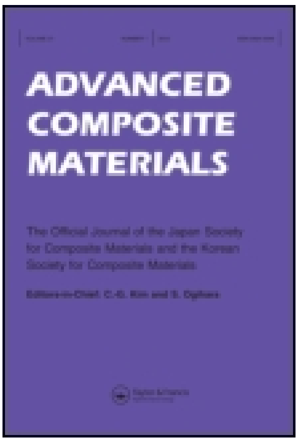

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Establishment of database of carbon/epoxy material properties and design values on durability and environmental resistance

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Technical report

Establishment of database of carbon/epoxy material properties and design values on durability and environmental resistance

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Abstract—In the fiscal year 2000, a database (CDDB) of durability and environmental resistance of several carbon/epoxy composites was established under Japanese government funding. In this project, some materials and properties have been added further to the existing basic material strength database (CMDB), which was established and recorded in a CD-ROM in the preceding fiscal year. To improve accessibility of the database for the general user, a prototype online database system was also studied. The original paper was presented at *JISSE-7* in Nov. 13–16, 2001.

Keywords: Data base; carbon/epoxy; design values; durability; environmental resistence.

1. INTRODUCTION

It is well known that CFRP materials have not only high specific modulus and strength but also good fatigue and corrosion durability. For this reason, CFRP has been widely used in the aircraft field. Now, it has begun to be used for general industrial purposes, for example, in the building construction field.

With these backgrounds, an Establishment of Database of Carbon/Epoxy Material Properties and Design Values project [1, 2] was carried out in 1999, as a part of an Establishment of Immediately Effective Intelligent Foundation project of the Ministry of the Economy, Trade and Industry. The purpose of this project was to develop and widen the field where CFRP could be used.

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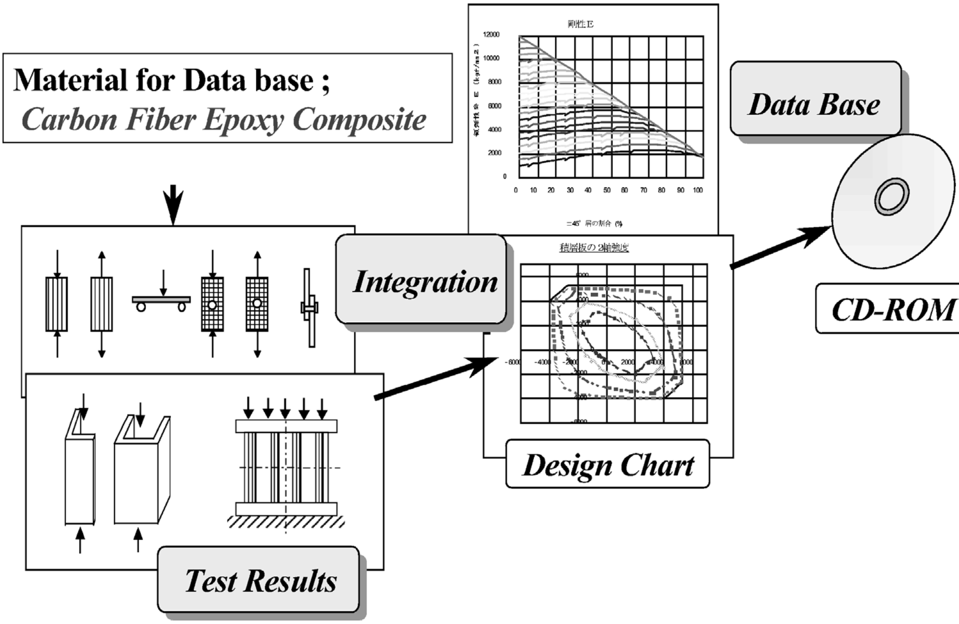


Figure 1. Establishment of database and CD-ROM.

Out of some problems revealed in that project, the following three problems are noted as those where improvement is considered to be necessary.

(a) Expansion of objective materials.

(b) Expansion of design data.

(c) Handling of the database.

Therefore, the Establishment of Database of Carbon/Epoxy Material Properties and Design Values on Durability and Environmental Resistance project was carried out [3] in 2000. In this project, the research of a user-friendly database for design was conducted by collecting data on strength, durability, and environmental resistance properties of CFRP, including low curing temperature pre-preg, etc, which are expected to be used widely in the future.

This report gives a summary of materials selected for the database, details of typical tests, and the database itself.

2. MATERIAL SELECTION FOR DATABASE

Several CFRP materials shown in Table 1 were selected for the database according to the following conditions;

(a) Carbon fiber: New generation Standard Modulus (235 GPa class) fiber, which would be used in major products in the near future, both for general purposes and aircraft.

Table 1.
Materials for database

Material name	Material designation	Fiber	Form of fiber	Name of supplier	Resin	Method of impregnation	Company in charge
T700UP	P3312G-19	T700GC	Tape	Toray	3900M	Preimpregnated	MHI
T700CP	FF6273H-24K	T700GC	Fabric	Toray	3680	Preimpregnated	MHI
T700UR	—	T700GC	Tape	Toray	R9803	RTM	FHI
T700CR	—	T700GC	Fabric	Toray	R9803	RTM	FHI
UT500UP	QU135-197A	UT500	Tape	Toho-Rayon	#135	Preimpregnated	KHI
TR30UP	TR830F190SMX Y WS	TR30	Tape	Mitsubishi Rayon	#830	Preimpregnated	MHI
TR30UPA	TR850G190SMX X S	TR30	Tape	Mitsubishi Rayon	#850	Preimpregnated	MHI
T700UPA	P3242G-19	T700	Tape	Toray	3680	Preimpregnated	MHI
T700CRA	—	T700GC	Fabric	Toray	TR-A3	RTM	FHI
T700CRA 1	—	T700GC + TR 40	Fabric+ stitching (6 mm)	Toray	TR-A3 1	RTM	FHI
T700CRA 2	—	T700GC + TR 40	Fabric + stitching (3 mm)	Toray	TR-A3 1	RTM	FHI
T700CRA 3	—	T700GC +Kevlar	Fabric + stitching (3 mm)	Toray	TR-A3 1	RTM	FHI

(b) Form of weaving: Unidirectional and fabric for pre-preg, and stitched cloth for RTM (Resin Transfer Molding).

(c) Supplier: Toray, Toho-Rayon (now, Toho-Tenax), and Mitsubishi Rayon (Three of the world's major suppliers).

(d) Resin system: Epoxy resin of 180 to 120 degree cure type or low temperature cure type.

(e) Impregnation: Two methods of impregnation (Pre-preg and RTM).

3. TEST ITEMS

3.1. Basic test results

Various kinds of test of Toho-Rayon UT500UP (one of 12 materials shown in Table 2) were conducted in KHI. Basic material properties shown in Table 2 have already been obtained in the previous project [1, 2].

In this year's project, a durability test and environmental resistance tests were conducted and data were added to the Database. Details of each test are described below.

3.2. Durability tests

A durability test under cyclic load was conducted to confirm that composite structures have enough durability for long term usage. Three items of durability test were performed as follows:

(1) Basic fatigue property test of composite laminate by using coupon specimen.

(2) Fatigue test of principal structural elements of practical composite parts.

(3) Confirmation test of fatigue property of typical sub-component structure.

Details of the durability tests are summarized in Table 3.

3.3. Environmental resistance test

A composite structure is required to keep its strength and stiffness against actual environmental effects. So an environmental resistance test of a composite was conducted in order to get properties of composite materials after environmental aging. Four major environmental factors that may affect resin properties of a composite were selected as follows:

(a) Effect of ultraviolet rays or ozone in the natural environment.

(b) Chemical agents or fuel, which are possibly in contact with composite structure during aircraft operation.

(c) Thermal cycling for composite structures during aircraft operation.

(d) Effect of nature environment cycling of sunlight and rain.

Table 2.
Basic material property test

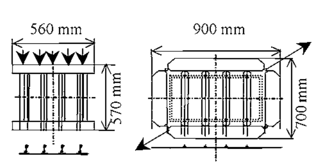
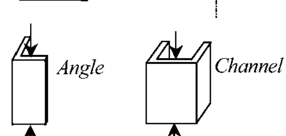
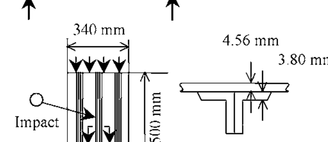
	Test item		Test piece
Material and coupon properties	Uncured physical properties	Arial weight	
		Resin content	
		Volatile contents	3 each
		Resin flow	
		Gel time	
	Chemical properties	Water contents	
		DSC	
		Infrared	3 each
		Liquid chromatograph	
		Dynamic mechanical	
	Cured physical properties	Cured thickness	
		Vf	3 each
		Specific gravity	
		Glass transition	
	Fire resistant property		3
	Mechanical properties of lamina	Tension 0°	
		Tension ±45°	
		Tension 90°	6 each
		Compression 0°	
		ILSS	
	Mechanical properties of laminate	No hole tension	
		OHT	
		No hole compression	6 each
		OHC	
		CAI	
	Fracture toughness properties	G_{IC}	6 each
		G_{IIC}	
Structural element properties	Fastener joint property	Single joint	6 each
		Double joint	
	Post buckling property of stiffened panel		
	Crippling test		
	CAI property of stiffened panel		

Table 3.
Durability of test item

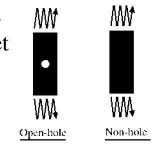
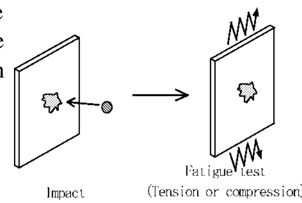
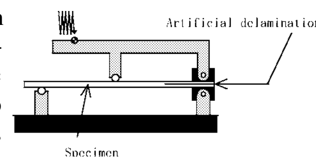
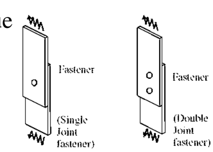
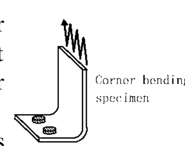
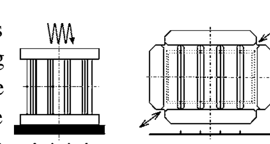
Test item		Summary of test	Specimen
Basic fatogue property test of laminate	Fatigue test of open-hole, and non-hole laminate (Tension)	Tension fatigue tests of open-hole and non-hole laminate are conducted to get basic fatigue properties of composite laminate ($R = 0.1$)	
	Fatigue test of laminate with impact damage (Tension, and compression)	Coupons impacted in advance are loaded cyclically to get data of fatigue property of damaged laminate (tension and compression, 2 energy of impact)	
	Fatigue test of delamination	Coupon with artificial delamination (release film inserted) is loaded cyclically (bending and shear load, $R = 0.1$), the number of load cycles up to first propagation of delamination is measured (2 varieties of energy release rate ratio of mode I and mode II are selected) (Energy release rate ratio of mode I and mode II are changeable by selecting position of loaded point and specimen loaded point)	
Elements property test	Fatigue test of fastener joint (Tension)	Single or double fastener joint fatigue test is conducted ($R = 0.1$)	
	Fatigue test of corner bending (Tension)	Fatigue test of specimen for corner bending (L shape) is conducted to get fatigue property of composite corner radius part (tension load, $R = 0.1$, 2 thickness specimen)	
Sub-components property test	Fatigue test of stiffened panel with local buckling of skin (Compression and shear)	At first static test of stiffened panel is conducted to get preliminary buckling data for fatigue test. Next, fatigue test is conducted ($R = 10$). The number of load cycle is measured up to delamination between stiffener base and skin	

Table 4.
Environmental resistance test

Test item	Summary of test	Environment condition	Test parameter
Ultraviolet rays	Open-hole compression test and observation of edge fracture of specimen are conducted after aging specimens in ultraviolet rays environment to evaluate effects of environment on material strength property.	• Strength of ultraviolet rays 0.3–0.4 W/m^2 • Wavelength 340 nm	• Aging time (250/500 H) • Painted/Not painted
Ozone	Open-hole compression test and observation of edge fracture of specimen are conducted after aging specimens in ozone environment to evaluate effects of environment on material strength property.	Ozone concentration 50 ± 5 ppm	• Aging time (250/500 H) • Painted/Not painted
Chemicals (fuel, solvent)	Open-hole compression test and observation of edge fracture of specimen are conducted after immersing specimens in chemicals to evaluate effects of environment on material strength property.	Fuel/solvent/ lubricating oil	• Aging time (500/1000 H) • Painted/Not painted
Thermal cycling	Open-hole compression test and observation of edge fracture of specimen are conducted after thermal cycling of specimens to evaluate effects of thermal cycle on material strength property.	• Temperature: −54–82°C	• Number of cycles (1000/2000 times)
Natural environment cycling	Open-hole compression test and observation of edge fracture of specimen are conducted after natural environment cycling of specimens to evaluate effects of nature environment on material strength property.	• Strength of ultraviolet rays 0.3–0.4 W/m^2 • Wavelength 340 nm • Temperature 60±3°C • Humidity 50 ± 4%	• Number of cycles (1000/2000 times) • Painted/Not painted

Details of each test are shown in Table 4. There is no reduction of material properties of UT500UP from environmental effects in Table 4. For example, results of ultraviolet rays test is shown in Fig. 2. This picture is displayed on the database software (CD-ROM) by selecting property type, material type, and environmental conditions.

There is no reduction in strength or increase in cracks of specimen edge after 500 hours aging under stratospheric conditions (strength of ultraviolet rays 0.3–0.4 W/m^2, wavelength 340 nm).

Hence, test specimens retained their excellent properties under environmental resistance test conditions.

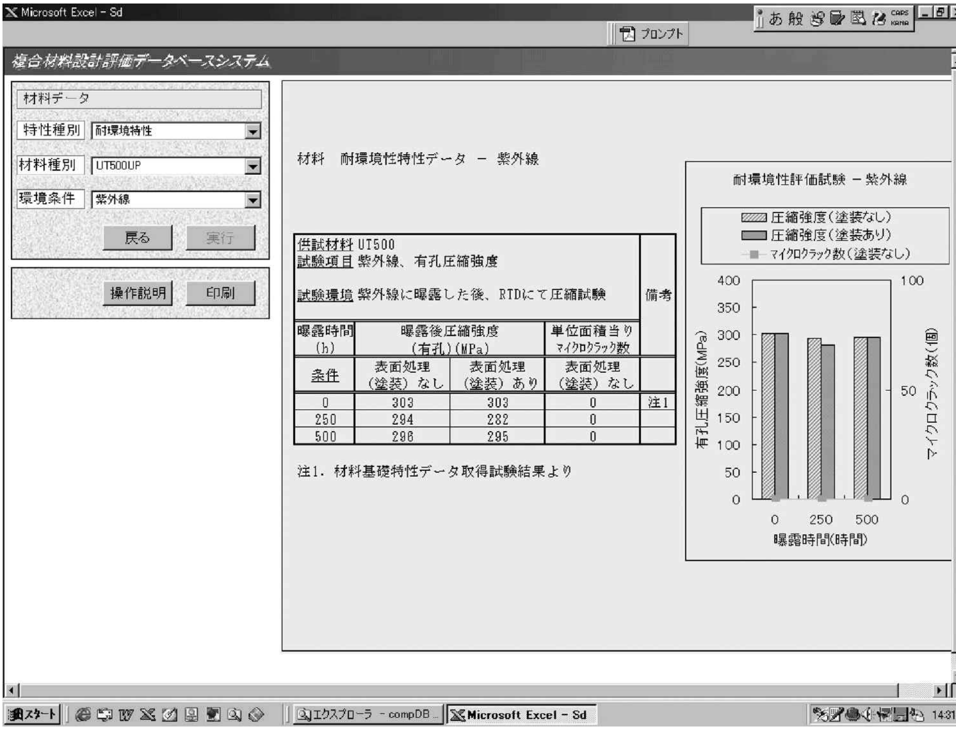


Figure 2. Test result of ultraviolet rays aging test (example of display of database software: material data, UT500UP, ultraviolet).

As this example shows, material properties under various kinds of environmental condition are collected in this database. So this database could be used as an effective tool for getting guidance when designing structures in the practical environment during operation.

3.4. Composition of the whole database

Composition of the whole of the database constructed in this project is shown in Fig. 3. The composition itself followed that of the previous database. Durability and environmental resistance data of this year are added to the previous database and integrated into one CD-ROM in this project.

The design chart is shown in Fig. 4. Without complicated stiffness or stress calculations of any ply orientation, this chart gives calculated results very quickly. In addition, an on-line type database, which is available on the Internet web, has been studied and the prototype has been made in this project.

In this database, not only the design data and raw data of test results but also other important information for design is included. Those are, ‘explanation’ such as the way to use database software, condition of design, etc. and ‘theoretical explanation’, such as basic information on composite materials, background information on theory, and reference documents.

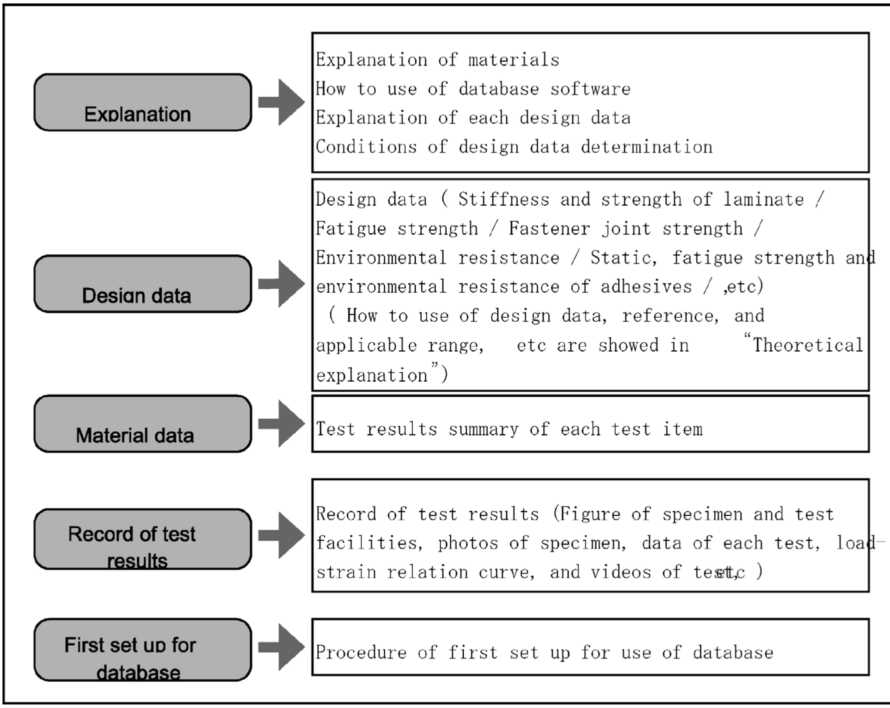


Figure 3. Composition of the whole database.

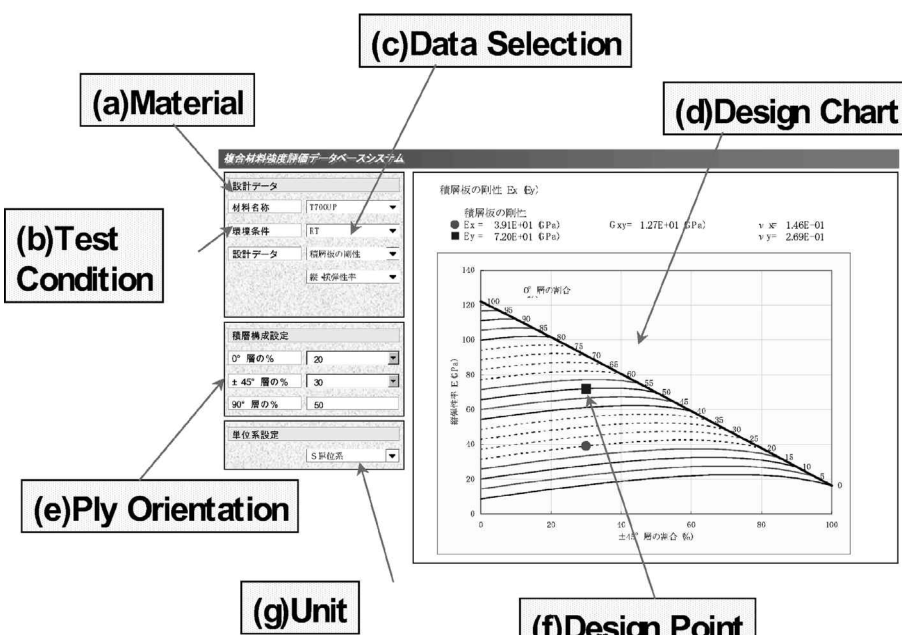


Figure 4. Design chart, without complicated calculation, the strength or stiffness of any kind of laminate orientation can be obtained from this chart.

4. CONCLUSIONS

Useful data of various materials were obtained by three private enterprises (KHI, MHI, FHI). Data were processed for composite structure designe and integrated into one CD-ROM by The Japan Research Institute. Also, Doshisha University constructed a prototype of an on-line database.

We hope the database could be used widely in the general industrial field and could contribute to the expansion of composite materials usage.

Acknowledgement

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