"INNOVATIVE AIRCRAFT POLYMER MATRIX COMPOSITES (*i*APMC)" PROJECT IN SIP SM^{4}I JAPAN- INTELLIGENT PROCESS MONITORING AND QUALITY ASSESSMENT OF CFRP STRUCTURES

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Abstract

SIP (Cross-ministerial Strategic Innovation Promotion Program) - SM^{4}I (Structural Materials for Innovation) was established in 2014 by the Council for Science, Technology and Innovation (CSTI) of the Japanese Cabinet Office, as one of the national R&D subjects to realize scientific and technological innovation strategically under its initiative. Under this SIP - SM^{4}I, our project, "Innovative Aircraft Polymer Matrix Composites (*i*APMC)" started in November 2014 as a five-year project. The main purpose of this project is to develop high-rate production aircraft PMC products and quality assurance technology for next-generation CFRP aircraft structures. This project consists of five research units, (1) OoA CFRP (Airframe) Unit, (2) Low-cost Autoclave CFRP (Airframe) Unit, (3) CFRTP (Engine) Unit, (4) High-Temperature CFRP (Engine) Unit, and (5) Academic Support and Material Evaluation Unit.

1. Introduction

Although carbon fiber reinforced polymer (CFRP) composites have been used extensively in many aerospace structures such as Boeing 787 and Airbus 350, low-cost and high-rate production CFRP are highly demanded for next-generation single-aisle commercial aircraft. Competition has been increasing between CFRP and light-weight metals and also among countries producing CFRP structures.

There exist several ways to develop low-cost and high-rate production CFRP. One is to develop low-cost and high-rate production autoclave CFRP prepregs. The mechanical properties must not be sacrificed with the low-cost manufacturing process. Alternatively, thermoplastic CFRP (CFRTP) and out-of-autoclave (OoA) CFRP are most promising material systems for such purposes as well. These CFRPs may be used as airframe secondary structures before applied to primary structures. CFRP structures have also been used in turbo-fan engines. High impact resistant CFRTP are being used in fan blades as well as fan cases. High-temperatures CFRP are highly demanded for inner frames by replacing titanium alloys. However, quality assurance is a key issue to be solved before there materials are used in practical aircraft applications.

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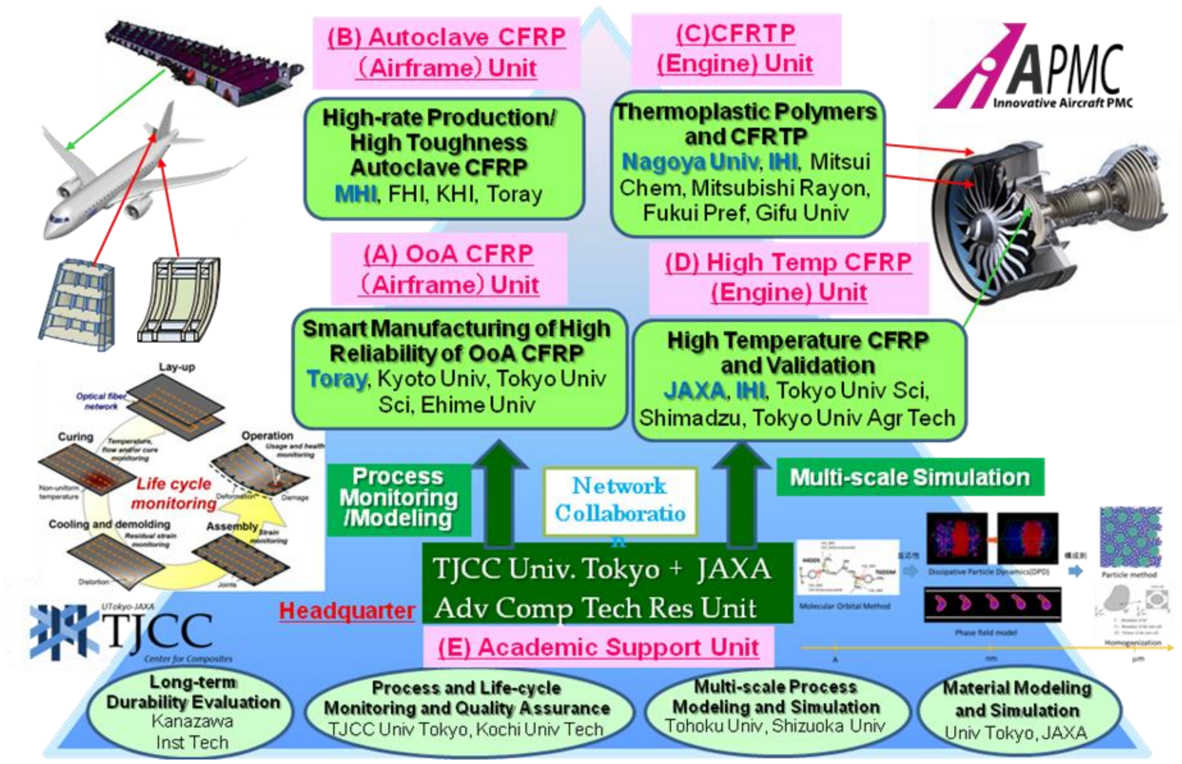

Figure 1. "Innovative Aircraft Polymer Matrix Composites (*i*APMC)" project.

2. Summarized Activities

2.1. OoA CFRP (Airframe) Unit

This unit deals with two different out-of-autoclave (OoA) methods to develop an intellectual technology for high volume production of aircraft primary/secondary structures by an innovative material system and processing technology. The first is to develop an interlayer toughened prepreg especially developed for OoA production and a fabrication system based on active control. We obtain appropriate actively control process conditions through multi-zone thermal processing environment. We also demonstrate consistent composite geometry and mechanical properties of these OoA products (Fig. 2). The second is to develop a 3D gap RTM (Resin Transfer Molding) technology with integrally fabricated multi-functional parts using pre-assembled 3D preforms. Highly drapable 2D sheets and 3D-preforms by dry carbon fiber placement as well as an efficient block assemble method will be developed for this purpose (Fig. 3). Toray Industries Inc. leads this Unit along with some universities.

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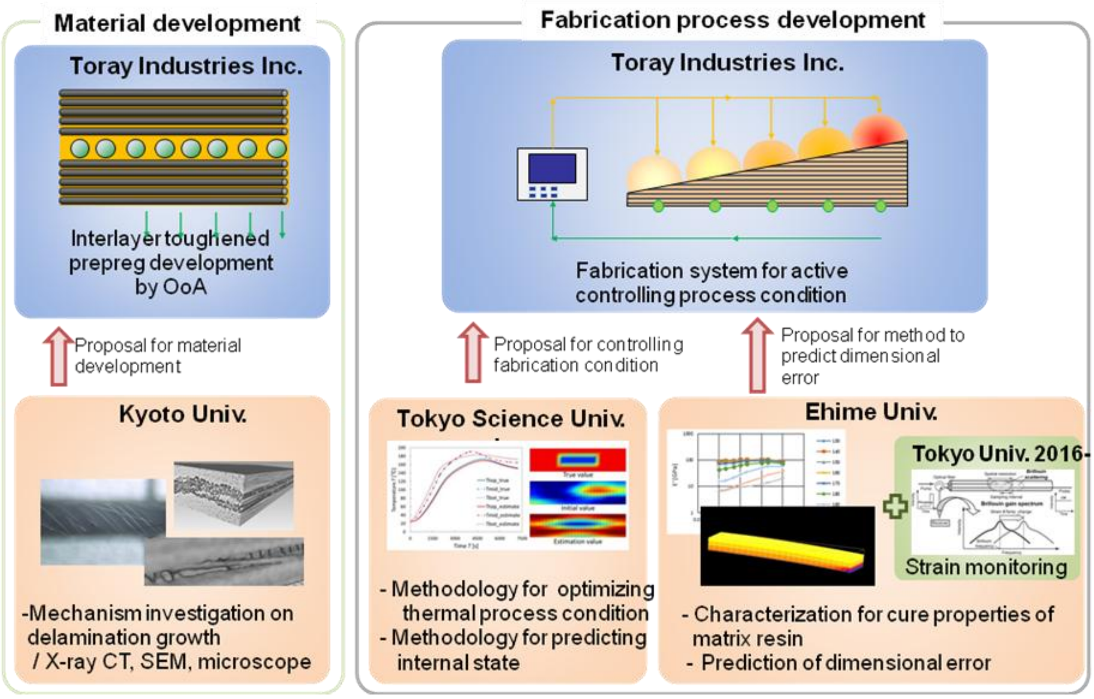

Figure 2. Interlayer toughened OoA prepreg and fabrication system based on active control.

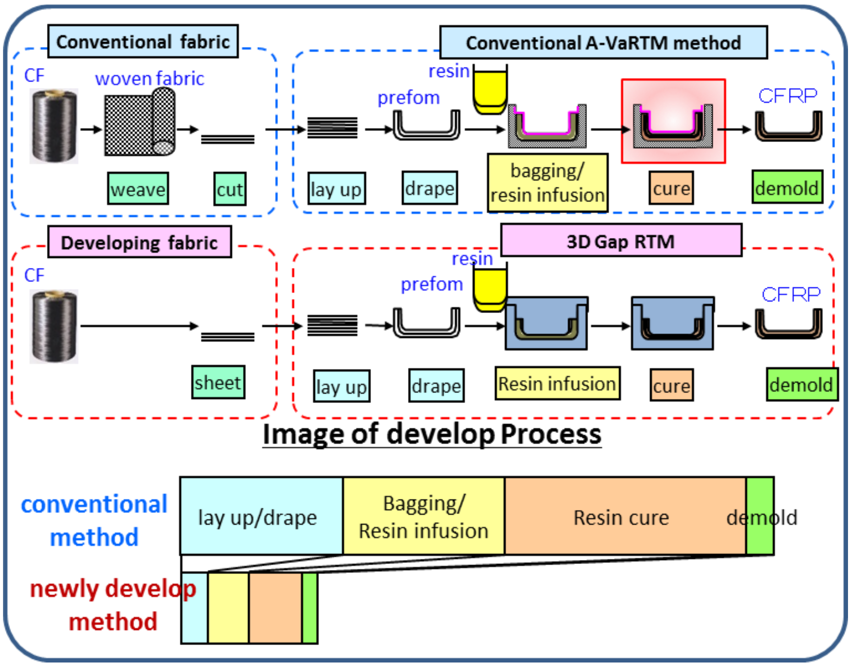

Figure 3. 3D gap RTM technology with integrally fabricated multi-functional parts using pre-assembled 3D preforms.

2.2. CFRTP (Engine) Unit

The purpose of this Unit is to develop novel CFRTP prepregs and engine products to meet higher efficient (low cost and high impact resistance) in next-generation aircraft engines, especially for turbo fan structures. A systematic study includes selection of carbon fiber, resin and fiber/resin interface,

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prepreg process development, tape placement process, and mechanical property evaluation. An optimum condition is selected to meet the demands for lightweight and impact-resistant fan blade structures (Fig. 4). IHI Co. Ltd. leads this Unit for near-future applications.

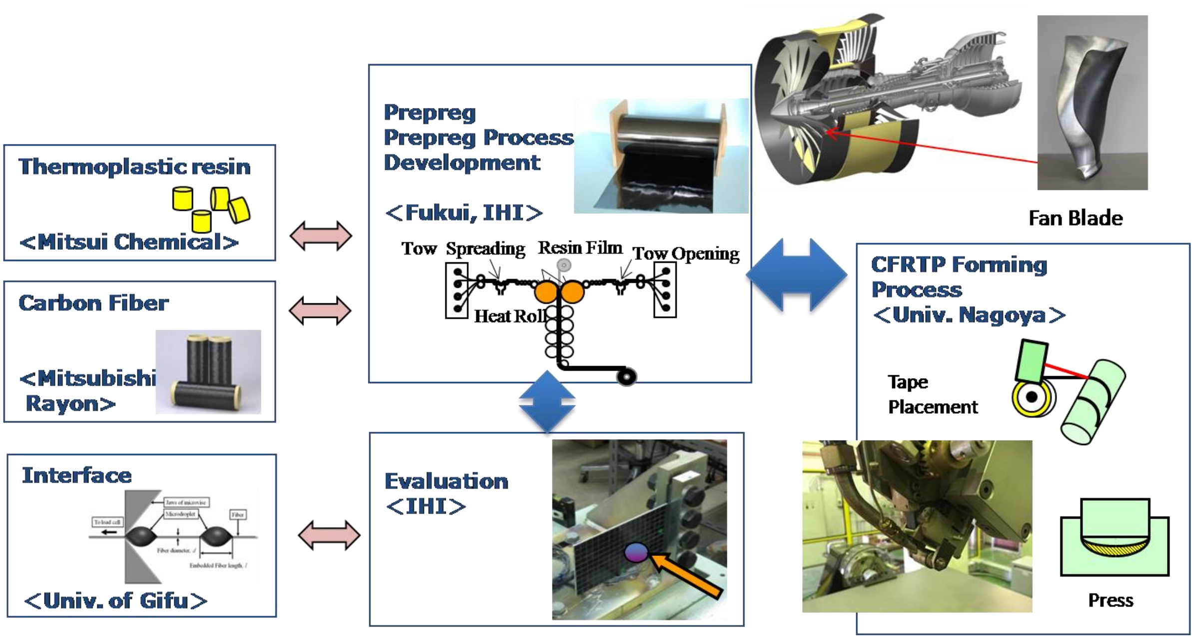

Figure 4. Development of novel CFRTP prepregs and engine products.

2.3. High Temp CFRP (Engine) Unit

High temperature CFRP is developed for internal parts in turbo-fan engines, such as inner frames. The research targets include (1) material development of high temperature CFRP and its process technology and (2) development of rational test methods for evaluating mechanical properties at elevated temperatures. JAXA (Japan Aerospace Exploration Agency) and IHI Co. Ltd. lead this Unit with support from Shimadzu Corp., Tokyo Univ Science and Tokyo Univ A & Tech. The target operating temperature is 250°C for long duration and 300°C for short duration, respectively (Fig. 5). Novel thermosetting polyimides and bismaleimides are being developed to reach mechanical properties superior to PMR-15 and heat resistance (Tg) superior to PETI-5.

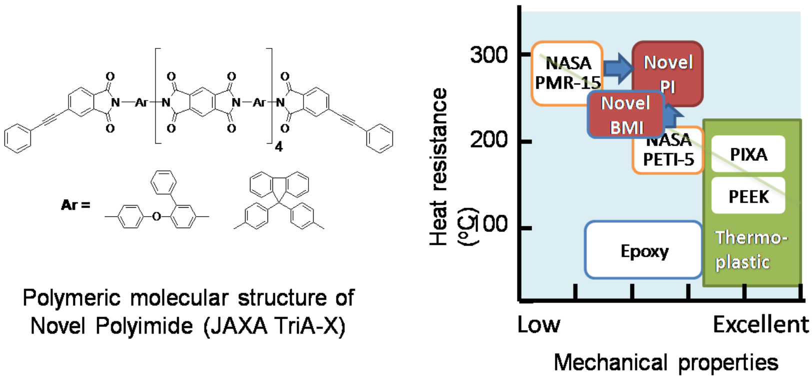

Figure 5. High temperature CFRP under development.

2.4. Academic Support Unit

The objective of this Unit is to establish an in-situ process monitoring system and process modeling/simulation methods to support new CFRP materials and processing to be developed in the whole program. Specifically, optical fiber sensor based process/life cycle monitoring methodology [2] and corresponding multi-scale modeling and numerical simulation procedure is developed for better quality control of CFRP products.

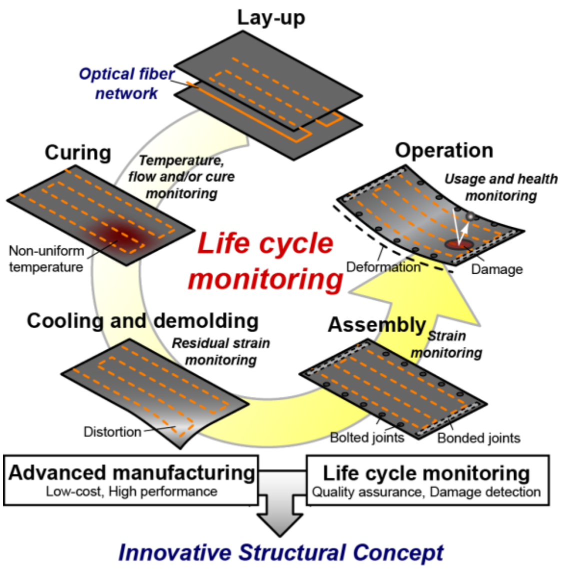

Figure 6. Life cycle monitoring concept [2].

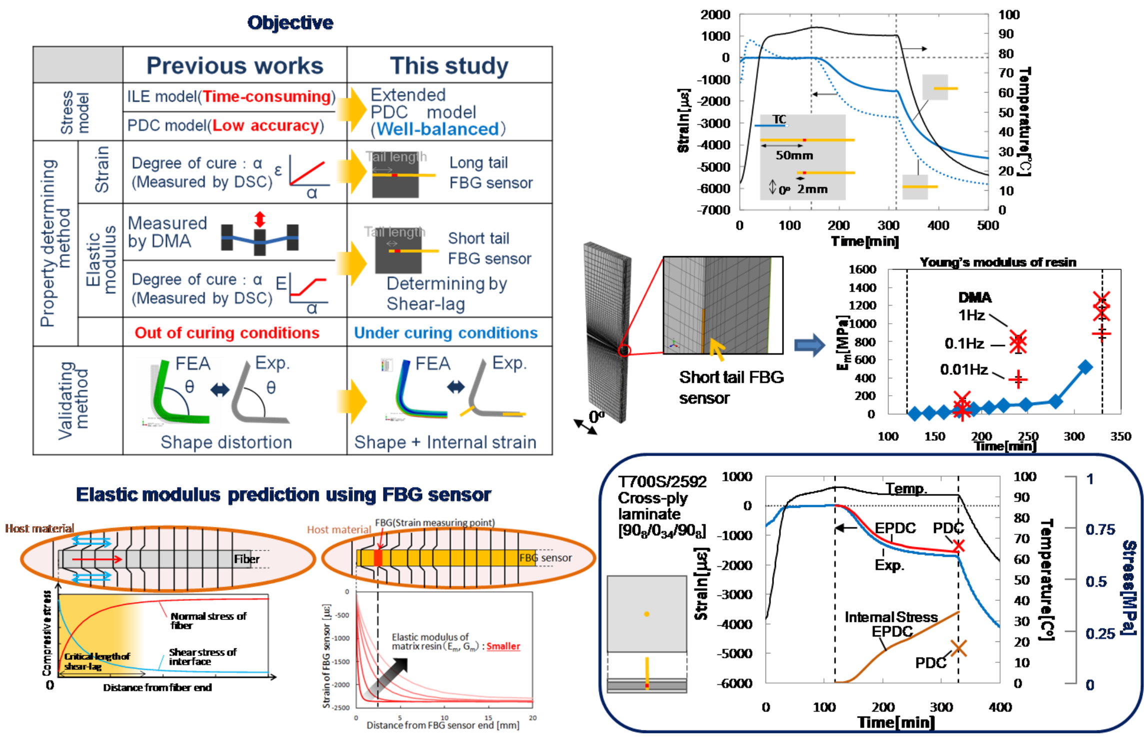

Figure 7. High accuracy cure process simulation of composites based on in-situ measurement of internal strain [3].

Embedded optical fiber sensors are most frequently used in our Unit to obtain the in-situ curing strain history in the whole manufacturing process which cannot be provided by conventional material characterization methods. Figure 7 shows high accuracy cure process simulation of composites based on in-situ measurement of internal strain [3].

3. Conclusions

This report presented a summary of our SIP - SM^{4}I "Innovative Aircraft Polymer Matrix Composites (*i*APMC)" project in order to develop high-rate production aircraft PMC products and quality assurance technology for next-generation CFRP aircraft structures. We understand the quality assurance is a key issue to be solved before there materials are used in practical aircraft applications. We believe current collaboration schemes among industries, national research institutes and universities are efficient to achieve this goal in near future.

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