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CONTENTS

Introduction of
Advanced Composite Evaluation Technology Center

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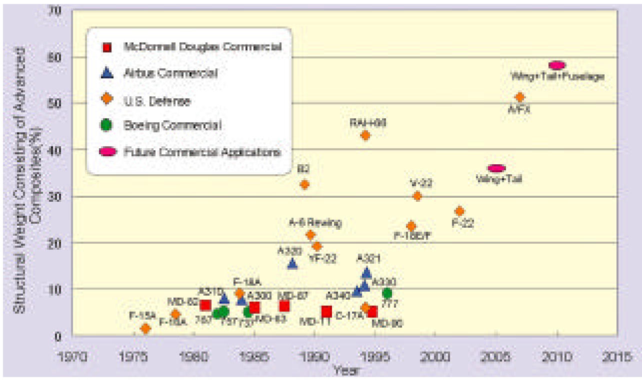

Figure 1 Composite Weight Ratio

1. Brief History of Aerospace Structure Materials and Evolution of Composites

The first aircraft built by Wright Brothers was constructed mainly of wood, wire and canvas. After their rapid development in 1930's, aluminum alloys were employed as basic structural material for almost all aircraft components till World War II. Such aluminum dominance still continues with enormous improvements in its properties, whereas composites were slowly emerging as structural materials after the invention of exceptionally strong carbon fibers at the middle of 60's. However, complicated mechanics and damage tolerant properties of the composites have prevented its complete dominance over aluminum alloys. In spacecraft applications, satellites are a few examples to which composites are adopted as major structural components. Conventional rockets are still built of aluminum alloys basically. It is strongly assured that composites will be more widely applied in the future aerospace vehicles with strong requirements for the best performances. Gradual increase of the composite weight ratio to the whole structure is continuously expected as Figure 1.

2. Strong Demand for Composite Database and Standard Testing Methods from Industries

Although composites show the great potential for weight reduction in aerospace structures with their high strength and lightweight, failure mechanism in composites is quite different from conventional metals. Many strength data are required for structural design because of heterogeneity, anisotropy and wide variety of material combinations. When we develop new composite systems using new fibers or resins, or even with slight change in resin systems, aerospace industries are forced to acquire a new set of baseline strength data having hundreds of specimens. This situation implies that sharing of composite database reduces great amount of evaluation cost in composite-related industries. Therefore Japanese aerospace industries have expressed strong demand for such composite database available on the Internet system. This demand is the major reason why Advanced Composite Evaluation Technology Center (ACE TeC) was formed at the time of re-organization of NAL.

Another technological requirement in composite evaluation is standardization of composite testing methods. In the United States, several composite testing methods were already standardized such as ASTM and SACMA (SACMA standards are not in the level of national class authorization).

In Japan, we also have JIS (Japan Industrial Standard) for composite testing. Some of those methods define inefficient size of coupon specimens leading to increase in evaluation costs.

An improvement of such methods would help to reduce this cost dramatically. Along with the evolution of composite materials, like a combination of textile reinforcements and new resin consolidation methods, a demand has arose for new testing methods such as interlaminar shear strengths evaluation based on double notch compression specimens. Because this method is highly dependent on details of specimen geometry, a cautious procedure for standardization is required. Thus, Japanese industry and academia are encouraging ACE TeC to establish standard testing methods systematically.

3. Current ACE TeC Activities - Standard Testing Methods Related

In polymer matrix composite field, some lacks were found in the definition of testing methods with JIS. Among them, interlaminar shear strength test through double notch compression (DNC) was chosen as the first target. Domestic round-robin tests (RRT)

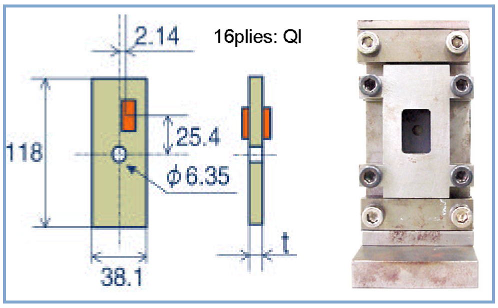

Figure 2 Proposed Specimen and Fixture (T-Ⅲ) for OHC Test

for this shear strength by eight organizations were almost finished and the baseline specimen dimensions and testing procedures are under discussion for definition. JIS draft for this DNC will be finished in the next fiscal year. The second target, open hole compression (OHC) testing method, was also selected in this year.

Although hundreds of OHC tests are done in Japan, the current de facto standard for OHC is US-based SACMA 3R-94 method. However, this method insists unnecessary long specimens and big fixtures with high testing costs. If we can define more reasonable sized specimens and fixtures that provide very close results with SACMA 3R-94's, it will bring a great advantage to Japanese composite related industries. Figure 2 shows one candidate of such new OHC testing fixture and specimen size, NAL-Ⅲ. NAL sponsored committee already started pre-RRT for these OHC tests. If the results are good, intensive RRT for OHC will be conducted in the next fiscal year.

In ceramic matrix composite field, standard compression testing method in ISO scheme is still under discussion. The consideration related to buckling occurrence during tests was very insufficient, or even wrong. Thus NAL (ACE TeC) formed domestic RRT committee and its RRT's were almost finished. A clear indication of the buckling effect on the compressive strength was obtained that some part of the ISO method is not appropriate. Therefore this committee might propose some alteration or building-up a counterpart of JIS methods.

4. Advanced Composite Database Related

Construction of advanced composite database was started just before the actual commencement of ACE TeC. Baseline data consist mainly of polymer matrix composites, particularly carbon fiber reinforced plastics (CFRP). Hundreds of data points were already obtained and they were uploaded to Internet site of NAL Advanced Composite Database (www.nal-acdb.com/). This website is available for all registered users, while overseas users are temporarily suspended due to our checking some legal inquiries. Apart from this database, NAL ACE TeC also started to write the composite application manual (similar to MIL-HDBK-17 at its completion). As this is a quite time consuming work, the committee was formed in the Japan Society for Composite Materials and yearly progress in the writing will be monitored.

5. Improvement in Composite Testing Capabilities

To achieve the above functions of ACE TeC, and to satisfy in-house and outside demand for composite tests under very severe environments, our center envisions improvement in composite testing capabilities. There are three directions and some actions were alreadt taken in this year :

(1) Increasing in loadframes; Three hydraulic loadframes and two screw driven loadframes of 100kN (30kN for one screw driven) were added to over 20 loading fleet (see Figure 3).

(2) Improvement in extreme testing technique; A furnace for 1900deg. C testing was improved.

(3) Upgrading NDE capabilities; A robotic ultrasonic system was refurbished in this year for graphite NDE capability.

6. Summary

Activities and mid-term goals of ACE TeC can be summarized as follows:

(1) Establishments of the standard composite testing methods and proposal to ISO and JIS.

(2) Acquisition of composite strength data and building-up of advanced composite database.

(3) Founding of composite application manuals like MIL-HDBK-17.

(4) Improvements in composite testing capabilities in loadframe quantity and NDE update.

Figure 3 Multiple Loading Systems for Composites

The Delivering Ceremony of the Small Supersonic Experimental Airplane

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The design phase of the Small Supersonic Experimental Airplane (Non-powered Experimental Airplane) was started in 1997, and the airframe construction began in 1999. The development of the experimental airplane was conducted by Mitsubishi Heavy Industries, Ltd. as the main contractor, and Kawasaki Heavy Industries, Ltd., Fuji Heavy Industries, Ltd. and IHI Aerospace, Ltd. as sub-contractors.

The construction was completed and the delivering ceremony was held at Komaki-Minami Plant of MHI on November 30, 2001. Two experimental airplanes, four launch rockets, and a set of ground support equipments were delivered at the ceremony.

All parts were transported to Australia by ship. The first flight test will be carried out in early of the 2002, after reassembling and final system functionality test on the ground. The launch rocket mentioned above consists of a rocket nose-section (guidance), a tail section (control) and a rocket motor. As a safety precaution, the motors filled with propellant will be delivered and shipped to the launch site right before the test flight. The ground support equipments were delivered at the ceremony including a launch control equipment, preflight check equipment, telemeter, safety-monitoring equipment, flight-monitoring equipment, and command transmitter, and so on. The launcher was shipped to Australia after the maintenance and inspection in Japan, and is already installed at the launch site.

Two flight tests are planned in the first half of the 2002, and these plans call for two more flight tests in 6 months after analyzing the data gathered from the first two flight tests.

The detailed test schedules should be fixed after coordinating with the local government.

The delivering ceremony of the experimental airplane (Mitsubishi Heavy Industries, Ltd, Komaki-Minami Plant: November 30, 2001)

Vertical Drop Test of a Transport Fuselage Section

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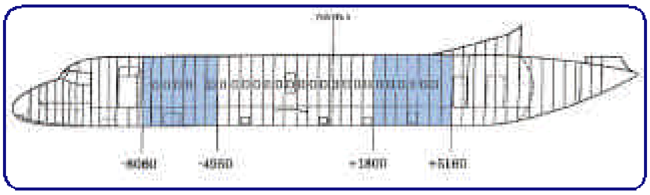
In December of the 2001, NAL Structures and Materials Research Center conducted a vertical drop test of a fuselage section of YS-11A transport airplane.

This test program is one of our research subjects on the structural crashworthiness of transport aircraft. Its primary objective was to assess the impact environment in the passenger cabin and the resultant dynamic behavior of passengers, as well as that of the fuselage structure, under a controlled crash condition. The test results will be also valuable for developing appropriate computational models used to simulate the crash behavior of a full-scale fuselage structures.

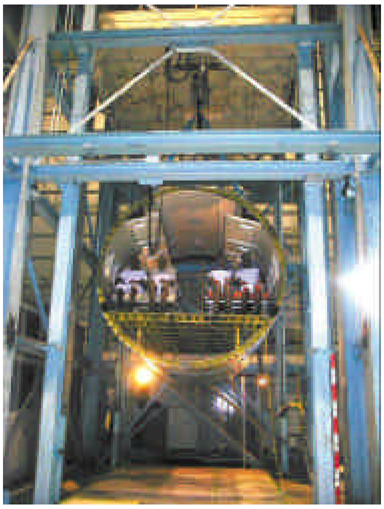
The test section was 2.88m in diameter, 3m in length and 1,600kg in total weight including 12 dummy passengers (standard Anthropomorphic Test Dummies).

The severe, but survivable, crash accident was simulated and the vertical impact velocity in the drop test was set as 6.1m/sec (20ft/sec). The instrumentations used in the test were accelerometers, strain gages, pelvic load cells and high-speed video recorders and so on.

The test results showed that the vertical accelerations measured on the cabin-floor were about 50G. The compressive load on lumbar measured with passenger dummies was about 500kg and was lower than the upper limit value required in the current airworthiness regulation. Fuselage structures under the floor level fractured in the typical manner that had been observed in similar tests conducted by FAA and NASA with various types of transport airplanes. The posttest deformation of the fuselage at the floor level was 20 cm. Any of the interior items in the cabin including passenger seats did not affect the evacuation of passengers. The drop test on the other section of YS-11A fuselage will be conducted in June of this year.



Test Sections of YS-11A Transport Airplane



Prop Test Facility and the Test Section Prior to Impact

Test Section After Impact

Launching Test of 25m-class SPF Airship

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Last autumn, we carried out the launching test of SPF (Stratospheric Platform) airship using the 25m-long airship (Figure 1). The purpose of this test was to evaluate and verify the flight characteristics of the ascending phase. The flight analysis includes: (1) Diaphragm performance (2) Buoyancy measurement, (3) Helium temperature change related to its volume change, (4) Valve operating characteristics

As shown in Figure 2, the vertical configuration is stable at the launching phase, because the buoyancy gas (helium) occupies 20% of the hull's volume, staying in upper part. The air is filled in the rest of the volume to maintain the rigidity of the airship, and it is expelled from the hull to keep the allowable pressure difference in the envelope with the airship's ascension. In the stratosphere, the configuration becomes horizontal with the buoyancy gas completely filled in the hull, as the conventional airships do.

The large size diaphragm was used to separate the contained gases (helium and air). Because helium expands even ten times in stratosphere, this structure was necessary to make the air expel smoothly. The newly designed launching device was also used for the first time in this project (Figure 1 and 3).

We conducted this test in the multi-purpose park in Taiki-cho, Hokkaido. We would like to appreciate for the town and its residents for their cooperation.

Figure 1 Test airship (25m in length)

Figure 2 Launching test

Figure 3 Tail on the launching device

Study on Temperature and Pressure Dependency of Surface Catalytic Effect in Re-entry Aerodynamic Heating

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For the re-entry vehicles, accurate knowledge of the aerodynamic heating is required for optimal design of the vehicle configuration and thermal protection system (TPS) in order to obtain maximum payload. When a re-entry vehicle flies at extremely high speed, a strong bow shock is formed on the front of the body, and dissociation of air takes place inside of the shock layer if the temperature behind the shock is high enough. Some of dissociated atoms recombine inside of the shock layer according to the drop of the temperature. However, if the flow is not in equilibrium, large part of them will remain through the boundary layer and finally they recombine on the surface, which causes the increase of aerodynamic heat.

One of the ways to protect vehicles from this severe thermal environment is to use the thermal protection system with the materials, which catalysts are as low as possible, because they prevent recombination of dissociating atoms on the surface and release massive dissociation energy. Silicon dioxide (SiO_2)-based materials are now widely used for this purpose because of their low catalysis. It is reported that catalytic efficiency of the SiO_2-based materials strongly depends on surface temperature and pressure. There had been only a few experimental results in lower pressure conditions, but not those in the real flight condition, due to the limitation of the test facilities used for catalytic research.

Kakuda Space Propulsion Center constructed a large high enthalpy shock tunnel (HIEST) for hypervelocity aerodynamic studies of re-entry vehicles and scramjet engines. HIEST was designed to simulate the temperature and the pressure of real re-entry flight condition and to study real gas effect caused mainly by molecular dissociation in the velocity range between 4-7km/s. The test time in several milliseconds was severe restriction for study on temperature dependency of catalytic efficiencies, because the surface temperature increases little in such short time.

By this experiments, we succeeded to obtain temperature dependency of catalytic efficiency in the temperature range up to 700℃ by heaters installed inside of the model, with which the surface temperature was controlled (Figure 1). A blunt nosed flat plate was used for the experiments. As the surface coatings, SiO_2 (used for surface coating of TPS) and silver (Ag) that has high catalytic efficiency were used.

The experimental results are shown in the Figure 2. At room temperature (20℃), SiO_2 catalyst was almost in agreement with our assumption from the CFD analysis with non-catalytic surface. The catalytic efficiency of SiO_2 is very low at room temperature. It was thought that it stays in low at the temperature up to 600℃ and heat flux does not change much. In this experiments, the heat flux to the SiO_2 began to increase from the room temperature.

I hope this experimental results help to make the details of temperature and pressure dependency of catalyst efficiency clear, and to construct accurate catalyst model to predict re-entry aerodynamic heating.

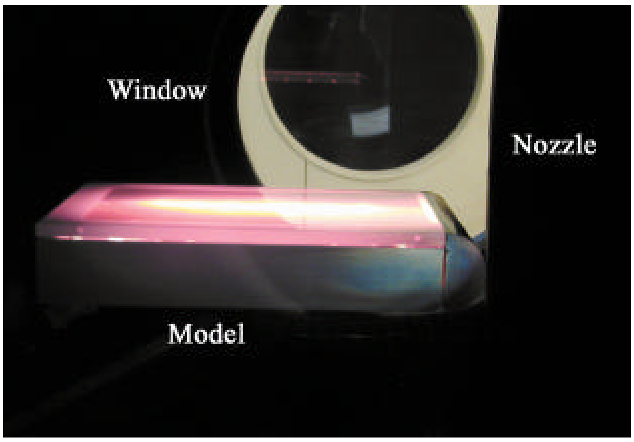

Figure 1 Experimental apparatus in the HIEST TestSection (700℃)

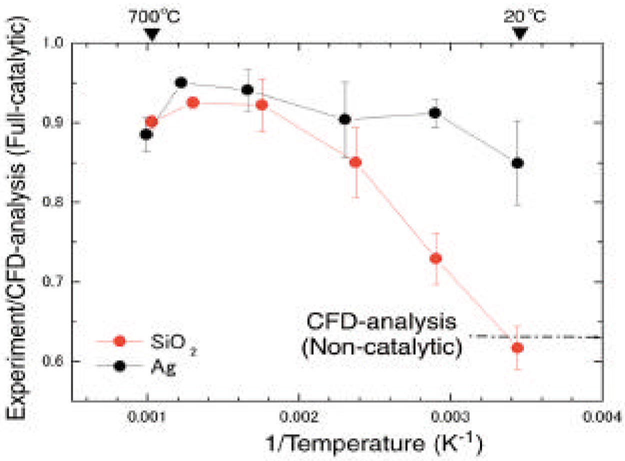

Figure 2 Temperature Dependency of Heat Flux Ratio

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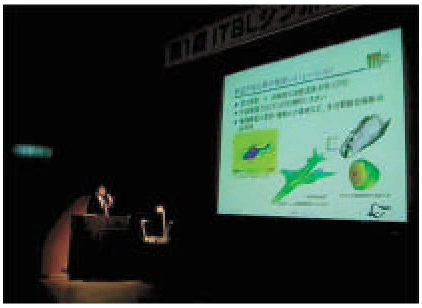
The 1st ITBL Symposium was Held

The 1st ITBL symposium was successfully held at National Museum of Emerging Science and Innovation on November 30, 2001, to introduce objectives and details of ITBL to broad audience.

ITBL (Information Technology Based Laboratory) is the project to construct one of a few information-platform in the world for science, technology and academic fields as a part of the e-Japan strategy. ITBL will provide the means to share the computational resources, such as supercomputer powers, software and databases, on high capacity network, and to construct virtual laboratories for research and development. It also helps to improve the usability of research and developments' results in a broad scope. Furthermore, ITBL will develop and provide systems to facilitate joint researches by using the large-scale databases and experimental facilities.

The six organizations which belong to the Ministry of Education, Culture, Sports, Science and Technology, including NAL, have started the development of ITBL since 2001.



NAL has been developing application software on ITBL for multidisciplinary analysis in the aerospace field.

ITBL web site (http://www.itbl.jp) and mailing list are opened for exchanging the information and the ideas.

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The 3rd NAL-SST-CFD Workshop

The 3rd SST-CFD workshop (International Workshop on Numerical Simulation Technology for Design of Next Generation Supersonic Civil Transport 2001) was held at NAL, from 3rd to 5th of December in last year. At the workshop NAL reported their research and development of numerical simulation and optimization technology used in the SST project of NAL. Seven invited organizations from overseas, such as Stanford Univ., Maryland Univ., NASA, Bombardier, DLR, and ONERA and so on, gave useful lectures to introduce the latest trend of research in this field. More than 100 people (17 from overseas) attended the workshop and enjoyed the opportunity to exchange the ideas and opinions on their researches and to have active discussions.

As one of the important feature of the workshop, we had two competition sessions. We spent the second day fully for them. The subjects were the followings:

(1) Optimum design of SST
(2) Flow analysis for SST configuration of NAL

For each subject the competitors presented their results and then the audience had open discussions. The data from wind tunnel experiment was also provided for the second subject and the current problems in numerical methods were shown clearly. We could also debate the differences among many computational results and those between computations and experiments about the problems on the second subject. Several useful suggestions for further study were proposed after the discussions. The follow-up for these issues are now conducted at NAL under the cooperation of CFD research center, Wind Tunnel Technology Center and Next Generation Supersonic Transport Project Center. It consists of more precise comparison of computational results and additional wind tunnel experiments. The follow-up report will be provided at Aerospace Numerical Simulation Symposium (ANSS) at NAL (July 3rd - 5th, 2002).

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