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Outline of the Japanese National Project on Structural Health Monitoring System for Aircraft Composite Structures and JASTAC Project

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Abstract

This paper presents outline of our structure health monitoring (SHM) project in Japan. We are developing three (3) SHM systems for composite structures of aircraft. This project is conducted by MHI (Mitsubishi Heavy Industries, Ltd.), KHI (Kawasaki Heavy Industries, Ltd.), FHI (Fuji Heavy Industries, Ltd.), Yokogawa (Yokogawa Electric Corporation) , Anritsu (Anritsu Corporation), JAXA (Japan Aerospace Exploration Agency) and University of Tokyo. SOKEIZAI Center (former known as RIMCOF - Research Center of Advanced Metals and Composites) is managing them under METI (Ministry of Economy, Trade and Industry of Japan) contract. METI has founded this project. This paper also, describes JASTAC (Japan-Airbus SHM Technology for Aircraft Composite) project.

1 INTRODUCTION

In late years, regardless of large or small aircrafts, application of carbon fiber reinforced plastics (CFRP) to aircraft structure is increasing in form of monolithic parts and large structures. Primary purpose of CFRP application in structure is light weighting and subsequently anticipated improvement of fuel consumption. On the other hand, they cannot say that a destruction process, the durability and impact resistance of CFRP are grasped enough, and it is necessary to grasp structure integrity for safety aircraft operation. To promote the application expansion of CFRP, it is necessary to improve efficiency of maintenance for the operation of aircrafts made by CFRP, and to realize the large reduction of the maintenance cost. Condition monitoring of airframe by structure health monitoring (SHM) methods using optical fiber has possibility to expand CFRP application. Thus, based on monitoring structure damage by SHM in flight, innovative aircraft design and lighter weight aircraft is expected.

2 JAPANESE NATIONAL PROJECT ON SHM

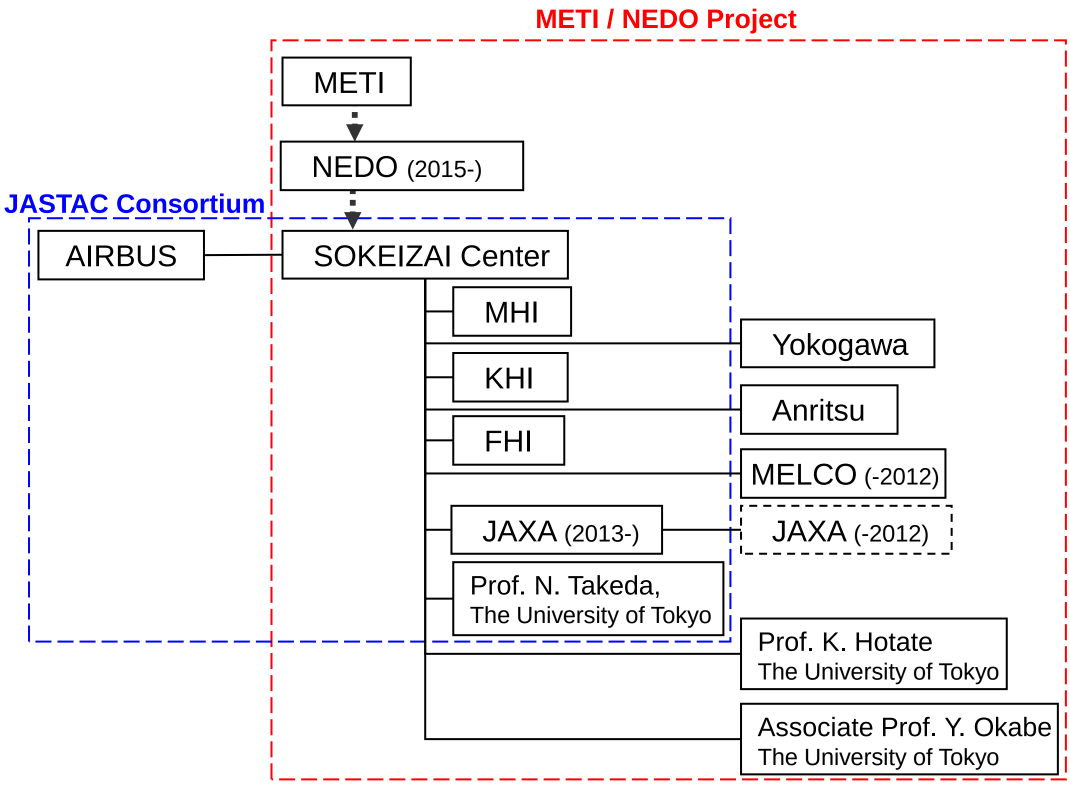
In “Advanced Materials & Process Development for Next-Generation Aircraft Structures“ that SOKEIZAI Center performed in response to commission from METI (the

Ministry of Economy, Trade and Industry of Japan) from 2003 FY (Fiscal Year) to 2007 FY, we had checked validity of basic technology in SHM systems.

Based on this result, SOKEIZAI Center has carried out next project, “Advanced Materials & Process Development for Next-Generation Aircraft Structures (Development of Structure Health Monitoring technology)”, 2008 FY through 2012 FY (first phase) and 2013FY through 2015FY (second phase). This project is commissioned by METI (2008FY through 2014FY) and NEDO (since 2015FY).

A leader of this project is Professor Nobuo Takeda in the University of Tokyo. Currently (at second phase), this project is conducted by MHI, KHI, FHI, Yokogawa, Anritsu, JAXA and the University of Tokyo. Prof. Nobuo Takeda, Prof. Kazuo Hotate and Associate Prof. Yoji Okabe are involved in this SHM project from the University of Tokyo. (Refer to Figure 1.)

We have the JASTAC (2006FY-2012FY) and JASTAC-II (2013FY-2015FY) project with AIRBUS. Some of the project members have joined this JASTAC / JASTAC-II project. This is described in a later section.



METI: Ministry of Economy, Trade and Industry in Japan
NEDO: New Energy and Industrial Technology Development Organization
SOKEIZAI Center: R&D Institute of Advanced Metals and Composites - RIMCOF
MHI: Mitsubishi Heavy Industries
KHI: Kawasaki Heavy Industries
FHI: Fuji Heavy Industries
JAXA: Japan Aerospace Exploration Agency
MELCO: Mitsubishi Electric Corporation
Yokogawa: Yokogawa Electric Corporation
Anritsu: Anritsu Corporation

Figure 1: SHM project organization chart.

3 OUTLINE OF SHM TECHNOLOGIES

In this project, we are developing a SHM technology mainly for the three (3) purposes as follows.

1. System should be small and light weight for airborne.

2. System should have reliability that allows measuring distributed strain and detecting damage of aircraft structures under actual flight environment such as temperature, humidity, impact, vibration and so on.

3. System should have measurement accuracy and range which enable SHM of a practical use level. This should greatly improve the inspection efficiency of aircrafts.

Currently, we are developing three (3) SHM systems (Refer to Figure 2) [1, 2]. MHI, KHI, FHI, Yokogawa and Anritsu are developing and verifying those SHM systems. The University of Tokyo is supporting them with measurement principle and JAXA is supporting them with document research, test and analysis.

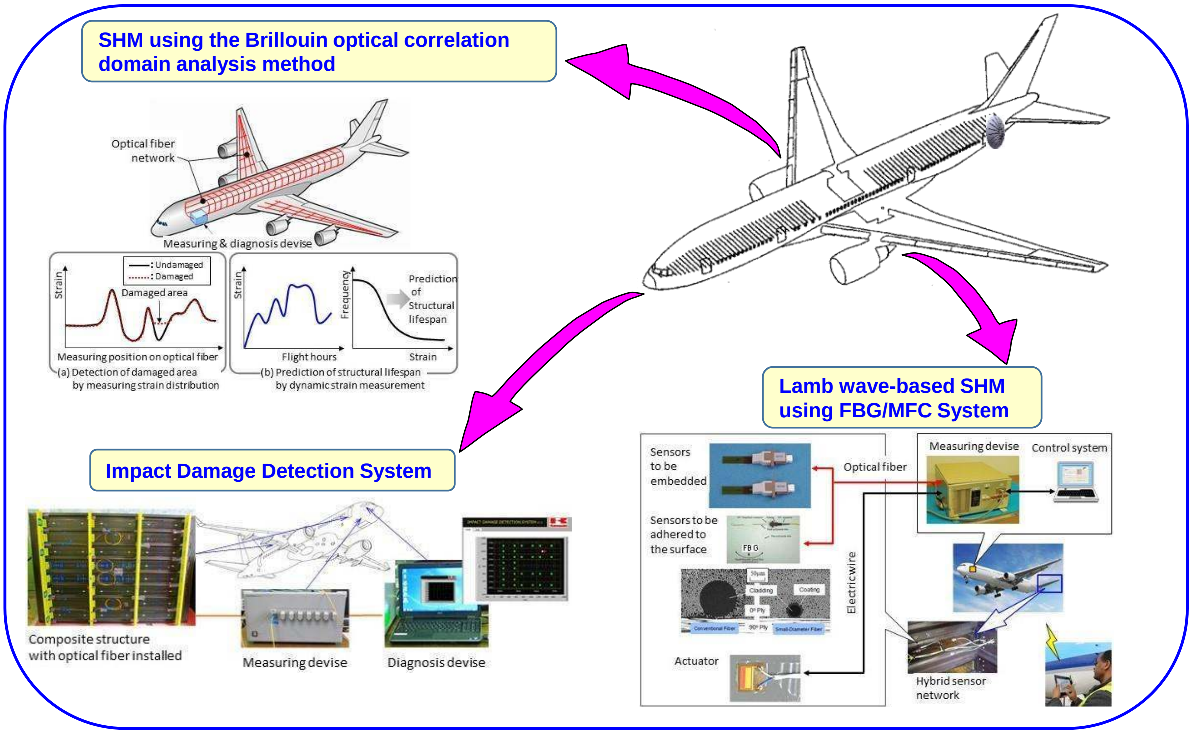


Figure 2: Three SHM systems in the METI Project.

1. Development of aircraft structural health monitoring system using distributed optical fiber sensor by MHI and Yokogawa

   This SHM system utilizes Brillouin scattering phenomena as measurement principle. This system can monitor distributed strain at arbitrary locations along an optical fiber continuously or on demand.

2. Development of enhancement technology for optical fiber based impact damage detection system applied to practical composite airframes by KHI and Anritsu

   This SHM system utilizes elastic wave from the impact at a structure. FBG sensors catch elastic wave from impact location and the system estimates the impacted location and magnitude of the impact. The impact used for tests is BVID (Barely Visible Impact damage) level.

3. Development of the Lamb wave-based structural health monitoring technology using FBG/MFC hybrid system for aircraft bonding structures by FHI

   This SHM system actively utilizes lamb wave. The lamb waves are generated by MFC (Macro Fiber Composite) actuators, propagate in structures and reach FBG sensors. The system estimates de-bonding length of the structure. It can also capture growth of de-bonding.

In first phase (2008FY-2012FY), we verified that systems (equipment, optical fiber attached portion) have sufficient durability under actual flight environment, by environmental testing defined in RTCA/DO-160E. We also studied durability of optical fiber adhered on structure surface, capability of SHM with bolt jointed specimens and form core sandwich panels, automatic installation of optical fiber by a robot, repair concept of optical fibers embedded in a CFRP structure, and so on.

Then, in second phase (2013FY-2015FY), we focused on studying reliability and durability of SHM systems by verification test and investigating procedure of preparing certification plans for SHM systems.

4 JASTAC PROJECT

AIRBUS and Japan consortium, MHI, KHI, FHI, SOKEIZAI Center and Prof. Takeda of the University of Tokyo are cooperating on SHM using optical fiber sensors. Prof. Takeda is an adviser for this project. This is JASTAC (Japan Airbus SHM Technology for Aircraft Composite) project (Refer to Figure 1.). This project has planned to work technology evaluation, component test, and technology optimization for application to commercial aircraft. This project has stared in 2006 and ended in 2012 once and JASTAC-II project started in 2013. JAXA will join the JASTAC-II project to support other Japan consortium members.

Targets of SHM systems in JASTAC are to detect delamination, debonding and impact and to monitor strain.

We have conducted a joint test campaign in AIRBUS sites Getafe, Bremen, Stade and Hamburg during 2010 and 2011. The SHM capability has been tested using subcomponents of aircraft structures. The technology maturity has been improved by this joint test campaign.

And then, in 2015 (during JASTAC-II project), ground tests using airframe have been conducted to verify the SHM system.

TRL (Technology Readiness Level) is used to measure maturity of the SHM system. TRL is classified Level 1 to 9 as shown on Table 1. We started TRL 3 at beginning of JASTAC project. Currently, we have reached TRL 6.

TRL	Stage	TRL Definition
1	Discover	System is only an idea on paper
2		In depth formulation on equipment
3	Understand	System partly a physical stage
4	Adapt	System at a laboratory stage
5		System at a laboratory stage and compliant to aircraft environment
6	Validate	System at a prototype stage and compliant to aircraft environment
7	Refine	System at a prototype stage tested in-flight
8		System in its final form, qualified through further ground-tests and in-flight trials
9	Use	System in its final form, further proven through extensive in-service use

Table 1: Technology Readiness Level.

5 CONCLUSIONS

SHM application to aircraft is being studied for both of manned and unmanned aircraft and this is one of the key technologies for CFRP application expansion. There is various technology of a non-destructive inspection (NDI) of inspecting CFRP but, it is only this SHM system which can work on aircraft and which is going to monitor damage and strain in flight.

We will study concrete application location and method, and research is advanced and it goes from now on aiming at certification and in-service application. But, it is hard that all equipment are airborne from beginning. We think that we set only optical fibers on aircrafts and measurement equipment will be started on a ground basis. Reduction of human error in an inspection is expected by mechanization and automation progressing of an inspection with SHM systems.

Since FY2013 (at second phase), we have also studied for utilizing these SHM methods as manufacturing process monitoring. Then, in the future, this study is expected to lead to "life-cycle monitoring"[3] for CFRP parts from manufacturing stage through operating stage (Refer to Figure 3).

Aerospace Council in SAE International published the guidebook of SHM for fixed wing aircraft implementation. This is a part of standardization activity for SHM applications in the world. We are also taking part in this activity, and the optical fiber sensor is also listed as one of the SHM technologies.

CFRP is one of key points in Japan. We expect that the SHM which combine this CFRP and optical fiber sensors will support expansion and development of CFRP aircraft.

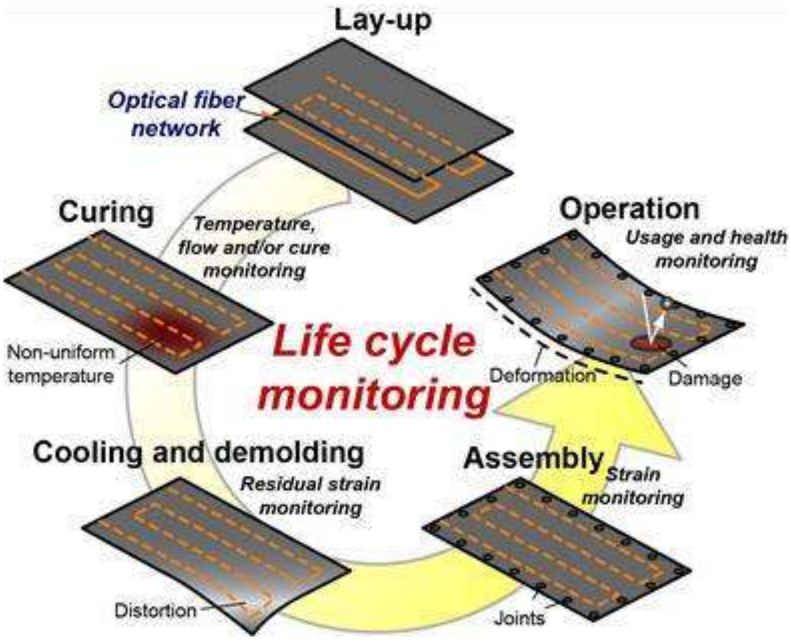


Figure 3: Concept of Life cycle monitoring. [3]

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