

FAA Research and Development Efforts in SHM

P. SWINDELL and D. P. ROACH

ABSTRACT

SHM systems are being developed using networks of sensors for the continuous monitoring, inspection and damage detection of commercial aircraft structures in order to improve safety, reduce costs and human induced damage. Aircraft OEMs, SHM system developers and airlines are interested in leading the way in more widespread SHM use. There is a need for an overarching plan that will guide near and long-term research activities that will comprehensively support the evolution and adoption of SHM practices in civil aviation. The Federal Aviation Administration is addressing these issues through the development of an SHM Research and Development roadmap.

INTRODUCTION

The future of Structural Health Monitoring (SHM) could potentially be an aircraft filled with sensors monitoring the condition of numerous critical structures looking for indicators that can warn an aircrew of pending problems that could be detrimental to the current flight. SHM could serve as a way for aircraft maintainers to know when it is time to schedule needed maintenance on an aircraft's structure because it has a problem that needs to be repaired. A system or systems, collecting and analyzing data and making decisions that affect maintenance and/or aircraft operations is in the author's opinion, a long way into the future for commercial transport aircraft. There will have to be a huge paradigm shift in risk management by aircraft OEMs, operators and regulators before such SHM systems are ever used to their fullest potential.

Safety of the flying public is of paramount importance to the FAA, aircraft operators and OEMs. One of the FAA's primary goals is to improve the safety of the flying public. Aircraft OEMs are trying to sell low cost, low maintenance aircraft to operators around the world. Aircraft operators are still under very tight financial restrictions and are looking for ways to lower their operating costs. SHM has the potential to improve safety while lowering maintenance costs.

Paul Swindell, FAA William J Hughes Technical Center, Atlantic City, NJ 08405, Dr. Dennis Roach, Sandia National Laboratories, FAA Airworthiness Assurance Center (AANC), Box 5800 MS-0615, Albuquerque, NM 87185

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14. ABSTRACT SHM systems are being developed using networks of sensors for the continuous monitoring, inspection and damage detection of commercial aircraft structures in order to improve safety, reduce costs and human induced damage. Aircraft OEMs, SHM system developers and airlines are interested in leading the way in more widespread SHM use. There is a need for an overarching plan that will guide near and long-term research activities that will comprehensively support the evolution and adoption of SHM practices in civil aviation. The Federal Aviation Administration is addressing these issues through the development of an SHM Research and Development roadmap.					
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Today, SHM is in its infancy. SHM systems are being developed using networks of sensors for the continuous monitoring, inspection and damage detection of commercial aircraft structures in order to improve safety, reduce costs and help eliminate human induced damage during normal maintenance operations. Aircraft OEMs, SHM system developers and airlines are interested in leading the way in more widespread SHM use. There is a need for an overarching plan that will guide near and long-term research activities that will comprehensively support the evolution and adoption of SHM practices in civil aviation. The Federal Aviation Administration is addressing these issues through the development of an SHM Research and Development (R&D) roadmap. This paper will describe the current efforts to develop the FAA's SHM R&D roadmap and one of the research projects that will be started.

FAA SHM RESEARCH ROADMAP

The researchers at the FAA's William J Hughes Technical Center, Atlantic City, NJ with the support of their sponsors at the Transport Aircraft Directorate, Seattle, WA began the development of a R&D roadmap for SHM to include short and long term research activities to comprehensively support the evolution and adoption of SHM practices in commercial transport aircraft. The plan will contain input from aircraft manufacturers, regulators, operators and research organizations and will address issues to include design, deployment, performance and certification. It will be used to assess what regulatory guidance is needed to ensure safe incorporation of SHM in commercial aviation. The FAA tasked personnel at the Airworthiness Assurance NDI Center (AANC) in Albuquerque, NM to develop the roadmap and to include the following tasks: 1) Produce an SHM technology readiness database, 2) Develop and implement an SHM Industry Survey, 3) Develop an SHM sensor database, and 4) Review all pertinent FAA, industry and military SHM related documents and to assess the current state of SHM today and provide guidance for future FAA related research. The report is due to the FAA in July 2011 and should be published by the end of the calendar year.

SHM INDUSTRY SURVEY

A comprehensive survey was developed and was implemented with the aviation industry to determine the technology maturation level of SHM, identify integration issues and prioritize research and development needs associated with implementing SHM on transport aircraft. This survey was sent to people involved in the operation, maintenance, inspection, design, construction, life extension and regulation of aircraft. Over 450 responses were received that provided information on SHM deployment, usage, validation, certification, standardization, sensor evolution and operation, and cost-benefit analysis. The survey responses indicated a strong interest in SHM, identified over 200 potential applications covering structures, engines, and other systems. Industry's main concerns with implementing SHM are getting a positive cost-benefit and the time to obtain approval for SHM use. OEMs and operators felt that R&D efforts should be

focused on global systems, sensor technology, system validation and integration, and regulatory guidance. There was a strong desire for guidelines and standardization in the areas of sensor design, validation and certification.

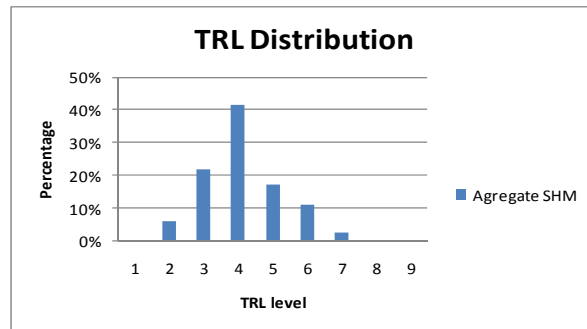
SHM SENSOR DATABASE

Sensors are a critical part of a SHM system. If a sensor is not working properly, the SHM system will not operate properly and either miss the damage it was meant to monitor and report damage that may not exist. SHM system reliability is only as good as the sensors being used to collect the data. The sensor database was developed to display a number of sensors that are in different phases of a sensor life cycle. This database describes the many different sensors on the market today. There are over 80 sensors in the database with numerous applications and uses. The database provides the many physical parameters that can be sensed such as strain, temperature, pressure, load, corrosion, displacement and bond integrity. The database provides a description, application and a photograph. The sensors were identified from technical publications, conference proceedings, industry brochures, the SHM Industry Survey, and internet searches. There are a limited number of known nondestructive inspection techniques but there is a much larger number of sensors that can be utilized to support these techniques. They can be tailored and configured for customized applications. The database shows that SHM sensing is mature and expansive, in addition to being highly tested and proven in various test settings. There are many fully mature sensors that are being produced, used, tested and evaluated. The sensor database is tool that can be used to describe what SHM sensors look like, how they work and what they can detect.

SHM DOCUMENT REVIEW AND TECHNOLOGY READINESS DATABASE

Over 3000 papers were compiled, read and tabulated to determine the current state of SHM readiness. The SHM Technology Readiness Database was developed to store, manage and analyze data trends found in the database. The SHM Technology Readiness Database highlights SHM trends and includes a listing of SHM sensor and sensor systems with their maturation ratings based on selected SHM criteria. This criteria, used to establish the evolution model for the various SHM technologies, is based on the Technology Readiness Levels (TRL) widely used by military, NASA, and government agencies. The nine TRLs are: 1) TRL1 = Basic Principles, 2) TRL2 = Technology concept and/or application formulated, 3) TRL3 = Proof-of-Concept, 4) TRL4 = Component and/or breadboard validation in laboratory environment, 5) TRL5 = Component Validation, 6) TRL6 = System/subsystem model or prototype demonstration in a relevant environment, 7) TRL7 = Prototype Demonstration, 8) TRL8 = Actual system completed and certified through test and demonstration, and 9) TRL9 = System Proven in Mission Operations. The database summarizes information on the type and depth of activity associated with the various SHM technologies. The figure shows a normalized

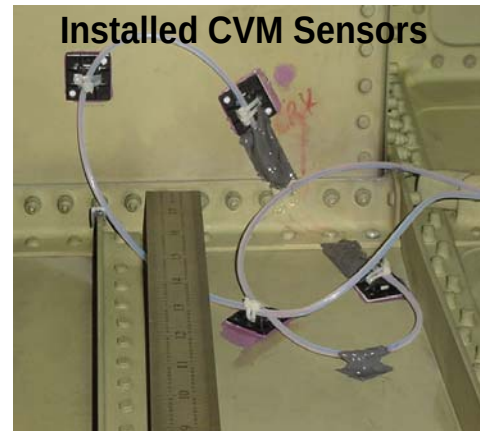
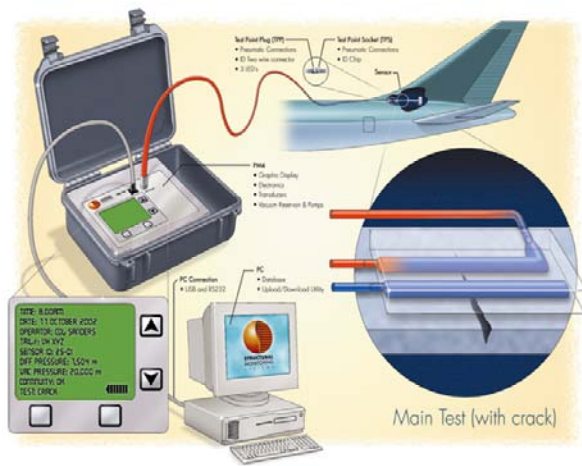
distribution of the SHM systems and sensors listed in all of the papers. The data indicates that a significant number of SHM systems are at the technology readiness level (TRL) of 4. The data indicates that since 2006, the peak has moved from TRL 2/3 to 4 with new incursions in TRL 7. This movement of the peak seems to indicate a rapid maturation of SHM technologies which give hope that the peak will be in the TRL 7 range with several technologies making it to the TRL 9 range in approximately 5 years.



Normalized TRL Distribution from All Papers

FUTURE SHM RESEARCH

The FAA is planning follow on research based on the results of the data developed to create the SHM roadmap. The FAA is establishing a team from the AANC, Delta Air Lines, the Boeing Company, an SHM system OEM and the FAA to propose the next logical step for SHM implementation. The recommendation will be to use one of the more mature SHM technologies and determine the required steps to get FAA/OEM/operator approval to use that technology on an aircraft to monitor some known problem area in conjunction with an approved NDI technique for comparison of capabilities. The technology most likely to be used will be the Comparative Vacuum Monitoring (CVM) system developed by Structural Monitoring Systems. CVM shown in the figure below is used to detect surface cracks. The CVM is one of the advanced NDI methods that has been evaluated by AANC in support of FAA funded research. As a result, the CVM has flown a number of years on Delta and Northwest Airline aircraft to determine the CVM's ability to withstand temperature extremes, aircraft fluid contamination and system reliability (ability to work after years on aircraft). The CVM is a self-adhesive, elastomeric sensor with fine channels on the adhesive face that when adhered to the structure under test, the fine channels and the structure itself form a manifold of galleries alternately at low vacuum and atmospheric pressure. When a crack develops, it forms a leakage path between the atmospheric and vacuum galleries, producing a measurable change in the vacuum level. Delta Air Lines and Boeing are working on finding an application that the CVM can be used on and provide a positive cost-benefit analysis. The application will most likely be a service bulletin driven inspection that will allow the CVM to be used in conjunction with an approved NDI procedure.



Crack Detection Via CVM System and Aircraft Test Installations of Sensors

CONCLUSION

The FAA is recognizing the potential future use of SHM systems on transport category aircraft. The SHM R&D roadmap is almost finished and will provide the direction and guidance for future SHM research on large transport aircraft. The resulting research will be used in industry specifications that can be used in future SHM applications. A snapshot of SHM capabilities will be available once the FAA publishes the work from the AANC. These efforts have provided a clear understanding of the current status of SHM technology and the pending regulatory issues facing the aviation industry to safely adopt SHM practices.