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AEC-NASA SPACE NUCLEAR PROPULSION OFFICE

FINAL REPORT ON GTR-18
TEST OF BEARING CAGE MATERIALS

JULY 1967

NERVA PROGRAM

CONTRACT SNP-1

MASTER

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FINAL REPORT ON GTR-18
TEST OF BEARING CAGE MATERIALS

P. P. Dessau
W. Weleff

C. M. Rice
Program Manager
Nuclear Rocket Operations

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ABSTRACT

This report summarizes the results of Test 37/R106 to determine the radiation effects on bearing cage materials in a liquid-hydrogen environment. The test was conducted in support of the NERVA program under the auspices of the Space Nuclear Propulsion Office, Cleveland (SNPO-C), under Contract SNP-1.

Materials tested included four polyimide-based composites, a nickel compact impregnated with molybdenum disulfide, a polybenzimidazole glass reinforcement, a CDJ graphite, and a proprietary composite. Specimens were irradiated in liquid hydrogen and tested at room temperature. The gamma dose was 7×10^{10} ergs/gm(C). Data were obtained on tensile, compressive, and flexural strengths for control and irradiated specimens.

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I. INTRODUCTION

GTR-18 irradiation was performed in July 1966 at General Dynamics, Fort Worth, with the Ground-Test Reactor. Bearing cage materials and resistance temperature transducers for Test 23/R104 were irradiated in the same liquid-hydrogen Dewar. Test 23/R104 is covered in AGC Report No. RN-S-0370, Fast and Thermal Neutron and Proton Effects on Platinum Resistance Transducers at Liquid Hydrogen Temperature.

The objective of Test 37/R107 was to evaluate the effects of irradiation on the mechanical properties of candidate materials for the bearing cages of the NERVA turbopump assembly. This report covers the effects of radiation on tensile, compressive, and flexural strengths of the candidate materials. Wear specimens of materials irradiated in GTR-18 that showed satisfactory strength properties after irradiation and satisfactory wear properties before irradiation have been stored for future wear testing.

II. TEST MATERIALS AND PROCEDURES

A. SPECIMENS

1. Specimen Schedule

A total of 156 specimens were prepared, of which 78 were for control and 78 were irradiated. Table 1 lists the irradiated specimens by type and material.

2. Materials

The following paragraphs give a brief description of the materials tested.

TABLE 1
BEARING CAGE MATERIALS, TEST SCHEDULE

<u>Material</u>	<u>Quantity of Specimens Irradiated for Each Test Property</u> ⁽¹⁾			
	<u>Tensile</u>	<u>Compression</u>	<u>Flexure</u>	<u>Wear</u>
SP - 10% MoS ₂	6	4	6	2
SP - 10% MoS ₂ - 20%	6	4	6	2
SP - 30% Bronze	6	4	6	2
SP-3	0	0	3	0
MoS ₂ - 35% Ni	0	0	0	6
CDJ Graphite	0	2	0	4
PBI - Glass Cloth	6	0	2	0

NOTE: (1) A like number of specimens were prepared as controls.

a. Superpolymer (SP) composites.

Superpolymer is a proprietary resin of the E. I. DuPont Company. It is an aromatic polyimide, polypyromellitimide. When molded, it is known under the trade name Vespel. It is available with various fillers, such as graphite, molybdenum disulfide, and metal powder, to meet particular service conditions. The following four composites of the material were tested:

- (1) SP with 10-vol% MoS_2
- (2) SP with 10-vol% MoS_2 and 20-vol% Grade-D phosphor bronze
- (3) SP with 30-vol% Grade-D phosphor bronze
- (4) SP-3 (SP with 15-wt% MoS_2)

b. Polybenzimidazole (PBI)

Polybenzimidazole is in the same family as the polyimides. It is easier to process than the polyimides, particularly when laminating with glass cloth. Samples of this material impregnated in Type -128 E-glass cloth were tested.

c. Nickel-and-Molybdenum-Disulfide Composites

Nickel- MoS_2 composites have a sintered-metal-powder matrix with molybdenum disulfide dispersed within the metal matrix. Microscopic pockets of MoS_2 supply lubricant to create a thin continuous film to separate the working surfaces. Specimens of a composite of 65-wt% MoS_2 and 35-wt% nickel were irradiated.

d. CDJ Graphite

CDJ graphite is a commonly used molded product characterized by high strength and density.

3. Materials Processing

Information pertaining to the processing of all these materials to their final form is proprietary. In general, SP and PBI are premixed on a weight basis to provide the desired volumetric compositions. The powdered-metal compacts, metal powder and MoS_2 , are mixed on a weight basis and sintered according to a predetermined temperature-pressure-time cycle to produce a dense, high-strength compact.

4. Specimen Design

Figure 1 shows specimen design. The tensile, compressive, and flexural specimens were fabricated in accordance with ASTM D638-64T, ASTM D695-63T, and ASTM D790-66, respectively.

B. ENVIRONMENT AND TESTING

Specimens were irradiated in liquid hydrogen at a temperature of -423°F . The gamma dose was 7×10^{10} ergs/gm(C). The fast-neutron fluence was 3×10^{16} nvt ($E > 1.0$ Mev). Estimated accuracy and precision for these values are ± 25 and $\pm 7\%$ for gamma dose and ± 20 and $\pm 5\%$ for neutron fluence.

Tensile, compressive, and flexural testing of the specimens was performed at room temperature in accordance with ASTM D638-64T, D695-63T, and D790-66, respectively.

Figure 1
Tensile, Flexural, Compression, and Wear Specimens;
Bearing Cage Materials

III. TEST RESULTS

A. STRENGTH PROPERTIES

Table 2 lists the values obtained in the tensile, compressive, and flexural strength testing. Figures 2, 3, and 4 show the typical appearance of polyimide composite specimens after tensile, compressive, and flexural testing.

B. RADIATION EFFECTS

1. Polyimide-Based Composites

A review of the data shows that the ultimate compressive strengths of polyimide-based composites were unaffected by radiation. In the case of ultimate tensile strength, no significant conclusions can be drawn from the data as to the effect of radiation. Data from GTR-17* show that the ultimate tensile strength of SP-3 was unaffected by a gamma dose of 3×10^{10} ergs/gm(C). The ultimate tensile strength of the composite of 70% SP and 30% bronze tended to decrease with irradiation. Flexural strengths were unaffected by irradiation, except in the case of the composite of 70% SP and 30% bronze. The data for this material show that its flexural strength increased about 25% as a result of irradiation.

2. PBI-Glass Cloth

The ultimate tensile strength of the PBI-and-glass-cloth laminate decreased as a result of irradiation. Its flexural strength increased.

*AGC Report No. RN-S-0327 (Final Report on GTR-17), Effects of Radiation on Organic Materials Irradiated in Liquid Hydrogen, March, 1967

3. CDJ Graphite

Only flexure-strength specimens of this material were tested. The results show that the flexure strength of CDJ graphite was not affected by irradiation.

TABLE 2
BEARING CAGE MATERIALS, TEST DATA

<u>Material</u>	<u>Ultimate Tensile Strength, psi</u>			<u>Ultimate Compressive Strength, psi</u>			<u>Ultimate Flexural Strength, psi</u>		
	<u>Control</u>	<u>IR or AD</u>	<u>% Change</u>	<u>Control</u>	<u>Irradiated</u>	<u>% Change</u>	<u>Control</u>	<u>Irradiated</u>	<u>% Change</u>
90% SP -	7,400	6,300		21,300	20,600		11,400	14,400	
10% MoS ₂	8,200	7,200		21,700	21,400		12,100	10,400	
	6,200			22,300	20,800		13,200		
Average	7,300	6,800	-7	21,800	20,900	-4	12,200	12,400	+2
70% SP -	7,000	6,800		19,900	21,400		12,200	12,300	
10% MoS ₂ -	6,900	5,500		20,400	20,400		13,000	13,100	
20% Bronze	5,800	6,500		21,200	20,400		11,100		
Average	6,600	6,300	-5	20,500	20,700	+1	12,100	12,700	+4
70% SP -	8,000	7,300		30,400	32,200		12,500	15,200	
30% Bronze	9,200	7,300		23,700	32,200		12,400	15,000	
				33,700	33,500		11,300		
Average	8,600	7,300	-15	29,300	32,600	+11	12,100	15,100	+25
SP-3	10,500	8,300		NOT TESTED			NOT TESTED		
	8,800	8,500							
		9,400							
Average	9,700	8,700	-10						
PBI	34,500	14,000		NOT TESTED			61,000	69,300	
Glass	33,400	28,000					60,800	66,400	
Reinforced							64,300	67,100	
							50,900		
Average	34,000	21,000	-38				59,300	67,600	+14
CDJ Graphite	NOT TESTED			NOT TESTED			12,900	11,600	
							11,200	12,200	
Average							12,100	11,900	-2

Figure 2
Tensile-Test Specimens

Figure 3
Compression-Test Specimens

Figure 4
Flexural-Test Specimens