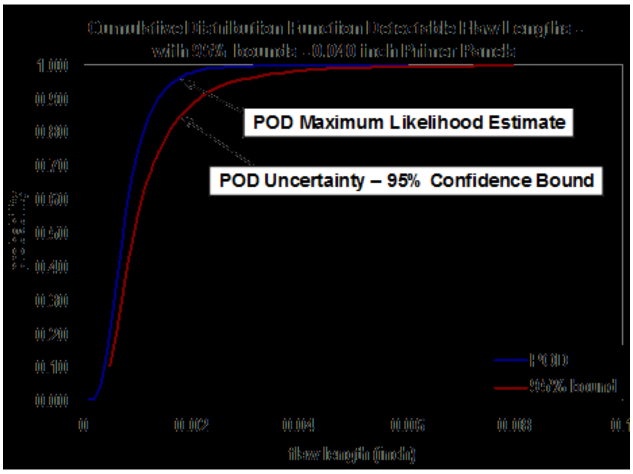

Fig. 4. Typical probability of crack detection curves generated by CVM data and data analysis using One-Sided Tolerance Intervals.

Fig. 5. Long-term flight testing of CVM sensors on operating aircraft

6 Integration of SHM Systems with Airline Maintenance Programs

The maintenance program instituted by each air carrier is the means used by operators to ensure the proper performance and long-term reliability of their aircraft. Maintenance programs are intended to produce the maximum aircraft availability while ensuring compliance with FAA regulations. Specifically, the maintenance programs, which are based on the manufacturer’s instructions for continued airworthiness, seek to guarantee the safety and reliability of all aircraft systems and structures, repair any damage or operational problems identified, and accommodate continuous improvements to enhance reliability or advance aircraft designs. The maintenance program must be modified to accommodate the unique operation, use, and maintenance associated with SHM systems. In turn, SHM systems can help carriers achieve their goal of increasing the usage of their aircraft. Currently, some aircraft experience over 5,000 flight hours in a year placing added emphasis on cost-effective and streamlined maintenance practices.

Operators organize their inspection and maintenance tasks to achieve compliance with regulations and OEM recommendations while maximizing aircraft availability. The various checks associated with general aircraft maintenance are as follows:

1. Walk Around – visual checks conducted prior to each flight.
2. Service Checks – brief checks conducted every several days to service consumable items like fluids and to check for wear.
3. A-Checks – scheduled line maintenance check conducted every 25-40 days.
4. B-Checks – scheduled line maintenance check conducted every 45-75 days.
5. C-Checks – detailed maintenance and inspection visit conducted every 12-15 months.
6. D-Checks – heavy maintenance visit or complete aircraft overhaul conducted every 2-5 years.

The intervals between services are dependent upon aircraft utilization, flight cycles, and required aircraft maintenance tasks. Activities up through B-Checks can normally be accomplished during overnight stays for the aircraft. C-checks can take up to one week to complete while D-Checks require approximately one month to complete. Operators may choose to implement their maintenance activities in block, segmented, phased, or continuous maintenance visits. These options allow the various maintenance tasks to be broken into different intervals and completed in segments over the required interval.

The objectives of a maintenance program are: a) to ensure realization of the inherent safety and reliability levels of the equipment; and b) to restore safety and reliability to their initial levels when deterioration has occurred. The application of SHM methods provides the potential to reduce aircraft maintenance tasks and down time but the promise of new technology must always be reviewed in light of airworthiness compliance issues. The effects of SHM on the Instructions for Continued Airworthiness (ICA) must be addressed whenever a commercial aircraft application is pursued and associated modifications to the maintenance program are made.

The scope of the maintenance programs include three major areas: 1) scheduled maintenance tasks including inspections, function checks and other maintenance based on time or flight cycle limitations or other prescribed intervals, 2) unscheduled maintenance tasks that are based on the findings from scheduled maintenance or that arise from unforeseen events (e.g. high loads, bird strike, hard landing, over-temperature condition), and 3) maintenance requirements for major components including engine overhaul, propeller overhaul, and airframe maintenance. The maintenance manual includes instructions on what to do, when to do it, how to do it, and checks to ensure that the work was done properly.

SHM systems can be interjected to carry out a wide array of maintenance tasks. For example, SHM can be used to monitor operating environments and aid in the determination of unscheduled maintenance tasks. SHM can automatically (real-time, on-board data acquisition) or semi-automatically (discrete intervals, off-board data acquisition) conduct inspections that could allow for condition-based repairs, component replacement and/or component servicing. SHM systems can detect operational problems or other non-routine occurrences that may be precursors to failure such that maintenance activities can efficiently be scheduled ahead of time. SHM systems could be used as an additional quality assurance measure where reliability trends can be tracked to ensure the effectiveness of the existing maintenance programs. Results from such monitoring can also be used to justify the addition of new, or the modification of current, maintenance tasks. Operators may adopt SHM techniques through changes in their maintenance manuals. Deviations from the OEMs maintenance recommendations and instructions for continued airworthiness will require appropriate approvals.

7 Conclusions

The effect of structural aging and the dangerous combination of fatigue and corrosion has produced a greater emphasis on the application of sophisticated health monitoring systems. In addition, the costs associated with the increasing maintenance and surveillance needs of aging structures are rising. Corrective repairs initiated by early detection of structural damage are more cost effective since they reduce the need for subsequent major repairs and may avert a structural failure. Global SHM, achieved using sensor networks, can be used to assess overall performance (or deviations from optimum performance) of large structures such as aircraft, bridges, pipelines, large vehicles, and buildings. The ease of monitoring an entire network of distributed sensors means that structural health assessments can occur more often, allowing operators to be more vigilant with respect to flaw onset.

Through the use of in-situ SHM sensors, it is possible to quickly, routinely, and remotely monitor the integrity of a structure in service and detect incipient damage before catastrophic failures occur. These sensors can be attached to a structure in areas where damage is known to occur. On a pre-established engineering interval, a reading will be taken from an easily accessible point on the structure. Each time a reading is taken, the system performs a self-test. This inherent fail-safe property ensures the sensor is attached to the structure and working properly prior to any data acquisition. This study showed the viability of using the One-Sided Tolerance Interval (OSTI) approach to determine the Probability of Detection for a fixed sensor detecting a crack which is propagating in a known direction in the vicinity of the sensor. The OSTI approach yields a reasonable estimate for the CVM crack detection capability even with small data sets.

Aircraft downtime is one of the largest costs associated with carrier operations. Current escalations in aircraft utilization hasten the arrival of A, B, C, and D-Checks yet imply the need for less downtime for maintenance. This need for more effective maintenance may be partially addressed through the introduction of SHM practices. Rapid, automated inspections - used in lieu of tedious and slow manual inspections - elimination of disassembly for access (remote interrogation of sensors), automated data analysis and disposition, and automated record keeping are several of the features that can produce a positive cost-benefit analysis for SHM.

Carriers can modify their maintenance manuals to use SHM methods for required maintenance tasks. Similarly, revisions in applicable OEM manuals (e.g. NDT Standard Practices Manuals) can provide one level of approval and allow for the safe and uniform utilization of SHM systems. The Supplemental Type Certificate (STC) process must be augmented to include all aspects of SHM equipment manufacturing, installation, and operation to proactively address the desire to apply SHM systems. The granting of an Alternate Means of Compliance or a reference in an aircraft manufacturer’s Service Bulletin can be the method used to approve SHM usage. Such applications provide excellent proving grounds for the validation, approval, documentation, and certification processes discussed here.

This program established an optimum OEM-airline-regulator process and determining how to safely adopt SHM solutions. Close consultation with regulatory agencies is being used to produce a process that is acceptable to both the aviation industry and the FAA. The activities conducted in this program facilitate the evolution of an SHM certification process including the development of regulatory guidelines and advisory materials for the implementation of SHM systems via reliable certification programs. Formal SHM validation will allow the aviation industry to confidently make informed decisions about the proper utilization of SHM solutions.

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