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DEPARTMENT OF ENERGY

COOPERATIVE AGREEMENT No. DE-FC02-92CE40993

RESEARCH AND DEVELOPMENT OF MATERIALS/PROCESSING
METHODS FOR THE CONTINUOUS FIBER CERAMIC COMPOSITES
PROGRAM

Submitted by:

DOW CORNING CORPORATION

RECEIVED
SEP 09 1994
OSTI

Andy Szweda
Program Manager

We have no objection from a patent
standpoint to the publication or
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Mark P. Dvorscak *Aug 30 1994*
Office of Intellectual *2* Date
Property Counsel
DOE Field Office, Chicago

Monthly Report
for
July 1994

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Monthly Highlights for July, 1994

- Higher levels of matrix filler in the CFCC has been found to increase the fatigue life of CFCCs at both 982°C and 1204°C.

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Monthly Report For June 1994
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Technical and Management Activities

1.0 Applications Assessment

A draft Task report for the Application Assessment of the sealless pump application has been completed and will be delivered within the next month.

3.0 Materials and Process Development

3.1 Process Feasibility

Subtask 3.1.2 - 3-D Preform Development

This Task has been completed.

Subtask 3.1.3 - Matrix Densification and Impregnation

This Task has been completed.

Subtask 3.1.4 - Fiber Coatings

This Task has been completed.

Subtask 3.1.5 - Process Demonstration

Earlier in the program Materials Science Corporation (MSC) had performed material property predictions on the various 3-D architectures that Dow Corning were processing into composites. These 3-D preforms were woven by Techniweave. MSC used available 2-D mechanical property data supplied by Dow Corning as the input into their micromechanical model. MSC used their model to predicted both elastic and thermal properties. In order to evaluate the ability of their model to predict the properties for the 3-D composites, tensile test were carried out at ORNL and elastic modulus (E_x) measured. The actual measured values of elastic modulus were then compared to the predictions. Table 1 summarizes these results. The range of predicted values represents the difference between Techniweave's predicted total fiber volume fraction and the actual measured value. Table 1 also shows that MSC's predicted values were significantly lower than the actual modulus values measured. For comparison purposes calculations of elastic modulus were made using Rule Of Mixtures. These results are also summarized in Table 1. It appears that

the predictions using the Rule Of Mixtures are somewhat closer to the actual measured values than MSC's predictions.

Mechanical testing continues to be performed at ORNL as part of our User Agreement. Figure 1 summarizes all the fatigue data measured to-date. This data is also shown as a function of time in Figure 2. A significant outcome of this testing has been the recognition of an extended fatigue life of specimens with higher filler levels. Microstructural investigation have been initiated on these specimens to identify any features that could be attributing to the extended fatigue life. It is expected that all testing at ORNL should be completed by the end of August.

Due to the large number of samples being tested as part of our User Agreement an enormous amount of data is being generated at ORNL. A recent upgrade in computer equipment at Dow Corning has allowed the more timely transfer of data from ORNL to Dow Corning. It is likely that a full analysis of all the data is likely to extend beyond the completion of the Phase I program.

In order to evaluate the performance of the dogbone tensile specimens that have been tested at ORNL, the location of tensile fractures have been mapped for all the fast fracture specimens. This data is shown plotted in Figure 3. The majority of tensile failures are found to fall within the gage section of the specimen. The few samples which failed within the grip region were most likely due to poorly bonded end-tabs. The data shows that there is no influence of test temperature on the fracture location and also indicates that the dogbone configuration selected is appropriate for testing CFCC materials.

Samples from the process study that was carried out between Dow Corning and Kaiser Aerotech have been sent for porosimetry measurement. These samples were fabricated at Dow Corning and include material that have been processed to various levels of open porosity. The porosimetry will identify the size, shape and distribution of the open porosity and how this changes through the infiltration/pyrolysis process. The porosimetry data will analyzed and the results provided in the next monthly report.

5.0 Program Management

5.1 Management Activities

- Discussions with DOE, Chicago Office concerning Kaiser Ceramic Composites' CFCC Phase II proposal and the issue of novation of the existing Cooperative Agreement have occurred this month.

Table 1

Architecture	Measured Modulus (GPa)	MSC Predicted Modulus (GPa)	Rule Of Mixtures Predicted Modulus (GPa)
Orthogonal	101.5-103.8	62.8-66.0	82.28-84.62
Orthogonal	109.0-111.4	57.8-61.0	84.22-86.17
Angle Interlock	97.2-99.7	56.6-69.8	86.64-89.59
Angle Interlock	89.3-93.4	69.4-73.01	94.10-96.59

Figure 2: Fatigue Data for CFCC as a Function of Temperature and Filler Content

Figure 1: Fatigue Data for CFCC as a Function of Temperature and Filler Content

Figure 3: Fast Fracture Location in CFCC Dogbone Configured Test Specimens

MILESTONE LOG

ID No.	Description	Sub-Task	Planned Start	Estimat'd Start	Actual Start	Planned End	Estimat'd End	Actual End
1	Kickoff Meeting with Solar Turbines for Criteria Determination - Turbine Component	1.1.1A	2NOV92		2NOV92	2NOV92		2NOV92
2	Identification of Energy Saving, Benefits, etc. - Turbine Components (Solar Turbines)	1.1.2A	2NOV92		2NOV92	1APR93		17SEP93
3	Identification of New Gas Turbine Designs (Solar Turbines)	1.3.1A	16FEB93		16MAR93	16JUL93		16JUL93
4	Summary Report with Conceptual Design that Define System Changes - Turbine Components (Solar Turbines)	1.3.1A	15AUG93		15AUG93	15AUG93		15 SEP93
5	Kickoff Meeting with Solar Turbines for Criteria Determination - Heat Exchanger Components	1.1.1B	2NOV92		2NOV92	2NOV92		2NOV92
6	Identification of Energy Saving, Benefits, etc. - Heat Exchanger Components (Solar Turbines)	1.1.2B	30NOV92		2NOV92	15MAR93		17AUG93
7	Establish Performance Parameters and Conceptual Designs - Heat Exchanger Components (Solar Turbines)	1.3.1B	16FEB93		16MAR93	15AUG93		15JUL93
8	Summary Report with Conceptual Design that Define System Changes - Heat Exchanger Components (Solar Turbines)	1.3.1B	14SEP93		15AUG93	14SEP93		15JAN94
9	Select Two 3-D Fiber Architectures (Dow Corning/Techniweave)	3.2.1	31DEC92		31DEC92	31DEC92		31APR93
10	Fabricate 3-D Preform (Techniweave)	3.2.1	1JAN93		11JAN93	5MAR93		31JUL93
11	Fabricate Hybrid 3-D Preform (Techniweave)	3.2.1	5MAR93		21JUL93	8APR93		31JUL93
12	Coat 3-D Preforms	3.2.1	10JAN93		14AUG93	17JUN93		31AUG93
13	Fabricate 3-D Composites (Dow Corning)	3.1.3	5FEB93		01SEPT93	31MAY93		30JAN94
14	Carry Out NDE of 3-D Composites (Argonne)	3.1.5	9APR93		30DEC93	20MAY93		15JAN94
15	Characterize Microstructure & Mechanical Properties of 3D Composites (Dow Corning)	3.1.5	5FEB93		15FEB94	20MAY93		15APR94
16	Compare Data Generated to Micromechanical Models (MSC)	3.1.5	1JUL93		15JUL94	4AUG93		30JUL94

ID No	Description	Sub-Task	Planned Start	Estimat'd Start	Actual Start	Planned End	Estimat'd End	Actual End
17	Conduct Thermochemical & Thermomechanical Analysis of Fiber/Coating/Matrix Combinations (MSNW)	3.1.4	1OCT92		11AUG92	11NOV92		30NOV92
18	Select Interface Coatings (Dow Corning/MSNW)	3.1.4	1OCT92		11AUG92	11NOV92		30NOV92
19	Develop Coating Processes (MSNW)	3.1.4	19NOV92		24NOV92	23DEC92		1MAR93
20	Characterize Initial Coated Fiber (MSNW)	3.1.4	19NOV92		1MAR93	23DEC92		15MAR93
21	Produce Selected Coated Fibers (MSNW)	3.1.4	14JAN93		1APR93	17MAR93		30SEP93
22	Fabricate 2-D Composites Containing Coated Fibers (Dow Corning)	3.1.3	18MAR93		21APR93	30JUN93		31JAN94
23	Measure Mechanical Properties Composites (Dow Corning)	3.1.5	18MAR93		21MAY93	15MAY93		30APR94
24	Characterize Microstructure of Composites (Dow Corning)	3.1.5	18MAR93		01JUL94	30JUN93	31AUG94	
25	Identify Matrix Fillers and Loadings (Dow Corning)	3.1.3	1OCT92		4JAN93	10MAR93		10JAN93
26	Fabricate 2D Composites (Kaiser Aerotech)	3.1.3	18MAR93		21APR93	30JUN93		30JAN94
27	HT Mechanical Characterization (ORNL)	3.1.5	5FEB93		13DEC93	18JUN93	31AUG94	
28	Characterize Microstructure & Failure Analysis (Dow Corning)	3.1.5	22APR93		15MAR94	30JUN93	31AUG94	
29	Generate & Analyze Material Property Database (Dow Corning)	3.1.5	1JUL93		15MAR94	4AUG93	31AUG94	
30	Compare Data Generated to Micromechanical Models (MSC)	3.1.5	1JUL93		01JUL94	4AUG93		31JUL94
31	Containment Shell - Application Analysis & Design Studies (Sundstrand Fluid Handling)	1.1C 1.3C	17FEB94 15MAY94		17FEB94 15MAY94			15JUN94 15JUN94
32	CFCC Definition (Kaiser Aerotech/Dow Corning)	1.2C	17FEB94		17FEB94			31MAY94
31	Final Report	5.0	30NOV93	1SEP94		30NOV93	30SEP94	

COST and LABOR REPORT

	JUL	AUG	SEP	TOTAL FY92	OCT	NOV	DEC	JAN	FEB	MAR
COST REPORT (\$M)										
PLAN	\$3.90	\$16.90	\$6.50	\$27.30	\$21.30	\$45.50	\$58.70	\$40.20	\$44.00	\$49.26
DCC	\$3.94	\$16.91	\$6.46	\$27.31	\$10.34	\$26.54	\$40.68	\$27.52	\$17.57	\$25.21
ST								\$2.73	\$5.35	\$10.78
KA					\$7.64	\$10.69	\$10.04	\$9.91	\$9.07	\$8.85
MSNW						\$8.13	\$4.24		\$11.99	\$4.62
ANL					\$1.72					
TW					\$1.63	\$0.18	\$3.69		\$0.28	
MSC										
SFH										
TOTAL ACTUAL	\$3.94	\$16.91	\$6.46	\$27.31	\$21.32	\$45.54	\$58.65	\$40.17	\$44.26	\$49.46
VARIANCE	(\$0.04)	(\$0.01)	\$0.04	(\$0.01)	(\$0.02)	(\$0.04)	\$0.05	\$0.03	(\$0.26)	(\$0.20)
DOE COST	\$3.26	\$13.97	\$5.33	\$22.56	\$18.59	\$39.85	\$50.57	\$34.11	\$39.76	\$43.11
LABOR REPORT (hrs)										
TASK										
1.0	0	0		0						
3.0	15	22	0	37	20	69	130.5	168	70	97.5
5.0	22	125	36	183	48	112	93	295	53	52
TOTAL (hrs)	37	147	36	220	68	181	223.5	463	123	149.5

COST and LABOR REPORT

		APR	MAY	JUN	JUL	AUG	SEP	TOTAL FY93	OCT	NOV	DEC	JAN
COST REPORT (\$M)												
PLAN		\$22.25	\$90.90	\$73.10	\$50.70	\$36.90	\$30.70	\$563.51	\$2.80	\$2.80	\$12.50	\$10.00
DCC		\$12.81	\$7.11	\$11.68	\$8.77	\$23.42	\$23.84	\$235.49	\$10.13	\$18.99	\$20.74	\$24.06
ST			\$2.80	\$5.60	\$4.74	\$5.17	\$4.34	\$41.51	\$11.98		\$4.86	\$2.55
KA				\$13.04	\$11.05	\$11.20		\$35.29		\$17.40	\$3.30	
MSNW		\$9.31	\$4.00	\$0.58				\$70.09				
ANL		\$2.77	\$12.10	\$11.73	\$6.26	\$0.00	\$0.00	\$61.83	\$8.19			
TW				\$13.47		\$8.23		\$23.42	\$1.73			
MSC							\$1.26	\$7.03	\$1.53	\$1.35		
TOTAL ACTUAL		\$24.89	\$26.01	\$56.10	\$30.81	\$48.01	\$29.44	\$474.85	\$33.55	\$37.74	\$28.90	\$26.61
VARIANCE		(\$2.64)	\$64.89	\$17.00	\$19.89	(\$11.11)	\$1.27	\$88.86	(\$30.75)	(\$34.94)	(\$16.40)	(\$16.61)
DOE COST		\$21.73	\$24.09	\$50.80	\$27.71	\$41.48	\$24.85	\$416.65	\$30.42	\$32.70	\$24.48	\$22.17
LABOR REPORT (hrs)												
TASK												
1.0								0				
3.0		32.5	65.5	75.5	81.5	202	228	1240	72	169	123.5	142.5
5.0		38.5	11.5	28	22	55.5	37.5	846	5	9	66.5	115
TOTAL (hrs)		71	77	103.5	103.5	257.5	265.5	2086	77	178	190	257.5

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COST and LABOR REPORT

COST REPORT (\$M)

	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL FY94	GRAND TOTAL
PLAN	\$10.00	\$10.00	\$0.00	\$50.00	\$13.09	\$13.09	\$13.09		\$137.37	\$728.18
DCC	\$8.29	\$10.28	\$5.32	\$8.42	\$9.10	\$6.28			\$121.63	\$384.42
ST		\$2.51	\$0.43						\$22.34	\$63.85
KA		\$8.16			\$7.89				\$36.75	\$72.04
MSNW									\$0.00	\$70.09
ANL									\$8.19	\$70.01
TW									\$1.73	\$25.15
MSC									\$2.88	\$9.91
SFH				\$2.86	\$4.24				\$7.10	\$7.10
TOTAL ACTUAL	\$8.29	\$20.96	\$5.76	\$11.28	\$21.24	\$6.28	\$0.00	\$0.00	\$193.51	\$695.47
VARIANCE	\$1.71	(\$10.96)	(\$5.76)	\$38.72	(\$8.15)	\$6.81	\$13.09		-30.75	\$58.10
DOE COST	\$6.85	\$18.10	\$4.79	\$9.53	\$18.44	\$5.19	\$0.00	\$0.00	\$172.86	\$611.86

LABOR REPORT (hrs)

TASK	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL FY94	GRAND TOTAL
1.0									0	0
3.0	55	34	50	54.5	26	36			2339.5	3611
5.0	20	14	15.5	27	28	17			1158	2187
TOTAL (hrs)	75	48	65.5	81.5	54	53	0	0	3491.5	5798

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