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COMPOSITE MATERIALS:
AN ANNOTATED BIBLIOGRAPHY

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Compiled by
HELEN M. ABBOTT

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Lockheed

MISSILES & SPACE COMPANY
A GROUP DIVISION OF LOCKHEED AIRCRAFT CORPORATION
SUNNYVALE, CALIFORNIA

ABSTRACT

COMPOSITE MATERIALS

This is an annotated bibliography of 190 selected references pertaining to composite materials. Material composites are broadly considered as physical combinations of two or more dissimilar materials. Boron carbide impregnated with aluminum (Boral), metal fibers in glass or plastics, or glass fibers in aluminum are examples of some of the various combinations that are being studied.

Sandwich materials were not included in the search, although few fabricated articles cannot in some way be referred to as composites. Space flight and supersonic aircraft have made great demands for ingenious composites.

The search was completed September 1962

Availability notices and procurement instructions following the citations are direct quotations of such instructions appearing in the source material announcing that report. The compiler is well aware that many of these agencies' names, addresses and office codes will have changed; however, no attempt has been made to update each of these notices individually.

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This selective bibliography has been prepared in response to a specific request and is confined to the limits of that request. No claim is made that this is an exhaustive or critical compilation. The inclusion of any reference to material is not to be construed as an endorsement of the information contained in that material.

TABLE OF CONTENTS

1. Achbach, W. P. and Runck, R. J.
AN EVALUATION OF MATERIALS FOR ROCKET-MOTOR CASES BASED ON MINIMUM WEIGHT CONCEPTS. Defense Metals Information Center, Battelle Memorial Institute, Columbus, Ohio, DMIC Memorandum 147, March 8, 1962

Comparisons are made between the properties of different materials, including steel, titanium, and glass, as potential materials of construction for rocket-motor cases. These comparisons are useful in two situations in which the highest strength-to-weight ratio is wanted: where buckling is not critical; and where buckling is critical. High-strength steel wire-resin composites may have the potential to exceed the properties of monolithic steel plate in some rocket-motor cases. As compared with monolithic titanium plates, however, high-strength titanium wire does not have sufficiently greater strength to indicate any advantages in rocket-motor cases.

2. AEROSOL PREPARATION OF COMPOSITE METAL POWDERS FOR DISPERSION STRENGTHENING. Aeroprojects, Inc., West Chester, Pa. Bi-monthly Progress Rept., July-Sept. 1960. Rept. No. AERP-PR-N-311-7, Contract NOas 59-6247-C

The selection of a dispersed phase suitable for metal strengthening is governed by the requirements outlined in a previous report; the most difficult of these is to properly space finely divided solids in a metal matrix. The problem can be simplified either by coating metal particles with refractory films of the proper thickness or by coating refractory cores with metals. Metal particles have been coated with refractory oxides by aerosolizing a slurry of the metal suspended in a solution of a salt of the desired refractory and then decomposing the salt. Composite nickel powders prepared by this method have been compacted and hot-extruded. Electron microscopy shows that uniform dispersions of the desired size and spacing can be achieved by this technique. An alternative approach to the problem of second-phase size and spacing is to coat refractory cores with metals. In this technique, metal is deposited on refractory particles of the desired size and shape by the vapor-phase decomposition of a volatile metal compound. The process has the advantage that second-phase materials which are difficult to prepare by the pyrolysis method can be incorporated into a metal matrix. Metal coating of refractory particles is discussed.

3. Allen, J. M.
ENVIRONMENTAL FACTORS INFLUENCING
METALS APPLICATIONS IN SPACE VEHICLES,
Defense Metals Information Center, Battelle
Memorial Institute, Columbus, Ohio. (DMIC
Report No. 112) 1 Dec 50. (AF 18(600)-1375))

Metals will be used extensively both in the vehicle structure and in the supporting and auxiliary equipment that is used for space flight. This report describes the specialized environments which are imposed on metals and the possible consequences of these environments. In general, the specialized environments are identified with (1) the natural environment of space, (2) the entry into an atmosphere, or (3) the power-conversion system utilized by the vehicle. One promising method of using metals for severe heat-flux applications is the development of metal-ceramic and metal-plastic composite materials. Cermets, with relatively homogeneous physical and thermal properties, have been under development for over a decade. In general, the cermets retain the brittle properties of ceramics and have oxidation resistance not appreciably better than that of the metal constituent. They have, therefore, found limited use as structural components in oxidizing environments, such as atmosphere-entry applications.

4. Baskey, R. H.
FIBER REINFORCEMENT OF METALLIC AND
NONMETALLIC COMPOSITES. PHASE I. STATE
OF ART AND BIBLIOGRAPHY OF FIBER METAL-
LURGY. Clevite Corp., Cleveland, Ohio, Feb 62.
Interim technical engineering rept. 2 Oct 61-16 Jan 62,
(ASD TR 7-924 7-924, vol 1) Feb 62, (Contract
AF 33(657)7139, Proj. 7-924) ASTIA AD-274 379

Progress in fiber metallurgy is summarized. Whiskers possess the maximum strength but are not available commercially. The survey confirms that of the three fibers available, (glass, ceramic, or metal) only glass fibers are used extensively to reinforce material. Metal fibers have a limited commercial application as a reinforcing agent. In instances where metal fibers are used to reinforce metals, the processes are still laboratory or pilot plant size. Part I of this survey presents a review of the current state-of-the-art on strengthening theories, methods of producing fibers, or whiskers, methods of reinforcing composites with fibers or whiskers, and whisker formation. Part II is a bibliography of fiber metallurgy and consists of abstracts of each of the 293 articles or patents covered by the survey. The bibliography covers the following topics: (1) production and properties of metal fibers,

(2) production and properties of ceramic or glass fibers, (3) reinforcing composites with fibers, fiberglas, or wire, (4) whisker growth mechanisms and (5) reinforcing composites with whiskers.

5. Baskey, R. H.
FIBER REINFORCEMENT OF METALLIC AND NONMETALLIC COMPOSITES. Clevite Corp., Cleveland, Ohio. Interim technical rept., 17 Jan - 17 Apr 62, (ASD TR 7-924, v. 2), May 62. (Contract AF 33(657)7139) ASTIA AD-275 565

Initial parameter studies indicated that powder metal bars of stainless steel type 316 were reinforced by 14 vol-% 10-mil diam continuous W wires. The room temperature tensile strength of the stainless steel was increased from 40,000 psi to 48,000 psi by adding W wires. Nichrome V (80 Ni-20 Cr) matrices were not reinforced by either W or Mo wires.

6. Beckley, D.
REFRACTORY COMPOSITE NOZZLE MATERIAL DEVELOPMENT AT THE AEROJET GENERAL CORPORATION, SACRAMENTO, CALIFORNIA. Paper presented at the 6th Meeting of the Refractory Composites Working Group, Aeronautical Systems Div., Wright-Patterson AFB, Ohio, June 16-19, 1962. (Summarized in DMIC Rept. 175)

Tungsten, the most refractory metal, cannot be used in contact with tantalum carbide, one of the most refractory nonmetals, due to adverse chemical interaction. This chemical reactivity was suspected as the mode of failure in early evaluations of nozzles in solid-propellant rocket firings. The approaches to this problem which have been taken are discussed.

7. Bell, J. E.
THE EFFECT OF GLASS FIBER GEOMETRY ON COMPOSITE MATERIAL STRENGTH, Boeing Airplane Co., Seattle, Wash. American Rocket Society 15th Annual Meeting, Dec. 5-8, 1960, Wash. D.C. Preprint ARS 1583-60, 1960, 27p.

This paper reports the results of a study to determine the effect of glass-fiber geometry on composite material strength. Equations are derived for the load distribution in a composite material and also for the stress distribution. To determine the effect of fiber geometry, epoxy-resin composites are analyzed for composite efficiciency. These same composites are analyzed for glass-fiber efficiency. The highest composite efficiency determined was 58 percent for filament-wound fibers and the highest fiber efficiency was 68 percent for cross-laminated fibers. In general, this type of analysis may be useful in evaluating fiber geometries in other composites. No attempt was made here to analyze other systems.

8. Better Metal Composites. MATERIALS IN DESIGN ENGINEERING, v. 55, p. 15, 125, Feb 1962.

Two new techniques for securing a good bond between the two components of a composite electrical contact. Cu is cast-on to a sintered tungsten shape, anchoring itself in the tungsten pores and providing an integral Cu stud for attachment to a backing; a strip of contact metal is roll bonded to a base metal without solder or flux to produce a "void-free" bond.

9. Bischoff, G. H. and Rossetti, A. H.
DEVELOPMENT OF A POROUS METALLIC COMPOSITE MATERIAL. Emerson and Cuming, Inc., Canton, Mass. Final technical rept., 24 June 60, 69p. (WAL TR 375/1), (Contract DA-19-020-505-ORD-4971, Proj. TR4-003) ASTIA AD-265 637

The feasibility of making a porous metallic composite by bonding hollow metal spheres was demonstrated. Methods were developed for making hollow metal spheres by metallizing the surface of ceramic and plastic spheres. Hollow glass microspheres in the 1. 0 to 5. 0-mil diam. range were metallized by electroless Cu, Ni, and Ag processes. The building up of a sufficient metal thickness on these microspheres for bonding into a porous metallic composite appears impractical. Hollow clay spheres and hollow alumina bubbles were metallized by both electroless processes and by electrolytic processes. Expanded polystyrene spheres were metallized by electrolytic processes. Heavy metal coatings of 1 to 5 mils thickness were electroplated on 137-mil diam polystyrene spheres. The polystyrene was then completely removed by heating to 600-650 F. Ni, Cu, and Ag were successfully electroplated to form hollow metal spheres by this process.

10. BORON REINFORCEMENTS FOR STRUCTURAL COMPOSITES, Aeronautical Systems Div., Wright-Patterson AF Base, Ohio, Summary Rept. No. ASD-TDR-62-257, March 1962

Batch-process boron filaments having strengths of 500,000 lb/in.^{2} with a high of 1 x 10^6 lb/in.^{2} and moduli of 55 x 10^6 lb/in.^{2} corresponding to a filament specific strength and modulus of 5.3 x 10^6 and 580 x 10^6 in., respectively, were prepared by chemical vapor plating. Production of continuous filaments by a laboratory-scale apparatus produced uniform filaments 2 to 4 mils in diameter over 700 ft long. These filaments had strengths of 250,000 lb/in. and moduli of 55 x 10^6 lb/in.^{2}, some having strengths as high as 400,000 lb/in^2. At 1800° F some retained about 60% of room-temperature strength. Tests on composite structures containing up to 64 filaments in epoxy resin indicated high conversion of filament to composite strength and modulus resulting in a composite specific strength and modulus as high as 3.4 x 10^6 and 448 x 10^6 in. respectively.

11. Bradstreet, S. W., Jr. Ceramic coatings for high temperature service. CORROSION, v. 16, no. 7, p. 309t-311t, July 1960.

Several types of coatings may be used for service in extreme thermal environments. For moderate temperatures (to about 1700 C) for short-time periods, these coatings may be rather simple refractory layers. Under the more severe conditions of ramjet and rocket operation, reinforced materials, graded substrate-coating interfaces, or multilayers are required. Where thermal gradients are severe and where high-shear stresses and abrasion exist, composites must be used which utilize controlled ablation. The principles which appear to dominate the attachment of a ceramic coating to a variety of substrates are reviewed, and the deficiencies and advantages of different combinations are discussed. Principles for "tailoring" protective coatings for refractory metals are suggested, and a flame-sprayed ceramic coating of potential value as a combustion catalyst is used to illustrate these principles.

12. Buhl, J. E., Jr., Pulas, J.G., and Graner, W.R.
REINFORCED PLASTICS FOR HYDROSPACE VEHICLES.
Paper presented at the Filament Winding Conference,
Society of Aircraft Materials and Process Engineers,
March 28-30, 1961, Pasadena, Calif.

This paper presents background information on the use of glass-reinforced plastics for the construction of deep-submergence pressure hulls. The characteristics of an ideal material for deep-depth operating hulls are described and available information on structural response to static loading of cylindrical hulls made of glass-filament reinforced plastics is summarized to demonstrate their potential advantages over metals. Work to date indicates that experimentally determined pressures obtained from a limited number of tests with structural models fabricated from commercially available glass-reinforced plastic materials agree well with the pressures computed from formulas based on thin-shell theory considerations for isotropic materials. Plans for future research are reviewed.

13. CARBONIZED PLASTIC COMPOSITES FOR
HYPERTHERMAL ENVIRONMENTS. Aeronautical Systems Division, Wright-Patterson
Air Force Base, Ohio. Final Report, Report
No. ASD-TDR-62-352.

A new class of thermally protective materials were synthesized, which have outstanding resistance to dimensional erosion in simulated re-entry environments. The process for making the materials consisted of controlled pyrolysis of precursory reinforced plastics to form a porous carbonized matrix, which was subsequently impregnated with either an organic or inorganic ablative gas-forming filler. Material and fabrication variables for preparation of improved impregnated matrices were investigated and composites having controlled properties were obtained. The ablative behavior of the composites was determined by exposure in an air plasma arc.

14. Carrol-Porczynski, C. Z.
Asbestos in composite materials. ENG.
MATERIALS & DESIGN, v. 5, p. 30-33,
Jan 1962.

Discussion of the use of asbestos/glass-fiber and asbestos/-ceramic-fiber composites for high-temperature applications such as the manufacture of rocket-engine components. The methods of producing such composites, and of using them for component fabrication, are outlined.

15. Ceramic coating fills gap for corrosion-free designs.
IRON AGE, v. 186, n 13, p. 118-19, Sept 29 1960.

New family of construction materials called Nucerite combine structural strength and resistance to impact damage, with resistance to attack in hot, corrosive environments; ceramic-metal composites developed by Pfaudler Co are valuable in process industries; mechanical properties, heat and corrosion resistance, and other characteristics are discussed.

16. Chia, C. Y., Duft, B. L., and Stevens, D.
ESTABLISHMENT OF THE POTENTIAL OF FLAKE REINFORCED COMPOSITES AS ENGINEERING STRUCTURAL MATERIALS, Narmco Industries, Inc. San Diego, Calif. Quarterly prog. rept. n. 2, 1 Apr - 1 July 61. (Contract NOw 61-0305-c) ASTIA AD-265 263

An evaluation of geometric concentration effects on circular lap joints was conducted. This included the development of methods of analyzing circular lap joints, and, experimental verification of concentration factors at the edge of the flake as high as 4. The notch sensitivity of flake reinforced composites was evaluated. Although flake reinforced composites behave as brittle materials, they were determined to be relatively insensitive to notches, experimentally. The electrical properties of glass flake reinforced composites and mica flake reinforced composites were evaluated and compared. Mica flake composites appear to be as good as glass flake composites.

17. Chia, C. Y., Duft, B. L., et al
ESTABLISHMENT OF THE POTENTIAL OF FLAKE REINFORCED COMPOSITES AS ENGINEERING STRUCTURAL MATERIALS, Quarterly progress rept. n. 3, 1 July-30 Aug 61, Oct 61. (Contract NOw 61-0305-c) ASTIA AD-266 379

Composite materials studies indicated that combination of flake and fiber in a laminate will provide high compression, flexural, and tensile strengths. Increase in the modulus can be expected also. Additional studies provided data to substantiate the theory that flake laminates are insensitive to stress concentration. Techniques were evaluated for molding cylinders of glass flake material. Limited success was achieved which indicates that quality cylindrical flake laminates are possible. Studies on thread shear strength and machinability indicate that flake laminates could be used efficiently for inserts in primary structures.

18. Chia, C.Y., Duft, B, and Dharmarajan, S.
POTENTIAL OF FILAMENT WOUND COMPOSITES.
Narmco Industries, Inc., San Diego, Calif.
Monthly progress rept. no. 7, 1-30 Sep 61, Sept 61.
(Contract NOw 61-0623-c) ASTIA AD-265 241

Theoretical relations for flexural rigidity and modulus of elasticity at any point have been derived for composite beams with fibers in all laminations oriented at an arbitrary angle, and for composite beams with fibers in alternate laminations at different angles with the longitudinal axis of the beam.

19. Christensen, J. W.
STAINLESS STEEL SANDWICH COMPOSITE
MATERIAL PROGRAM. Sclaky Bros., Inc.,
Los Angeles, Calif. Final engineering rept.
17 May 57-30 Apr 59, 1 Mar 60. (Contract
AF 33(600)35074) ASTIA AD 239 183

A method was developed for spot welding high-strength heat-resistant stainless steel sandwich material. A sandwich welding machine was constructed which incorporates (1) a commercial welding power supply; (2) transverse-indexing pneumatically-actuated dual-tip multiple electrodes, (3) transverse-indexing manually-imposed multiple-node weld electrodes with integral individual kinetic force and circuitry for programmed electrical energization, (4) adjustible gap distance between upper and lower Cu-electrode platens, (5) provision for varying the transverse weld area, (6) infinite and unrestricted progression of sandwich panel materials through the welding area, and (7) basic design of a machine which is adaptable for processing varying configurations of sandwich panel. The core material with 3/16-in square cells is spot welded to the facing sheets and the nodes of each cell are also joined by spot welds. The sandwich height can be increased from 3/8 in., and there appears to be no specific limitation to the width or length of the sandwich. Sandwich design, configuration can include contours, wedges, tapered skins, and some airfoil sections. The sandwich panels have high-strength consistent ductile welds and high strength in edge compression, flat compression, flexure, and tension.

20. Clausen, E.M., Krumwiede, D.M. and Benzel, J.F.
SYNTHESIS ON FIBER REINFORCED INORGANIC
LAMINATES. Final rept., Nonmetallic Materials Lab.,
ASD, Wright-Patterson AFB, Ohio. WADD TR 60-299,
Pt. II, June 62, 72p.

The use of inorganic materials as the matrix for reinforced composites is studied. The objectives of this research were to study the compositional and processing variables on matrix strength, the explanation of the observed deformation of matrix bodies, and research on protective fiber coatings. Type of bonding acid used, premilling time of raw materials, reacting temperature, and milling time of reacted materials were considered variables affecting strength. Reactions occurring during drying, firing, and the mechanism of deformation were studied. Tin oxide, vapor deposited antimony oxide, molybdenum trioxide, organic-inorganic oxides, and liquid silver were considered as coatings for glass fibers. Strength and corrosive effects of matrices on Al_2O_3, TiO_2, and ZrO_2 rods were examined.

21. Composite-Bonded metals resist chemical and nuclear attack. IRON AGE v. 186, n 15, p. 90-1, Oct 13, 1960

Heretofore no single material possessed all properties of ideal chemical and nuclear shield; new series of metallurgically bonded Pb clad metals developed by Knapp Mills Inc now promise to fill void; presently being produced and known as Insmetals, are Bauxillium, Pb surfaced Al, Cupralum, Pb surfaced Cu, Ferrolum, Pb surfaced C steel, Inslead, high density shielding Pb, Nicrolum, Pb surfaced stainless steel or Ni alloy, and FerroNicrolum, Pb surfaced stainless clad steel; new techniques insure sound bonds.

22. COMPOSITE MATERIAL REPORT
Bendix Corp., South Bend, Ind. Paper presented at the fourth meeting of the Refractory Composites Working Group, Nov. 14-17, 1960, Cincinnati, Ohio

This paper summarizes coating materials for throat inserts for solid propellant rockets, especially the use of ceramic materials.

23. COMPOSITE MATERIALS AND COMPOSITE STRUCTURES. PROCEEDINGS OF THE SIXTH SAGAMORE ORDNANCE MATERIALS RESEARCH CONFERENCE. CONDUCTED AT SAGAMORE CONFERENCE CENTER, RACQUETTE LAKE, NEW YORK, AUGUST 18, 19, 20 AND 21, 1959. Rept. no. MET 661-601, (Contract DA 30-069-ORD-2566) ASTIA AD-233 158

Contents: Army research and development, by Richard A. Weiss, Composite materials and structures, present and future: Role of composite materials in the DOD materials research and development program; Scope of composite materials and structures; The Air Force looks at composite materials; Guns as composite structures; Army activities on composite structures and composite materials; and Future possibilities in fibered materials. Aspects of strengthening of composites: Fundamental mechanical behavior of composite crystalline mixtures; Super-high strength wire, a component of metallic composites; and Fiber-reinforced metallic composites. Metallic composites: Development of composite structures in Europe; Development of composite structures in U.S.A.; and Laminated metal-ceramic composite materials. Glass-reinforced plastics: Properties of glass fiber-reinforced plastics; Investigation of glass-metal composites; Properties of glass fibers at elevated temperatures; and Properties of glass flake-reinforced plastics. Composite pressure vessels: Materials and fabricating problems associated with high-strength light-weight homogeneous pressure vessels; Plastic-metal composite structures; and Pressure vessels from plastic bonded glass fibers. Composite systems for thermal protection; Principles of composites for heat absorption; Analysis of surface-boundary layer interaction; Heat protection by ablation; Reinforced refractory ceramic coatings; and Geometrical considerations for composites.

24. Courtney, A. L.
SERVICES TO GENERATE ENGINEERING DATA ON THE BEHAVIOR OF PLASTIC COMPOSITE STRUCTURES UNDER VARIOUS CONDITIONS OF STRESS. The Bendix Corp. South Bend, Ind. Final Rept. No. BPAD-863-14385, March 10 1962. (Contract NOw 61-0488-C)

This report covers utilization of prepreg materials. These materials were used to fabricate both 7-inch-diameter pressure vessels and 18-inch multi-ported cases. The cases were built to develop construction techniques applicable to prepreg materials and obtain the degree of correlation between split "D" ring tension tests and actual performance in pressure vessels. Prepreg materials have opened completely new horizons in ways to locate precisely the desired amount of added reinforcements in a rocket case. These added reinforcements are of little value if their outer extremities cannot be faired out to provide a smooth transition into the base structure. One of the major advantages of prepreg materials is the ease with which the designer can provide for a scarf-type joint. The techniques developed during this program were aimed specifically at reducing the stress concentrations in areas such as knuckle region, on center port openings, off center port openings (nozzle) and termination of tape ends. The necessity of having an evaluation chamber which would be programed to prevent premature failure in the end dome regions without affecting the balance of material in the cylindrical section was one of the reasons for developing the techniques used.

25. Crossley, F. A.
DEVELOPMENT OF DUCTILE BERYLLIUM COMPOSITES, Armour Research Foundation, Chicago, Ill. Bimonthly rept. no. 2, May 61 ,(Rept n. ARF 2212-2) (Contract NOw 61-0370-c) ASTIA AD-258 089

Further efforts to produce ductile Be composites consisting of beryllium particles in a ductile matrix are reported. A number of composites were tested in uniaxial compression in order to determine the matrix composition and heat treatment for the best mechanical properties. Silver-base matrices containing 6, 7, and 8% Al were evaluated. The best results were obtained for the Ag-6Al matrix which indicated that Ag-5Al should be evaluated. A 3/4-in.-diam compact (Ag-6Al matrix) was canned in Cu and successfully extruded at 500 C with a reduction ratio of 2.5:1.

26. Crossley, F. A.
DEVELOPMENT OF DUCTILE BERYLLIUM COMPOSITES. Armour Research Foundation, Chicago, Ill. Bimonthly rept. no. 3, 18 May-17 July 61, 17 July 61, 2p. (Rept. no. ARF 2212-3) (Contract NOw 61-0370-c) ASTIA AD-260 313

Further work towards the objective of producing ductile Be composites consisting of Be particles in a ductile matrix is described. Cylindrical compacts, 3/4 in. in diameter, are in preparation to provide information on the effects of variations in the processing procedure. Candidate Al-base and Ag-base matrix alloys were prepared for evaluation of their tensile properties in the age-hardened condition. A vacuum chamber is under construction so that liquid phase sintering in vacuo may be accomplished.

27. Crossley, F. A.
DEVELOPMENT OF DUCTILE BERYLLIUM COMPOSITES. Armour Research Foundation, Chicago, Ill. Bimonthly rept. no. 4, 18 July - 17 Sep 61, 17 Sep 61, 6p. (Rept. no. ARF 2212-4) (Contract NOw 61-0370-c) ASTIA AD-263 678

Progress is reported on the development of ductile Be composites consisting of Be particles in a ductile matrix. The vacuum chamber is now in operation. This chamber will permit pressure liquid-phase sintering in vacuum. It is hoped that this will answer the porosity problem. Tensile tests and hardness evaluations of heat-treated binary alloys spanning the Ag-Al system indicate that the correct matrix can be found which satisfies the strength and ductility requirements for the attainment of ductile beryllium composites.

28. Crossley, F. A., and Van Thyne, R. J.
DEVELOPMENT OF DUCTILE BERYLLIUM COMPOSITES.
Bimonthly rept. no. 5, 18 Sep-17 Nov 61, 17 Nov 61,
3p. (Contract NOw 61-0370-c) ASTIA AD-266 424

Further efforts directed to the development of ductile composites consisting of Be particles in a ductile matrix of compositions selected from the Al-Ag system are reported. Efforts are being directed toward making relatively large (2 1/2 x 1 1/4 x 1 1/4 in.) compacts from which specimens will be prepared for tensile test evaluation.

29. Crossley, F. and Van Thyne, R. J.
DEVELOPMENT OF DUCTILE BERYLLIUM
COMPOSITES. Armour Research Foundation, Chicago, Ill.
Final rept., 23 Dec 60-22 Dec 61, 1 Feb 62, ARF 2212-6,
(Contract NOw 61-0370-c) ASTIA AD-273 287

An effort to produce ductile Be composites by liquid-phase sintering is reported. Ductility in a predominantly Be composite was sought through the attainment of a structure in which Be particles are enveloped in a ductile metallic matrix. As the result of the investigation of Al-Ag binary alloys, Al-40 to 50% Ag compositions were added to the Ag-5 to 8% Al compositions as candidate matrices satisfying the requirement that the flow stress of the matrix be matched to that of the principal phase. Composites produced for final evaluation contained defects originating from the processing schedule. The feasibility of applying liquid-phase sintering to produce Be composites was established. However, to obtain a fair evaluation of the question of ductility improvement, it is necessary to develop compacting and sintering procedures which will yield sound material for mechanical testing.

30. Daley, H.S., Siuta, T, and Yurenka, S.
HIGH TEMPERATURE RESINS, ANALYSIS OF PROCESS
PARAMETERS AND EVALUATION PROCEDURES
FOR FILAMENT WOUND COMPOSITES. Narmco
Corp., San Diego, Calif. Part 111 Evaluation
Procedures WADD TR 60-791, Part 111, Feb. 1962,
(Contract AF 33(616)6737))

The objective of the program was to determine the most significant basic mechanical properties of filament-wound composites, and to provide optimum standardized test methods and procedures for defining them at both room and elevated temperatures. The program also included the design and fabrication of a versatile laboratory filament-winding machine to fabricate these specimens. An account of the various test-specimen configurations considered is presented, along with a detailed discussion of those actually evaluated. The evolution and development of the various test configurations are described, and construction details for each of the evaluation procedures are presented by drawings. The most satisfactory evaluation procedures for each mechanical property were determined on the basis of the data obtained. A standard cylindrical specimen was designed, from which all of the basic mechanical properties could be obtained. Detailed fabrication instructions for producing the basic specimen and some of its variations were determined. Winding-machine operating and maintenance instructions are presented in as much detail as possible. An account of the underlying theories and principles governing the design and use of this machine is given to facilitate understanding of the operating instructions and the capabilities of the machine.

31. Dank, M., Nelson, R. A., and Sheridan, W. R.
Water-stabilized arc tests on nonmetallic materials.
J. ELECTROCHEM. SOC. v. 106, no. 4, p. 317-21,
April 1959.

Erosion rates on possible heat resistant materials for uses ranging from liners for uncooled rocket engines to experimental machines used in thermonuclear research; materials include graphites, ceramics, principally oxides, plastic-ceramic composites, and reinforced ceramics; temperatures within electric arc estimated at 7000 to 12,000 K and velocities from 100 to 1000 m/sec.

32. Davis, R. M. and Milewski, C.
HIGH TEMPERATURE COMPOSITE STRUCTURE.
Martin Co., Baltimore, Md. (Final Report,
July 1960 to June 1962). Flight Dynamics Lab.,
Wright-Patterson AFB, Ohio, June 1962.
(Contract AF 33(616(-7497)) (ASD-TDR-62-418)

Two reentry heat shield systems intended for efficient operation with surface temperatures in the range of 3000° to 4000° F when adapted to spherical nose cap shapes were designed, developed, fabricated, tested and evaluated. The heat shields were of the radiative type, utilizing a foamed aluminum oxide material in the structural insulation design concept. Dense facings and resin impregnation were used to alter the basic foam, with the latter proving to be the better modification, as shown by simulated reentry tests in a large hot gas facility. Effects of various combinations of plasma jet enthalpy and heating rates on resin-impregnated ceramic foams were compared. These more closely simulated reentry conditions for ablative (and semiablative) type materials.

33. DEVELOPMENT AND EVALUATION OF HIGH-TEMPERATURE RESISTANT COMPOSITE PLASTIC PLATES. Midwest Research Inst., Kansas City, Mo. Final rept. 15 Dec 59-14 Feb 61, 28 Feb 61. (Contract NOa(s) 60-6099-c) ASTIA AD-255 980

The tensile and flexural properties were determined for the resin obtained from the diglycidvl ether of bisphenol A and 6.5 pph of trimethoxvboroxine. The resin has high ultimate flexural and tensile strengths; about 5% of the 76 F flexural strength was retained at 300F. This cured resin should be usable in three-layer canopies at skin temperatures up to 350 F. Maximum thermal rigidity was obtained from the hexahydrophthalic anhydride - vinylcyclohexene dioxide resins at a ratio of 0.7 to 0.8 mol anhydride per mol equivalent epoxide. This resin should structurally resist temperatures up to 450 F in three-layer composite canopies. A film-forming mold release agent was developed for releasing epoxide resins cast in plate glass molds. Castings of epoxide resins made in the coated plate glass molds had excellent optical properties. The syntheses of novel epoxide resins based on two bicyclic (2.2.1) heptane rings with three different types of connecting groups, a carbonate, an ester, and an ether are discussed.

34. DEVELOPMENT OF REFRACTORY COMPOSITE MATERIALS SYSTEMS FOR SOLID PROPELLANT ROCKET MOTORS. Hughes Tool Co., Culver City, Calif. Summary status rept. 4 Dec 61. (Contract DA 04-495-ORD-3068, Proj. TB4-004) (WAL TR 766.3/1-4) ASTIA AD-276 038

Progress is reported on the development of composite rocket nozzle systems for use with high temperature, high alumina content solid propellants. Material thickness requirements were determined by heat transfer analysis. The differential equations governing heat flow were solved by utilizing finite difference techniques with the computing performed on an IBM 704 machine. A major portion of the effort was devoted to the development of methods to form carbides mp greater than 4000 F on graphite. The most successful method consisted of sintering or melting and carburizing metal powders on graphite between 2200 and 5000 F in a carbon resistance furnace. A number of carbide systems were developed with excellent adherence and show promise for use as the flame surface of graphite nozzles. Flexural strength properties of metal wire reinforced chemically bonded high temperature oxides, for use as backup structures to a carbide coated graphite nozzle were determined.

35. Dixmier, G.

GLASS-PHENOLIC-RESIN LAMINATES.

(Les stratifies verre-resines phenoliques)

Royal Aircraft Estb., Farnborough. Ministry of Aviation, London. Library Trans. #859, Nov 59. ASTIA AD 233 321.

This paper is concerned with the production of glass-phenolic resin laminates. The first section is an analysis of the part played by the resins in a plastic reinforced with glass fibers. Information is given on the preparation and composition of the phenolic resins used in this work. The technique of moulding laminates which was developed, together with these methods of preparation, is discussed. Finally, the results of mechanical tests and some thermal properties at temperatures between ambient and 400 C are given.

36. Duft, B, Dharmarajan, S, and Otto, W.

POTENTIAL OF FILAMENT WOUND COMPOSITES,

Narmco Industries, Inc., San Diego, Calif.

Monthly progress rept. no. 2, 1-30 Apr 61.

May 61. (Contract NOw61-0623-c) ASTIA AD-256 657

Analysis was directed toward obtaining a quantitative estimate of the residual stresses resulting from curing of a glass monofilament encased in a concentric cylinder of resin. As the composite is cured, in general, it develops residual tensile stresses which will add to those produced by the external loading to initiate cracks in the resin. These cracks will expose the surface of the fiber and provide sites for fracture initiation in the composite. The stresses at the interface of filament and resin were analyzed. The axial stress in the resin will be the decisive stress to initiate crack in the resin in a direction perpendicular to the axis of the composite. This will break the resin into lengths which will depend upon the shear strength of the resin. The optimum design of the composite is shown as a function of the resin content and glass content.

37. Duft, B, Thompson, C. E., et al
POTENTIAL OF FILAMENT WOUND COMPOSITES.
Narmco Industries, Inc., San Diego, Calif.
Monthly progress rept. no. 8, 1-31 Oct 61,
Oct 61. (Contract NOw 61-0623-c) ASTIA AD-266 830

Research was continued on the potential of filament wound composites. Difference in principal stresses were determined photoelastically for composites reinforced with broken fibers. Glass rod reinforced composites, cured at room temperature, and .010 in. diameter-glass fiber reinforced specimens cured at 200 F, were evaluated in tension. The failure in the .010 in. diameter glass fiber reinforced specimen was observed at a distance of 10D to 40D from the gap. The failure of the glass rod reinforced specimen occurred as expected at the point of discontinuity. Effects of coatings on fiber strength were investigated. Preliminary data indicates coatings to be advantageous for the preservation of E-glass strength.

38. Duft, B, Thompson, C. E., et al
POTENTIAL OF FILAMENT WOUND COMPOSITES.
Narmco Industries, Inc., San Diego, Calif.
Monthly progress rept. no. 9, 1-30 Nov 61, Nov. 61.
(Contract NOw 61-0623-c) ASTIA AD-268 612

A study on the effect of coupling agents, with and without coatings, on the tensile strength of E glass fiber was conducted. The fibers were tested before and after water immersion of 1 and 7 days. Tests of coated fibers subjected to elevated temperatures were conducted. A preliminary evaluation of the single discontinuous fiber tensile tests previously reported was completed. Indications are that mechanisms of failure can be predicted reasonably well for this case, provided material properties are known. A comparison of the test data with developed theory is presented and shows good correlation. Test data for continuous parallel fibers, discontinuous parallel fibers, and parallel fibers, one continuous and the other discontinuous, are presented. Stress distribution by photoelastic measurement as well as stress plots along the fiber are also included. Indications are that theoretical predictions agree well with experimental results. Studies of the fractured surfaces of these specimens were made. Photomicrographs of these failures are presented which show interesting fracture phenomena.

39. Dunn, S. A., and Roth, W. P.
HIGH VISCOSITY REFRACTORY FIBERS,
Bjorksten Research Labs., Inc., Madison, Wisc.
Quarterly rept. no. 4, 20 July - 20 Oct 60, 20 Oct. ASTIA AD-253 238

The effect of several factors in the makeup and handling of the vitreous fiber reinforcement of composite thermal protection materials was examined in several series of comparative tests by using alpha-rod test equipment. The presence of color in the fibers was found to appreciably delay the transfer of heat through the sample. With colorless fibers, increases of viscosity did not delay the attainment of low level temperatures (200 C) at the rear of the composite. The angle of the fibers relative to the direction of the heat flux affected not only durability but also the transfer of heat. There was evidence to indicate that a thin coating of metal on fibers oriented at or near right angles to the direction of heat flux might improve the thermal protection properties of the composite. Calculations correcting previously determined standard viscosity temperatures to viscosities at one temperature showed that the viscosity of a glass may be increased 500-fold or more by additions of as little as 10 wt-% of a suitable insoluble, nonreactive additive.

40. Dunn, S.A. and Roth, W.P.
HIGH VISCOSITY REFRACTORY FIBERS,
Bjorksten Research Lab., Inc., Madison Wisc.,
Technical Summary Rept., Feb. 1962.
(Contract NOrd-19100)

The high-temperature materials used for thermal shielding on the nose cone and for nozzle construction in high-performance rockets have certain requirements in common and others sharply differentiated. The common requirements include: the ability to withstand high shear forces at high temperature for limited periods of time: resistance to thermal shock; and minimum weight. The objective was to search for and develop high-viscosity, high-melting materials, preferably in fiber form, for reinforcement of thermal-protection composites to be used in high-performance guided-missile propulsion systems.

41. Epner, M, and Gregory, E.
Some properties and metallography of steel-bonded
titanium carbide. TRANS. AM. INST. MINING
MET. ENGRS., v. 218, no. 1, p. 117-21, Feb 1960.

Composite materials consisting of alloy steels and up to 54 wt pct of titanium carbide are described; materials are capable of being annealed and hardened in manner similar to alloy steels; form and nature of phases present in these structures studied, and effects on properties of titanium carbide concentration, alloy elements, and heat treatment reported.

42. Farrell, J. W.
A COMPOSITE MATERIAL APPROACH TO AN EFFICIENT PRESSURE VESSEL. Temco Electronics & Missiles Co., Dallas, Tex., American Rocket Society 15th Annual Meeting, Washington, D.C., 5-8 Dec 1960. (Preprint) Paper No. 1582-60.

Improvement of the conventional materials such as steels, aluminum, magnesiums, and titaniums are near their peak. Alloy development is practically finished for these metals. Our future design ideas are depending on metallurgy for large improvements in beryllium, tungsten, molybdenum, etc. The past teaches us that it takes at least 10 years to develop high-strength reliable alloys. Therefore, we face a period in which we must better utilize existing materials. Composite materials are of immediate interest since known materials can be combined to create new characteristics and yield improvements in structural efficiency. An additional advantage exists in that development time and experimentation can be minimized by mathematics. Given elements of metals, plastics and ceramics can be mathematically formulated into composites with good confidence in predicted results. In example, a design approach is explained in detail for a novel pressure vessel utilizing a metal shell and circumferential wound filament glass in selected areas.

43. FILAMENTIZED CERAMIC RADOME TECHNIQUES.
Horizons, Inc., Cleveland, Ohio. Interim engineering rept. no. 2, 1 May - 31 July 61, 31 July 61. (Contract AF 33(616)7872, Proj. 1-761-(4161) ASTIA AD-272 112

A filamentized refractory ceramic body was developed which, in fired form, comprises synthetic A1203 fibers bonded with a matrix taken from the quarternary system CaO-A1203-Si02-P205. The composites are prepared by cold setting techniques yielding high green strength and ready formability at room temperature through the medium of utilizing the matrix as an air setting cement prior to firing. Fired composites containing in excess of 50-wt-% A1203 fibers exhibit dielectric constants substantially less than 10 and extended life at temperatures up to 2250 F. Detailed analysis of the results in the light of phase relation information available from the literature indicates a route for development of similar composites with temperature resistance considerably higher than the level of 2250 F.

44. Forms, shapes and composites. MATERIALS IN DESIGN ENGINEERING, MATERIALS SELECTOR ISSUE, v. 52, n. 6, p. 366-407, Mid-Nov. 1960

Available forms and application of materials are presented.

45. Fugardi, J., and Zambrow, J. L.
THE CLADDING AND WELDING OF STAINLESS STEEL TO MOLYBDENUM AND NOIBIUM.
Sylvania-Corning Nuclear Corporation, WADD TR 58-674, Oct 59, (Contract AF 33(616)-3492)

This program was concerned with the development of clad composites of Type 310 stainless steel with molybdenum or niobium, and the development of a butt-weld to join composite sheets. A fundamental study was made to determine the best cladding combinations, cladding procedure, and welding techniques for the fabrication of the specified test samples. The program to determine the best cladding combination and procedure was based on direct hot-pressing studies, thermal shock, high-temperature diffusion, and rolling studies using many different kinds of material. Methods were investigated for the fabrication of composite sheets consisting of 310 stainless steel bonded to one side of either molybdenum or niobium sheet. A barrier material between the two sheets was used to minimize diffusion. The best barrier material found, on the basis of tensile strength, thermal-shock resistance, minimum diffusion during long-time high-temperature tests, and minimum formation of intermetallic compounds at the bonding surfaces, was nickel for the molybdenum to Type 310 stainless steel composite and iron for the niobium to Type 310 stainless steel composite. Butt welds were made on composite sheets of stainless molybdenum and stainless niobium. The difference in the thermal coefficient of expansion between the stainless and the refractory metals used caused stresses and distortion in the weldments.

46. Galli, J.R., Wheeler, G.I., and Clampitt, G.H., et al
DEVELOPMENT AND EVALUATION OF ROCKET BLAST AND RAIN EROSION RESISTANT COMPOSITE COATINGS PRODUCED BY FLAME SPRAY TECHNIQUES. Boeing Airplane Company, Wichita, Kansas. WADC TR 58-493, Feb 1959, (Contract AF 33(616)-5284) ASTIA AD-209913

It was the purpose of this contract to determine the feasibility of utilizing multilayer coatings to protect metal surfaces from erosive and corrosive effects of rocket blast impingement. These coatings were to be comprised of two or more from the group: metal, ceramic, organic primer, and organic impregnant, with the metal and ceramic layers being applied by flame-spray techniques. In the course of this study six ceramics, four powder-spray metals, two wire-spray metals, four substrate metals, and approximately 60 organic materials were combined into a large number of different coating systems. These coatings were subjected to a wide variety of tests culminating with actual exposure to rocket blast. A total of 26 different coating systems were obtained which successfully withstood four rocket blasts without significant deterioration, verifying the feasibility of this technique. The successful coatings were all of the spray material-impregnant type with the most resistant spray materials being the ceramics. In addition to the work described above, a limited amount of study was directed toward a better understanding of the flame-spray process utilizing the techniques of microphotography, high-speed photography, and X-ray diffraction, along with certain theoretical derivations. It is felt that the results of this work, although not of extreme usefulness by themselves, represent a useful addition to the total knowledge about this complicated process.

47. Gates, L. E., Lent, W. E.
STUDIES ON REFRACTORY FIBER RESEARCH.
Hughes Aircraft Company, Culver City, Calif.,
Army Ballistic Missile Agency Summary Report
No. 1, Oct 30, 60. (Contract DA-04-495-ORD-1723)

The greatest portion of the work in this program was devoted to the development of a carbon-arc fiberizing apparatus and glass fiberizing techniques. The carbon arc provided a high-temperature source capable of melting all the refractory materials investigated. Refractory glasses were screened by evaluating the fiberizing characteristics of their compositions, formulated according to the hypotheses of glass formation. Four oxide compositions which produced high fiber yields were selected for comparison with E-glass fibers produced by the same method. Tensile-strength measurements of the fibers revealed no significant statistical difference in the strengths of the four compositions and E-glass. One refractory fiber composition was not visually affected when subjected to a temperature of 1250 C for 1/2 hour. Sufficient quantities of fibers were produced from the four selected refractory compositions for the fabrication of phenolic resin composite test specimens. Measurements of flexural strength, flexural modulus of elasticity, block compressive strength, and punch shear strength indicated that the refractory fiber-resin composites were slightly better than the E-glass-resin composites and compare favorably with chopped roving glass-phenolic resin composites, according to data reported by their manufacturers.

48. Geltman, G. L. and Huppert, P. A.
Trends in ceramic coatings for light metals,
CERAM. AGE v. 74, n 3, p. 32-9, Sept 1959

Report on work to develop improved coatings for aircraft and missile applications; coatings were converted porcelain enamels consisting of two phase system whereby refractory particles are embedded in glass matrix and trials were also made with adjustment of fluxing compound additions; average reflectance and gloss measurements range from 14-70% reflectance and 8-92% gloss; tables show test data.

48A. Gibeaut, W. A., and Maykuth, D. J.
SUMMARY OF THE SIXTH MEETING OF THE REFRACTORY COMPOSITES WORKING GROUP.
Defense Metals Information Center, Battelle Memorial Institute, Columbus, Ohio. DMIC Report 175, 65p. (Contract AF 33(616)-7747))

This report briefly summarizes the reports presented at the Sixth Meeting of the Refractory Composites Working Group. Subjects covered include protective coatings, heat-resistant composites, dispersion strengthening, plasma spraying, and test procedures. A compilation of the complete reports from this meeting will be published later by the Aeronautical Systems Division.

49. Goldsmith, A., Waterman, T. E., and Hirschhorn, H. J.
THERMOPHYSICAL PROPERTIES OF SOLID MATERIALS. VOLUME IV. CERMETS, INTERMETALLICS, POLYMERICS, AND COMPOSITES.
Armour Research Foundation, Chicago, Illinois. WADC TR 58-476, Revised Edition, Nov 1960, 798p. (Contract AF 33(616)-5212)

Thermophysical property data, and their variation with temperature, are presented for a great number of solid materials, based on literature published during the period 1940-1957. Each reported value is shown and annotated, and recommended "most probable value" curves are given. Materials covered include cermets, intermetallics, polymerics, and composite materials. Properties covered include the following: melting point, density, latent heats, specific heat, thermal conductivity, thermal diffusivity, emissivity, reflectivity, thermal expansion, vapor pressure, and electrical resistivity.

50. Goodwin, P. M.
A PROGRAM OF MATERIALS RESEARCH AND DEVELOPMENT FOR FILAMENT WINDING.
Bureau of Naval Weapons. Paper presented at the SAMPE Filament Winding Conference, Pasadena, Calif., Mar 28-30, 1961, 10p.

50. (cont)
A case is drawn for a concerted, comprehensive, nonmetallic filament-winding-materials research and development effort having as its predominant objective the exploitation of this still young field for the outstanding potential it holds in terms of advanced materials. The extreme diversity that a comprehensive program must of necessity contemplate by reason of the essentially infinite variety of possible material compositions, configurations, and constructions is discussed. The premium which this situation places on selectivity in choosing areas of effort and approaches, if progress is to be achieved, and accomplished without extravagance, and the concomitant need for timely input concerning design trends and objectives are reviewed. The essential features of a proposed long range program are developed. The status of the Bureau of Naval Weapons current materials efforts in the filament winding field is reviewed together with a brief discussion of projected plans for the immediate future. Finally, views concerning the possible impact of developments in other materials fields, notably, beryllium, are presented.

51. Greenspan, J., Henrikson, G. A., and Kaufmann, A. R.
BERYLLIUM RESEARCH AND DEVELOPMENT IN THE AREA OF COMPOSITE MATERIALS. Nuclear Metals, Inc., Concord, Mass. Rept. No. WADD TR 60-32, Jul 60. (Contract AF 33(616)-5912

The general objective of the program was to investigate the ductility properties of some beryllium composite materials in relation to the ductility of beryllium itself. An investigation of bend ductility in beryllium sheet as a function of sample width and sample thickness revealed that the magnitude of ductility was sensitive to grain orientation (i.e., fabrication history) as well as sample dimensions. In strip composites consisting of alternate strips of beryllium and aluminum or silver filler metal, the magnitude of bend ductility of the composite was generally intermediate between that of an individual beryllium strip and that of continuous beryllium as wide as the composite. Transverse strength of strip composites was found to be of the order of 1/8 - 1/4 that of beryllium. In clad composites the presence of a cladding did not institute unusual changes in the ductility of the composites. However, the presence of a cladding appeared to be significant as a "fail-safe" and surface-protection medium, and is suspected to be significant for any surface-sensitive property. Beryllium was amendable to cladding by either rolling or extrusion if a thin silver interlayer was present between core and cladding. The presence of an aluminum or silver coating did not institute unusual changes in the ductility or tensile strength of the beryllium composite. Polishing methods for beryllium surfaces are described.

52. Gücer, D.E., and Gurland, J.
COMPOSITE ALLOYS BY POWDER METALLURGY METHODS. Brown University, Providence, R.I., Technical rept. no. 6, Final rept. June 60, 17p. (Contract Nonr-56219) ASTIA AD-240 388

The deformation in bending of four composite, silver-base alloys was investigated on samples with, respectively, 15% of tungsten, molybdenum, tungsten carbide, or nickel. It was found that the overall plastic behavior of these particle strengthened alloys is unaffected by the nature of the second phase particles if the latter remain elastic. It was also attempted to produce composite bodies from non-wetting components by compacting of soft metal powders together with hard particles under very high pressures to produce cold welding and subsequent sintering to improve existing bonds. Factors investigated were compacting pressure, sintering temperature and repeated pressing-sintering cycles and their effects on density.

53. Hagan, M. and Weissman, M.
INVESTIGATIONS IN REFRACTORY COMPOSITES. North American Aviation, Los Angeles, Calif. Paper presented at the Fourth Meeting of the Refractory Composites Working Group, Nov. 14-17, 1960, Cincinnati, Ohio. North American Aviation Rept. No. NA60-1048.

Information on two types of investigations is presented. First is described the fabrication and testing of a re-entry vehicle leading-edge test section of beryllium oxide and graphite. Second are summarized some in-work projects on development and evaluation of oxidation-protective coatings for refractory metals.

54. Hahn, G.T., and Jaffee, R.I.
A COMPARISON OF THE BRITTLE BEHAVIOR OF METALLIC AND NONMETALLIC MATERIALS. Defense Metals Information Center, Battelle Memorial Institute, Columbus, Ohio. 16 May 61, 33p. DMIC memo no. 107, ASTIA AD-258 042

The nature and properties of brittle metallic and nonmetallic materials are compared in an attempt to develop a common basis for the design of tensile structures. Deformation and fracture are dependent on electron bonding, crystal structure, and the degree of order; these characteristics influence the strength and ductility parameters used by design engineers. Properties of brittle materials of importance in design include elasticity, plastic deformation, fracture, notch sensitivity, energy absorption, fatigue, and thermal-shock resistance. These properties of metals, ceramics, composite materials (reinforced plastics) and polymers are compared. Many similarities exist in the properties of metals and nonmetallics subject to brittle behavior. Ductility, notch sensitivity, and energy-absorption data indicate that nonmetallics are more susceptible to cracking and fracture than brittle metals. Design philosophies are discussed on transition-temperature; crack-propagation, and brittle material.

55. DISCUSSION FOR HIGH TEMPERATURE IN ORGANIC REFRACTORY COATINGS. Harvey Engineering Laboratories, Cambridge, Mass. Paper presented at the Fourth Meeting of the Refractory Composites Working Group, Nov. 14-17, 1960, Cincinnati, Ohio

This report summarizes work on plasma flame spraying done in the course of experimental work under various government contracts.

56. Hastings, C. H. and Grund, M.V. Radiographic inspection of reinforced plastics and resin-ceramic composites. NONDESTRUCTIVE TESTING, v. 19, n. 5, Sep - Oct 1961, p. 347-351.

The application of radiography for quality of reinforced plastics and resin-ceramic composite heat-shield material is discussed. Initial work has shown radiography to be of little value for evaluation of the reinforced plastics, but extremely important for the resin-ceramic material. The development of radiographic test procedures for specific qualities of the resin-ceramic materials; i. e., density gradient and soundness, for process control and eventual production inspection is described. Radiographs of representative discontinuities are presented and their effect upon serviceability discussed.

57. Hastings, C.H., LoPilato, S.A., and Lynnworth, L.C. Ultrasonic inspection of reinforced plastics and resin-ceramic composites. NONDESTRUCTIVE TESTING, v. 19, n. 5, Sep - Oct 1961, p. 340-346

Acoustic response of reinforced plastics and ceramics is sensitive to composite structure, fiber orientation, delaminations, cracks, resin distribution, porosity, and

57 (cont)
density gradients. In some resin-ceramic composites, a useful correlation exists between acoustic attenuation and tensile strength. Current production-line "accent" or "reject" decisions for ICBM re-entry vehicle materials are partly governed by this particular correlation. Frequently, the coordinated use of radiography and ultrasound permits determination of material quality, whereas the use of one nondestructive test technique alone would be inadequate for the inspection problems posed by the more recent composites. The value of a long-range nondestructive test development program is two-fold. First, process variations are indicated early in the material development program. Second, considerable reliability may be attached to nondestructive test results in subsequent production use.

58. Headrick, R. E.
COMPOSITE SEAL MATERIALS FOR EXTREME ENVIRONMENTS. Armour Research Foundation, Chicago, Ill. Final rept. on nonmetallic and composite materials, ASD TDR 62-286 Mar 62, 23p. (Contract AF33(616)-7310, Proj. 7340) ASTIA AD-274 082

Unusual and extremely promising composite seal materials are critically discussed. These composite seal materials were shown to be particularly promising for use in extreme aerospace environments. Evaluation of these materials, metal fiber skeletons impregnated with softer organic and inorganic materials, as seals at both static and dynamic conditions from liquid N temperatures to 1000 F and at pressures up to 5000 psi yielded unsurpassed results. The metal fiber skeletons (stainless steel or Mo) provide the strength and resilience, and the impregnating materials (soft metals, soft metal alloys, or compounded polymeric materials) provide the sealing barrier. In some cases the impregnants increased the resilience and lubricity of the composite. The limitations, potentials, and the availability of these materials are discussed.

59. HIGH TEMPERATURE COMPOSITE STRUCTURE.
Martin Co. Space Systems Div., Baltimore, Md. Sixth Quarterly Progress Report, 1 Oct through 31 Dec 61. Jan 1962, 46p. (ER 12185) (Contract AF 33(616)-7497; Proj. 1368)

Work performed during the period consisted of preparation, performance and post-test analyses of tests performed on a full-scale prototype panel; choosing of two advanced materials and systems studies; continued investigations of material properties, fabrication techniques, and quality evaluation; and management aspects of the program.

60. HIGH TEMPERATURE RESISTANT MATERIALS FOR MISSILE PROPULSION SYSTEMS. Naval Ordnance Lab., White Oak, Md. Quarterly rept. Jan - Mar 61, 4p. Mar 61. ASTIA AD-256 592L

Insulation studies using an oxy-acetylene panel test were conducted on graphite cloth and asbestos mat composites. The composites had a binder of nylon-phenolic. Best performance was seen with a composite laminate made up of a facing of graphite cloth 0.150 in. thick and an asbestos mat back-up 0.105 in. thick.

61. Hoffman, Oscar
STRESSES AND DEFORMATIONS IN FILAMENT-REINFORCED STRUCTURES. IAS 30th Annual Meeting, New York, N. Y., Jan 22-24, 1962. Preprint IAS-62-26, 1962

Navy-sponsored development of a method of analysis for composite shell structures built by embedding filaments of high tensile strength in a resinous matrix. The anisotropy of the structure is accounted for in the formulation of elastic relations between the membrane stresses and the plane tangent to the shell surface. These relations form the basis for predicting deformations due to applied loads and also for the analysis of the stress distribution in the component materials. The strength limitations of the matrix are accounted for by introducing a Mohr-type failure hypothesis. Related to the progressive failure of the matrix, several phases of the filament-matrix behavior are identified and analyzed. The analyses are formulated for the general case of nonsymmetrical filament patterns.

62. Holladay, J. W.
TITANIUM ALLOYS FOR HIGH-TEMPERATURE USE STRENGTHENED BY FIBERS OR DISPERSED PARTICLES, Defense Metals Information Center, Battelle Mem. Inst., Columbus, Ohio. DMIC rept. no. 117, 31 Aug 59, 74p. ASTIA AD 227 015

Available data are reviewed on heterogeneous structures of titanium in which the titanium matrix is reinforced by a dispersion of metal fibers or particles. Fiber reinforcement offers promise for improving the shorttime strength and modulus of elasticity in the temperature range of 1000 to 1400 F. It has been demonstrated that titanium can be strengthened by dispersion hardening and by fiber reinforcement, although the best conditions have not yet been fully established.

63. Islinger, J.S., and Gutfreund, K., et al
MECHANISM OF REINFORCEMENT OF FIBER-REINFORCED STRUCTURAL PLASTICS AND COMPOSITES. Armour Research Foundation, Chicago, Ill. WADC Tech rept no 59-600, pt. 1, Mar 60, 81p. (Contract AF 33(616)5983) ASTIA AD-237 291

This research effort was undertaken to study the mechanisms of reinforcement in fiber-reinforced structural plastics and composites. Analytical and experimental approaches included physical-chemical investigations of fiber-matrix interfaces, optical investigations of composites, and studies of the mechanical aspects of reinforcement. Data are presented for chemisorption studies and for microscopic investigations of fiber-resin composites using multiple beam interference microscopy. Several analytical techniques are summarized for describing the mechanical behavior of fiber-reinforced composite materials. Included are newly developed theories for the behavior of prismatic bars reinforced by uniformly distributed, parallel, short fibers, and for the transverse interface stress produced in axially loaded parallel fiber-resin composites.

64. Islinger, J.S., Gutfreund, K., et al
MECHANISM OF REINFORCEMENT OF FIBER-REINFORCED STRUCTURAL PLASTICS AND COMPOSITES. Armour Research Foundation, Chicago, Ill. Rept. for 1 July - 31 Dec 59 on Solid State Research and Properties of Matter, June 60, 55p. (Contract AF 33(616)-5983, Proj. 7021) WADC TR 59-600, pt. 2 ASTIA AD-243 609L

This is a continuation of the research effort undertaken to study the mechanism of reinforcement in fiber-reinforced structural plastics and composites. Analytical and experimental approaches include physical-chemical investigations of fiber-matrix interfaces, optical investigations of composites, studies of the mechanical aspects of reinforcement and investigations of the feasibility of graphite whiskers as reinforcements. Data are presented for chemisorption studies aimed at determining the nature of interfacial bonds and the fraction of each component in the glass-surface treatment-resin composite. Macroscopic studies of fibers terminating within a resin are described, together with interference microscopy investigations. Data are also presented for flexure tests of polyester specimens reinforced by a single layer of glass fibers located near one surface with fiber placement and treatment variations. A limited study of residual stresses in such a composite by analysis and by photoelastic methods is also presented. The development of micro-tensile specimens for assessing the feasibility of graphite whiskers as reinforcements for plastics is described.

65. Islinger, J.S., Gutfreund, K., et al
MECHANISM OF REINFORCEMENT OF FIBER-REINFORCED STRUCTURAL PLASTICS AND COMPOSITES.
Armour Research Foundation, Chicago, Ill. Rept for Feb - Dec 60, on Solid State Research and Properties of Matter. Apr 61, 72p. (Contract AF 33(616)-6987, Proj. 7021, Continuation of Contract AF 33(616)-5983) WADC TR-59-600, pt. 3 ASTIA AD269 949

The study of the mechanism of reinforcement in fiber-reinforced structural plastics and composites was considered. Analytical and experimental approaches included physical-chemical investigations of fiber-resin interfaces, photoelastic investigations of composites, and studies of the mechanical behavior of composites. Data are presented for chemisorption studies of the interactions of water with bare, silane-treated, silane-pretreated, and polymer-reacted glass fibers and of the reactions of alkenylsilane-treated E-glass with styrene under simulated service conditions. The photoelastically determined shrinkage and other residual stresses around single and groups of glass inclusions in cured polyester resins and simulated composites are presented. The mechanical properties in flexure of parallel fiber-reinforced composites with variations in reinforcement material and placement are given, together with data resulting from studies of the supposed orthotropic nature of the resin in fiber-reinforced composites.

66. Johnson, R.D.
REFRACTORY COMPOSITES AT CLEVITE.
Clevite Corp., Cleveland, Ohio. Paper presented at the Fourth Meeting of the Refractory Composites Working Group, Nov 14-17, 1960, Cincinnati, Ohio

This report presents Clevite' work on fiber metallurgy and presents specific applications on refractory composites.

67. Kelsey, R. H.
FILAMENTIZED CERAMIC RADOME TECHNIQUES.
Horizons, Inc., Cleveland, Ohio. Interim engineering rept no. 3, 1 Aug - 31 Oct 61, 12p., 31 Oct 61. (Contract AF 33(616)-7872, Proj. 1-761-(4161) ASTIA AD-267 611

67. (contd)
Research was continued on the development of filamentized ceramic radome techniques. A matrix composition was developed which has adequate thermal, electrical and mechanical properties for use in filamentized ceramic radomes. Techniques were evolved for handling this cementitious material to yield highly compacted bodies having unusually uniform properties and very low porosity. Statistically planned experimentation was found especially applicable to this investigation, producing maximum useful information most economically. Incorporation of alumina fibers into the matrix to form reinforced filamentized composites is in progress.

68. Kindall, J.V., and Susman, S.E.
HIGH TEMPERATURE RESIN SYSTEM FOR
GLASS FILAMENT WOUND COMPOSITE.
Narmco Industries, Inc. Paper presented at
the SAMPE Filament Winding Conference,
Pasadena, Calif. Mar 28-30, 1961

Narmco Research and Development Division has developed a superior resin system well suited to filament winding processes. This system is based upon Dow Chemical Company's epoxy-novolac resin, DEN 438. This paper treats the various factors involved with the development of this resin system for high-temperature glass filament-wound composites. The factors discussed include the effect of; curing agent system variations on pot life and wound composite physical properties, temperature on resin viscosity and pot life, resin content on composite physical properties, cure and post cure on physical properties, cyclic loading temperature and load rate on ultimate tensile strength, and boiling water on physical properties.

69. Klopp, W.D.
SUMMARY OF THE FIFTH MEETING OF THE
REFRACTORY COMPOSITES WORKING GROUP.
Defense Metals Information Center, Battelle Mem.
Inst., Columbus, Ohio. DMIC rept. no. 167
12 Mar 62, 74p. (Contract AF 33(616)-7747,
Proj. 2(8-8975) ASTIA AD-274 804

Information is summarized on refractory composites for use above 2500 F presented at the Fifth Refractory Composites Working Group Meeting held in Dallas on Aug 8 to 10, 1961. The subject of refractory composites is extensive; reports presented at this meeting dealt with protective coatings, heat-resistant ceramic composites, dispersion strengthening, plasma spraying, and high-temperature reactions. Protective metallic and intermetallic coatings are currently under development for V and the four refractory metals. Most attractive are the silicide coatings, which are protective to temperatures in the vicinity of 3000 F. Developments on silicide coatings include a fluidized-bed technique for application of the coating and recognition of substrate alloying effects on coating protectiveness. Aluminide coatings are simpler to apply. The application of silicide and aluminide coatings to actual space-vehicle components has shown that coating uniformity, edge protection, and repairability are serious problems.

70. Kobrin, C. L.
The new science of materials. IRON AGE METAL WORKING INTERNATIONAL, v. 1, p. 13-15, May 1962

Consideration of various mechanical and physical properties including magnetism superconductivity, toxicity and brittleness, for W, Mo, Cb, Ta, Be and Cb-Al alloys. Pyrolytic graphite strength as related to temperature. Development of composites of Al, Ti, stainless steel and tungsten carbide in a Co matrix. High strength steel processed by ausforming has maximum tensile strength. Plastics with improved strengths, heat and corrosion resistance.

71. Koppenaal, T. J., Parikh, N. M.
COPPER-COOLED TUNGSTEN FIBER ROCKET NOZZLE MATERIALS. Armour Research Foundation, Chicago, Ill. Quarterly rept no 1, 1 July - 30 Sep 61, Rept no ARF 2182-B2-27, (Contract DA 11-11-022-505-ORD-3092, Proj. TB4-002, ASTIA AD-265617

Cu and Cu-Ni alloys were used as a matrix of W fibers for the purpose of obtaining W-W bonding of the fibers. From the experimental results, the following conclusions are made: Maximum strength properties in 25% density composites made with 0.006 in. diam tungsten fibers were obtained by using a matrix of 90% Cu-10% Ni. Maximum strength properties in 75% density composites made with 0.001 in. diam W fibers were obtained by using a matrix of 95% Cu-5% Ni. Maximum strength properties in 75% density composites made with 0.002 in. diam tungsten fibers were obtained by using matrices of 90% Cu-10% Ni and 85% Cu-15% Ni. Another large increase was observed at 70% Cu-30% Ni, and this requires additional investigating. The strengthening mechanism in all of these cases presumably arises from a Ni-W or Ni-W-Cu bond between the W fibers.

72. Koppenaal, T. J., and Parikh, N. M.
FIBER-REINFORCED METALS AND ALLOYS.
Armour Research Foundation, Chicago, Ill.
Bimonthly rept. no. 1, 3 Apr - 18 June 61,
12p. 27 June 61. Rept. no. ARF 2221-1,
(Contract NOw 61-0555-c) ASTIA AD-260 214

Studies are being made of fiber-reinforced metals and alloys to evaluate their mechanical properties. The deformation characteristics of various composites were studied to determine: (1) the strengthening mechanism of the composite and (2) why the yield strength is dependent upon the type of fiber. Micro-yield measurements were made on composite specimens of Ag-10% mild steel and Ag-30% mild steel fibers (0.0025 to 0.003 in. in diameter, and on Ag with 30% fibers of mild steel, Mo, and heat-treated (hardened) type 410 stainless steel. The surface of a Cu-30% Mo fiber composite was polished and examined metallographically as a function of strain. Failed sections of Cu-10% and -40% mo fiber composites were examined. Three important features in the deformation behavior of fiber-reinforced metals are: (1) for a given type of fiber, the rate of work hardening is highly dependent on fiber density at small plastic strains, and relatively independent of fiber density at high strains; (2) for the initial 2% elongation, deformation is restricted to the softer matrix; and (3) for a given matrix, fiber size, and fiber density, the yield strength at small strains is nearly independent of the type of fiber, but becomes significantly dependent at higher strains.

73. Koppenaal, T. J. and Parikh, N. M.
FIBER-REINFORCED METALS AND ALLOYS.
Armour Research Foundation, Chicago, Ill.
Bimonthly rept. no. 2, 19 June 18 Aug 61,
Rept. no. ARF 2221-2, 28 Aug 61.
(Contract NOw 61-0555-c) ASTIA AD-263 679

Examination of the slip line structure of 30% density composite with an Ag matrix and fibers of mild steel, Mo, and heat treated-type-410 stainless steel after 4% elongation showed no slip lines in the stainless steel fibers, but large amounts of deformation in the mild steel fibers. Specimens were prepared from (1) as-impregnated, (2) reduced 30% and recrystallized, (3) reduced 60% and recrystallized, and (4) reduced 90% and recrystallized Ag matrix composites, respectively. The composites were prepared from 0.001-in. -diam type 430 stainless steel (SS) fibers (35% density), 0.0005-in. -diam type 430 SS fibers (50% density), 20-micron-diam type 304 SS fibers (15% density), and 0.001-in.-diam Fe-20% Cr-10% Al alloy fibers 15% density). The strength properties increased rapidly with reduction in area and the elongation decreased. Recrystallization (2 hr at 500 C) decreased the strength and increased elongation, but the strength of the composites (recrystallized) increased with prior reduction in area. The interfiber spacings were 0.0040, 0.0026, 0.0025, and 0.0021 in. for the as-impregnated, 30, 60, and 90% reduction in area condition, respectively. The density of the composites increased with the amount of rolling.

74. Koppenaal, T.J. and Parikh, N.M.
FIBER-REINFORCED METALS AND ALLOYS.
Armour Research Foundation, Chicago, Ill.
Bimonthly rept. no. 3, 19 Aug - 18 Oct 61,
26 Oct 61, 7p. Rept no. ARF 2221-3,
(Contract NOw 61-0555-c) ASTIA AD-265 965

Composites containing 5 micron-diam graphite fibers were made with Al, Al-4% Cu, and 50 Co-50 Ni alloy matrices. Al matrix composites made by heating above the mp of Al produced similar yield strengths and ultimate yield strengths less than that of pure Al. The graphite fibers were segregated in layers throughout the specimen. Composites made by sintering the Cu-Ni matrix gave low tensile strengths for the as-composited specimens, but the hot forged and rolled specimens showed higher values. Porosity resulting from sintering reduced the strength, although hot working reduced the porosity.

75. Koppenaal, T.J. and Parikh, N.M.
FIBER-REINFORCED METALS AND ALLOYS.
Armour Research Foundation, Chicago, Ill.
Bimonthly rept. no. 4, 3 Oct - 2 Dec 61,
Rept. no. ARF 2221-4, 28 Dec 61, 4p.
(Contract NOw 61-0555-c) ASTIA AD268 999

A description is given of the preparation and testing of Al-4% Cu matrices reinforced with 5-micron-diameter graphite fibers. The graphite fibers and matrix powders are mixed in a ball mill, thus producing a good mixture of the components. A number of different methods for compositing these materials were investigated. Unsuccessful attempts were made by sintering and hot-pressing. Hot extrusion produced composites significantly stronger than those prepared by simply heating the composites to above the melting point of the matrix. The extrusion temperature varied from 690 to 1100 F.

76. Koppenaal, T. J. and Parikh, N. M.
FIBER-REINFORCED METALS AND ALLOYS.
Armour Research Foundation, Chicago, Ill.
Bimonthly rept. no. 5, 19 Dec 61 - 18 Feb 62,
26 Feb 62, 9p. (Contract NOw 61-0555-c) ASTIA AD-272 858

The mechanical properties of an Al-4% Cu matrix strengthened with type 304 stainless steel fibers (0.001-in. diam) are tabulated. The strength of the matrix was about doubled by the addition of 50 wt-% of fibers. An examination of the microstructure of transverse and longitudinal sections from the 40 wt-% composite failed to show a fiberous structure. The extrusion temperature may have caused the Fe in the 304 fibers to dissolve in the Al matrix. A composite with 40 wt-% type 304 stainless steel fibers (0.0002 in. diam) had an as-extruded yield strength of 36.1 ksi, the ultimate tensile strength was 40.0 ksi. A number of hot-extruded composites were prepared with powdered Al and W fibers (0.001 in. in diameter). The addition of 50 wt-% W fibers nearly tripled the yield strength of pure Al; swaging the as-extruded specimens produced further strengthening. Typical microstructures of the as-extruded 50 wt-% W are presented for transverse and longitudinal sections. Most of the fibers have their longitudinal axes parallel to the longitudinal axis of the composite. Microstructures of the 40 wt-% W composite after swaging to a 60% reduction in area showed the fibers with their longitudinal axes parallel to the longitudinal axis of the specimen.

77. Koppenaal, T. J. and Parikh, N. M.
FIBER-REINFORCED METALS AND ALLOYS.
Armour Research Foundation, Chicago, Ill.
Final rept., 3 Apr 61 - 2 May 62; Rept. no.
ARF 2221-6, 9 May 62, 42p. (Contract NOw
61-0555-c) ASTIA AD-276 620

A fundamental investigation into the deformation mechanism of composite materials by microstraining and slip line observations showed that plastic deformation starts in the weaker matrix and that fibers strengthen the composites by decreasing the available slip length in the matrix. Hence, the main effect of fibers is to increase the rate of work hardening which leads to a higher yield stress. The mechanical properties of several different composites made from fibers of 0.0002 to 0.001 in. in diameter were investigated. Best results were obtained with an aluminum matrix strengthened with 1-mil diameter tungsten fibers; the yield strength nearly tripled with the addition of only 12 volume (50 weight) per cent fibers. Young's modulus also increased with the amount of fibers added. Another attractive set of composites was found with a silver matrix reinforced with type 430 stainless steel fibers, 1 mil in diameter. Attempts were made to reinforce an aluminum, an Al-4% Cu alloy, and a 50% Cu-50% Ni alloy matrix with 0.0002 in. diameter graphite fibers, but the graphite was found to be a relatively poor reinforcing material.

78. Krusos, J.N.
SHEET BERYLLIUM COMPOSITE STRUCTURES.
Aeronca Mfg. Corp., Middletown, Ohio.
Interim technical engineering rept., 1 Oct -
31 Dec 61. ASD TR 7-845, vol. 1, Jan 62,
(Contract AF 33(657)-7151, Proj. 7-845) ASTIA AD-273 596

This program involves design, development of manufacturing processes, testing and evaluation of reinforced ceramic heat shields combined with honeycomb panel load bearing structure. The ceramic heat shield is designed to reject approximately 98% of the incident heat flux by radiation at the surface and is capable of withstanding environments in excess of 3000 F for one hour. The load bearing semi-monocoque structure operates in temperature ranges suitable for stainless steels, super alloys and beryllium. A 90-in. long test section representing a portion of a typical lifting body reentry vehicle will be fabricated and tested.

79. Krusos, J.N.
SHEET BERYLLIUM COMPOSITE STRUCTURES.
Aeronca Mfg. Corp., Middletown, Ohio.
Interim technical documentary progress rept.,
1 Jan - 31 Mar 62, ASD TR 7-845, vol. 2
31 Mar 62. (Contract AF 33(657)-7151, Proj. 7-845)
ASTIA AD 276 815

The program was redirected to meet super-orbital mission loads as the design objective. The design surface temperature of the forebody structure during reentry is retained at 3400 F, and an ablative coating is contemplated to resist extreme heat rates which occur briefly during the super-orbital reentry phase. Materials selections for the structural portions include A-286 and Inconel X honeycomb, A-286, Inconel X and Be facing sheets. Development work is well underway on forming and brazing techniques particularly of Be. Material selections for the heat shield are not final but at present a refinement of the basic 40 lb/cu ft alumina foam is most promising. Composite panels were subjected to the ram-jet exhaust environment.

80. Krusos, J.N., Kjelby, A.S., et al
BERYLLIUM COMPOSITE STRUCTURES.
VOL. II - MATERIALS AND PROCESSES.
Aeronca Mfg Corp, Middletown, Ohio
Final Tech. Engineering Rept., Feb 4, 1960 to
Aug 31, 1961. Rept. ASD TR-61-706, Vo. II,
May 62. (Contract AF 33(616)-7050)

80. (cont'd)
Processes were developed for fabricating beryllium structural shapes to operate in environments encountered by aerospace vehicles during reentry. Beryllium sheet process development work included cutting, chemical milling, forming and brazing of sandwich panels consisting of stainless steel or superalloy honeycomb and beryllium faces. Ceramic heat shields were developed to resist temperatures in excess of 3000° F. The combination of ceramic heat shields and beryllium or superalloy sandwich structure was used to fabricate lightweight insulated components including flat and curved panels, and leading edges. The ceramic materials used in the heat shield were developed under this contract and consisted of lightweight foams alumina, silica and zirconia.

81. Kummer, D. L.
REFRACTORY COMPOSITE INVESTIGATIONS AT
MCDONNELL AIRCRAFT CORPORATION.
McDonnell Aircraft Corp., St. Louis, Mo.
Paper presented at the Fifth Meeting of the
Refractory Composites Working Group, Dallas, Texas,
Aug 8, 1961. (Summarized in DMIC Rept. 167)

Refractory-composite investigations at McDonnell Aircraft have been primarily directed toward hypersonic glid-re-entry-vehicle applications. This involves areas aerodynamically heated to 2500 to 4400 F with relatively long-time exposures and oxidizing conditions. Graphite-zirconium oxide composite nose caps and external thermal insulation for skin panels are discussed.

82. Kyte, R.M. and Pollman, D.
THE EFFECT OF RESIN SYSTEMS ON THE STRENGTH
OF FILAMENT WOUND GLASS FIBER COMPOSITES.
Boeing Airplane Co., Seattle, Wash. American
Rocket Society 15th Annual Meeting, Dec. 5-8, 1960,
Wash. D.C. Preprint ARS 1581-60, 1960.

The increased use of filament-wound glass-fiber components has prompted a number of studies to determine which factors influence their strength. The purpose of this paper is to present the result of one such study. In this study, methods for determining which resin systems are particularly suitable for filament-wound glass-fiber components were investigated; results of these investigations of basic resin properties and glass-filament properties and their effects on the strength of filament-wound composites are presented; methods for correlating the mechanical properties of various resin systems with composite strengths, and design implications are discussed in detail; and a basic plan for continuing studies into the effect of resin systems on the strength of filament-wound glass-fiber composites is outlined.

83. Lauchner, J.H. and Bennett, D.G.
FATIGUE AND INTERNAL STRESS ANALYSIS OF CERAMIC COATED METAL COMPOSITES.
Illinois U. (Urbana). Rept. no. 83; AFOSR TR 58-129. (Contract AF 18(604)28) ASTIA AD-203 494

Ceramic coated metal composites were studied in regard to their behavior under mechanically and thermally induced stresses. Residual coated metal system stresses were measured as a function of temperature and integrated with analysis of thermal shock, static and repeated loadings. Coating metal interfacial structure considerations indicate a saturation of the glassy phase by oxides of the base metal accompanied by the presence of residual strain gradients essentially within the interfacial zone. Theoretical analysis of flat plate coated metal composites was found to be in close agreement with experimental results obtained from annealed coated metal specimens in the absence of viscous or plastic flow. Cobalt bearing vitreous ceramic coatings were observed to fracture when strained approximately 1,000 micro inches per inch in tension of 10,000 micro inches per inch in compression under room conditions and finite straining periods. The maximum induced strain (thermal or mechanical) which cobalt bearing ceramic coatings could withstand without fracture was found to be a function of residual stress.

84. Lauchner, J.H. and Bennett, D.G.
SYNTHESIS OF FIBER REINFORCED INORGANIC LAMINATES. Illinois University, Urbana, Illinois. WADD TR 60-299 Apr 1961, 68p. (Contract AF 33(616)-6283)

Research was done on the matrix phase of glass fiber reinforced inorganic laminates. High temperature strength and stability of low elastic modulus matrix and high modulus fibers were objectives. Matrix glassy bonds, chloride, sulphate, spinel and phosphate bonds were studied with cleavable mineral and inorganic oxide type filler materials. Phosphate bonds, being best, were most studied. Phosphate bonded complex oxide bodies showing $AlPO_4$ and $FePO_4$ phases exhibited elastic moduli of about 0.3×10^6 psi and flexure strength up to 10,000 psi. Some bodies, as tested at 1000° F, deformed inelastically under loads of about 2000 psi. Such bodies were quite dense and moisture resistant but glass fiber protection from their corrosive effect is indicated.

85. Leggett, H., Jaffe, S., et al
DEVELOPMENT OF REFRACTORY COMPOSITE-MATERIALS SYSTEMS FOR SOLID-PROPELLANT ROCKET MOTORS. Hughes Tool Co., Culver City, Calif.
Quarterly progress rept., no. 2, Rept. no. HTC 61-30

85. (cont'd) 20 Jan 61, 68p. (Contract DA 04-495-ORD-3068 Proj. TB4-004. ASTIA AD 324 685

86. Leggett, H., Johnson, R. L. and Blocker, E. W.
DEVELOPMENT AND EVALUATION OF INSULATING TYPE CERAMIC COATINGS. PART II. The Marquardt Corporation, Van Nuys, Calif. WADD TR 59-102, Oct 60, (Contract AF 33(616)-5441)

A metal-reinforced, insulating ceramic coating system has been developed which will successfully withstand temperatures greater than 4000F. The composite is of the gross type and it consists of a chemically bonded zirconia or zirconia chromia phase bonded at low temperatures, reinforced with and anchored to a coated refractory metal. The composite system exhibits low thermal conductivity and excellent thermal-shock resistance. The developed macro-composite utilizes the desirable properties of refractory metallic structures by providing both insulation and oxidation protection. The metallic reinforcement, protected in the same manner, strengthens the ceramic layer and serves to anchor it to the basic metal structure.

87. Leggett, H. and Urode, R. J.
DEVELOPMENT OF REFRACTORY COMPOSITE-MATERIALS SYSTEMS FOR SOLID-PROPELLANT ROCKET MOTORS. Hughes Tool Co., Culver City, Calif. Quarterly progress rept no 3, Rept no HTC-61-46 20 Apr 61, 46p. (WAL TR 766.3/1-2) (Contract DA 04-495-ORD-3068, Proj. TB 4-004) ASTIA AD-269 974

Results of experimental techniques for conversion of graphite surfaces to carbides by vapor deposition of metals from iodide compounds are discussed. An additional method of deposition is described which consists of vaporizing iodine, combining with the metal and passing metal iodide into a deposition chamber where dissociation of the iodide and deposition of the metal occurs upon a pre-selected geometry. Initial fabrication of low-temperature-setting chemically-bonded thorium oxide bodies with apparent porosities of 35 to 60% for application as composite nozzle back-up material was successful.

88. Leggett, H. , R. J. Urode, et al
DEVELOPMENT OF REFRACTORY COMPOSITE MATERIALS SYSTEMS FOR SOLID PROPELLANT ROCKET MOTORS. Hughes Tool Co., Culver City, Calif. Quarterly progress rept. no. 4, Rept. no. 4. Rept. no. HTC 61-78 20 July 61. (WAL TR 766.3/1-3) (Contract DA 04-495-ORD-3068) ASTIA AD-269 975

Difficulties encountered in deposition of metals from metal halide vapor dissociation were primarily caused by the vapor transport system and the difficulty in attaining a leak proof system. Efforts to circumvent and eliminate these difficulties showed extremely promising results. Depositions of Ta showed conclusively that the method is applicable for obtaining fine grained adherent coatings of TaC. The most successful carbide formations by direct union were those of Ta, Mo and V. Excellent coatings of TaC were obtained when thin Mo coatings were used as an intermediate layer. Hard, adherent, M02C coatings were produced at all temperatures above 3400F. Coatings of VC, identified by X-ray diffraction were produced at a temperature of 3400F. The compounding of chemically bonded TH02 and Mo wire-chemically bonded Zr02 composites was shown to be feasible.

89. Levinson, D. W.
FIBER-REINFORCED STRUCTURAL MATERIALS. Illinois Institute of Technology, Armour Research Foundation, Chicago, Illinois. Paper presented at the ASM 1962 Golden Gate Metals Conference, San Francisco, Calif. Feb 17, 1962.

This paper discusses fiber reinforced materials, both organic and inorganic, from the standpoint of the relationship between constitution and properties. Current applications are discussed, and possibilities for future special-purpose and general applications are considered.

90. Levinstein, M. A. and Hall, W. B.
REPORT TO THE REFRACTORY COMPOSITE WORKING GROUP ON GENERAL ELECTRIC ACTIVITIES. General Electric Co., Cincinnati, Ohio. Report presented at theFourth Meeting of Refractory Composite Working Group, Nov 14-17, 1960, Cincinnati, Ohio

90. (cont'd)
From this investigation a 10Cr-Si-Al composition was selected as one of the most promising for use as a coating material for slurry application. The selection of this composition, subsequently termed LB-2, was based on the best combination of (1) ductility of the base columbium alloy after diffusion heat treatment, (2) oxidation protection for 2 hours at 2500 F, (3) ductility of the base columbium alloy after oxidation exposure, (4) oxidation protection under stress, and (5) reproducibility. Properties of plasma-sprayed materials and a System 400 coating are also discussed.

91. Levy, A.V.
Thermal Insulation Ceramic Coatings .
METAL PROGRESS, v. 75, n. 3, p. 86-9,
March 1959

Advanced aircraft and missiles require ceramic coatings to protect metal components in combustion area of engines (gas turbine, etc) that overcome shortcomings of frit type coatings; present state of flame spray unreinforced coatings; method of preparing surface of metal; reinforced ceramic coatings; types and configurations of reinforcing media under investigation; properties of two typical reinforced coatings.

92. Levy, A.V., Leggett, H, and Locke, S.R.
COMPOSITE CERAMIC-METAL SYSTEMS FOR
3000° - 6000° F SERVICE. Paper presented at the
American Rocket Society 15th Annual Meeting,
Washington, D.C., 5-8 December 1960, Preprint
ARS-1572-60.

The advent of the Aerospace Age has presented new and difficult requirements to materials producers that are as much of a revolution in the materials field as is the whole aerospace technology now being generated. The small-quantity demand for materials and unique performance requirements will force the user to create the material as an integral part of a systems program rather than obtain it from the materials producer in a form that is ready to be molded to shape. Probably the foremost example of materials that will follow this path of development and utilization are the composite ceramic-metal systems. The development of a composite material will require the same engineering approach in an aerospace system as do the other aspects of the system such as aerodynamics, heat transfer, structure, controls, etc. It is the purpose of this paper to document this approach in an effort to establish the concept of the user developing specialized material systems for aerospace utilization.

93. Libby, P. A.
PRELIMINARY ANALYSIS OF THE CAPABILITIES OF A COMPOSITE SLAB FOR AN ADVANCED HEAT-SINK DESIGN. Polytech. Inst. Bklyn., Dept. Aero. Eng. & Appl. Mech., PIBAL Rep. 535 (WADD TN-59-424, Pt. II), Jan 1960, 52p.

Analysis of the capability of a composite slab of beryllium oxide (BeO) and beryllium (Be) to absorb the heating associated with the re-entry of a high performance ballistic missile. The trajectory considered corresponds to a ballistic factor (W/C_DA) equal to 2,000 lbs. per sq. ft., a re-entry velocity of 20,000 ft. per sec., and a re-entry angle of 20°. The numerical results indicate that the maximum permissible heat transfer rates for the trajectory are obtained with a relatively thin slab of beryllium oxide. The addition of beryllium to this slab may be required for structural and thermal shock considerations but does not greatly improve the heat-sink capabilities. The permissible values of the heat transfer parameter are applied to a slender cone with a spherical cap of 0.25 ft. nose radius. It is shown that for laminar flow no heat transfer reduction is required on the cone, while for turbulent flow, a reduction to 1/2 is required.

94. Liu, Tien-Shih, and Stowell, E. Z.
PARAMETRIC STUDIES OF METAL FIBER REINFORCED CERAMIC COMPOSITE MATERIALS. Southwest Research Inst., San Antonio, Tex. Final rept. Jan 60 - Jan 61. 26 Jan 61, 73p. (Contract NOa(s) 60-6077-c) ASTIA AD-252 916

The purpose of this program was to conduct a theoretical study of the various parameters which affect the mechanical characteristics of metal fiber reinforced ceramic composite materials. In addition, a survey of properties of potential fiber and matrix materials was made so that promising combinations needing intensive investigation can be defined in specific terms. Certain room temperature mechanical behavior of metal fiber reinforced ceramics (MFRC) were predicted using an inclusion concept and from geometric, elastic, statistical distribution and plastic strength considerations. Certain elevated temperature mechanical behaviors of MFRC were predicted, using a universal visco-elastic concept. A survey of pertinent physical, chemical and mechanical properties was made on refractory metals, metal oxides, carbides, borides, nitrides, silicides, sulfides and single crystal whiskers.

95. Lockwood, P.A.
INVESTIGATIONS OF GLASS FIBER-METAL COMPOSITE MATERIALS. Owens-Corning Fiberglas Corp., Granville, Ohio. Final rept., 15 Mar 55 - 31 Oct 60, 30 Nov 60, 164p. (Contract NOrd-15764) ASTIA AD-274 530L

No abstract.

96. Long, J. V.
REFRACTORY COMPOSITE DEVELOPMENT AT SOLAR AIRCRAFT COMPANY. Solar Aircraft Co., San Diego, Calif. Paper presented at the Fourth Meeting of Refractory Composites Working Group, Nov 14-17, 1960, Cincinnati, Ohio

Strength and thermal conductivity are important properties studied. Solar has also continued the study and developments of plasma-arc-sprayed materials.

97. Long, R.A.
NARMCO ACTIVITIES IN THE FIELD OF REFRACTORY COMPOSITES. Narmco Industries, Inc., San Diego, Calif. Paper presented at the Fourth Meeting of Refractory Composites Working Group, November 14-17, 1960, Cincinnati, Ohio

This project deals with the bonding of thick AGT graphite to 60 mil thick tungsten sheet. The second project is based on the use of ceramic glass bond adhesives for bonding the refractory metals together for service temperatures up to 3000F. No refractory metal bonding experiments have been attempted.

98. Long, R.A.
NARMCO ACTIVITIES IN THE FIELD OF RE-FRACTORY COMPOSITES. Narmco Industries, Inc., San Diego, Calif. Paper presented at the Fifth Refractory Composites Working Group Meeting, Dallas, Texas, August 10, 1961. (Summarized in DMIC Rept. 167)

98. (cont'd)
The Narmco Refractories Research Department is continuing the investigations described in last year's meeting with two programs dealing with the bonding of tungsten sheet metal to graphite and the coating and bonding of ceramic glasses to refractory metals. The work conducted under these programs is discussed.

99. Luirette, A. J.
THE PROPERTIES OF COMPRESSION MOLDED
GLASS FLAKE REINFORCED RESIN COMPOSITES.
Narmco Industries, Inc., San Diego, Calif.
Rept. for 1 Apr 60-1 June 61, on Molded Glass
Flake Reinforced Composites. 1 June 61.
(ASD TR 61-300) (Contract AF 33(616)7195,
Proj. 7381) ASTIA AD-265 885

Four molding compositions using glass flake as reinforcement were selected for study by means of a series of screening tests. The physical, electrical and mechanical properties of the compositions after compression molding into flat laminates were determined. Simple geometric shapes such as a hemisphere were compression molded from these compositions. The properties of the simple shapes were compared to the properties of the flat laminates. Movement of the resin-flake mixutre in the molds resulted in very poor alignment of the flakes within the molding resulting in significantly reduced mechanical properties. It was concluded that this problem is inherent to presently available glass flake reinforced molding compounds and will prohibit the satisfactory compression molding of everything but extremely simple shapes such as flat plates using available molding compounds and molding techniques.

100. Lund, J. A., Krantz, T, and Mackiw, V. N.
Composite Powders. PRECISION METAL MOLDING
v. 18 n 10, 11 Oct 60, p. 56-8, Nov p 56-8.

Study of several nickel coated metal powders compositions and particle size distributions of elemental powders used in mixtures and as core particles for composite powders; data for prepared composites and mixtures; studies of segregation in compacts; progress of alloying and sintering in Ni-Cu, Ni-Mo and Ni-Cr compacts heated for various times is indicated.

101. McDaniels, D. L., et al
Preliminary studies of fiber reinforced metallic
composites. METALS PROGRESS, v 78, n 6, 118-121
Dec. 1960.

101 (cont'd)
Composites made up of tungsten wires in a copper matrix indicate that their strengths are directly proportional to the volume percentages and tensile strengths of the tungsten wires.

102. McGee, S. W.
AN INVESTIGATION OF METAL-CERAMIC COMPOSITES FOR HIGH-TEMPERATURE APPLICATIONS. Armour Research Foundation, Chicago, Ill. Monthly progress rept. no. 3, 1 - 30 June 59, Rept. No. ARF 2175-3 , 13 July 59. (Contract DA 11-022-505-ORD-3038) ASTIA AD-219 531

Three metal-ceramic compositions, having thermal expansions ratios less than, approximately equal to, and greater than unity, were selected for conical interface shear testing.

103. McGee, S. W., Read, R. H., and Tully, T. S.
AN INVESTIGATION OF METAL-CERAMIC COMPOSITES FOR HIGH-TEMPERATURE APPLICATIONS. Armour Research Foundation, Chicago, Ill. Monthly progress rept. no. 1, 14-30 Apr 59. Rept. no. ARF 2175-1 15 May 59, 6p. (Contract DA 11-022-505-ORD-3038) ASTIA AD-217 445

Ceramic and metallic materials were selected on the basis of high melting temperatures, high temperature strength, and availability. Experiments in which structural parameters for metal fiber-ceramic composite materials are to be evaluated include (1) evaluation of bonding strengths for binary combinations; (2) variation of materials to evaluate the effect of component physical properties upon composite properties, and correlation of the properties of the components with the properties of the resulting composites; (3) evaluation of known induced internal stresses upon composite properties; (4) measurement of known induced thermal stresses; and (5) differential temperature gap experiments (isothermal annealing at several temperatures) to evaluate the effect of changing the thermally induced stress. A conical interface shear test method is presented for the determination of the shear strength of bonded metal-ceramic configurations. A metal cone is embedded in one flat face of a right cylindrical ceramic block, and the configuration is hot-pressed to produce bonding between the metal and ceramic. The induced thermal shear stress acting at the conical metal-ceramic interface is expressed as a function of the cone angle. This combines vectorially with the shear stress applied in torsion to cause rupture.

104. McKinney, C.D., and Tarpley, W.B.
AEROSOL PREPARATION OF COMPOSITE METAL POWDERS FOR DISPERSION STRENGTHENING. Aeroprojects, Incorporated, West Chester, Pa. Report RR-61-30, March 1961. AD 257716, (Contract NOas 59-6247-C)

The feasibility of utilizing aerosolization apparatus for preparing composite metal powders of value in the preparation of high temperature dispersion-strengthened metals was demonstrated in the nickel-alumina, nickel-chromic oxide, and tantalum-alumina systems. The aerosolization apparatus produces, from bulk powders, individually dispersed particulate clouds which at the instant of separation are individually coated with the composite-forming shell material. Refractory coatings have been dispersed on micron-sized preformed metal particles in order to provide materials analogous to the starting powders of the SAP process. Preformed submicron refractory particles acting as deposition nuclei have also been coated with metal shells by gas-phase chemical reaction of a volatile metal compound. After extrusion, chromic oxide particles dispersed in nickel had a mean free path of 0.5 micron. Tantalum with dispersed submicron alumina showed a mean free path of 1 micron. Judging by electron microscopic criteria, these metals should have superior high-temperature properties in fabricated shapes to the limit of stability of the dispersed phase and possibly to 0.9 of the homologous temperature.

105. Machlin, E.S.
NON-METALLIC FIBROUS REINFORCED METAL COMPOSITES. Materials Research Corp., Yonkers, N. Y. Status rept. Sept 61, 243p. (Contract Now 61-0209-c) ASTIA AD-265 943

The literature on fibers and fiber reinforced composites was reviewed and evaluated. It was concluded that, in principle, non-metallic fiber reinforced metals can have the largest strength/weight and modulus/weight ratios of all known materials, exceeding the values of those presently available by many factors, particularly at elevated temperatures. In practice, realization of the potential has been frustrated by two factors (1) thermal degradation of fiber strengths; and (2) inadequate fabrication procedures. The inadequacies of fabrication techniques employed to date were considered in detail and the requirements for an adequate fabrication technique are listed.

106. Maloof, S. R.
DEVELOPMENT OF ULTRA-HIGH TEMPERATURE TUNGSTEN-BASE COMPOSITES FOR ROCKET NOZZLE APPLICATIONS. Avco Corp., Wilmington, Mass. American Rocket Society 15th Annual Meeting, Dec. 5-8, 1960, Wash. D.C., Preprint ARS 1573-60, 1960.

Tungsten-base composites have been developed which are capable of operating at gas temperatures above the melting point of pure tungsten. Lowering of the surface temperature of the composite, compared to pure tungsten, is due to the melting and vaporization of the second phase in the composite. Theoretical and experimental evidence is presented in support of these predictions. Furthermore, these composites are more easily fabricated and machined into rocket-nozzle inserts and are more resistant to thermal and mechanical shock than pressed and sintered tungsten.

107. Masterson, J. F.
Chromium composites - a new high-temperature material. SAE JOURNAL, v. 70, n. 6, p. 31-33, June 1962.

Discusses the dispersing of fine particles of metal oxide 'impurities' throughout the matrix of chromium, developing a family of chromium composite alloys suitable for application in the 2000-3000° F range.

108. Maziliauskas, S.
Developments in ceramic-metal compositions. CERAM. AGE, v. 75 n. 3, p. 40-1, March 1960

Variations in processing of cermets, which may be either metal modified ceramics or ceramic modified metals; one new forming technique involves flame spraying of thin ceramic type coating on metal; second involves alternate spray coatings of molten metals and ceramics on rapidly rotating disk prior to crushing composite layers together; information on conventional forming methods, low temperature and hot pressing, organic binders, filter type compounds, infiltration of metals or alloys into ceramic.

109. Micks, W. R.
COMPOSITE MATERIALS-CONSIDERATIONS FOR FUTURE RESEARCH. Institute of the Aerospace Sciences National Summer Meeting, June 19-22, 1962, Los Angeles, Calif. Preprint IAS 62-167, 1962.

In the interest of creating a better overall balance in research on composite materials, the greatest current need is for programs whose primary goals are enhancing basic understanding of composites and developing analytical models for use in predicting behavior. The design of experimental programs for research in high strength composite materials should consider the behavior of matrix and filament along with the mechanisms of their deformation and failure. While gains have been made by the empirical approach, future achievements may depend on a better understanding of macroscopic "weakness" and its cause in light of atomic "strength." The research goal for experimental development of a composite material should encompass the study of behavior mechanisms to ensure the maximum amount of information from each test.

110. Aerospace Materials and Process Engineers.
_IN_ NATIONAL SYMPOSIUM ON CERAMICS AND COMPOSITES, COATINGS AND SOLID BODIES, HELD IN DAYTON° OHIO, Nov. 14-15, 1961, Society of the Aerospace Materials and Process Engineers.

The following papers were presented: Protective coatings for molybdenum; Protective coatings for columbium; Reinforced refractory coatings; The design of a spray flame coating; Graphites and their properties; Processing and properties of pyrolytic graphite coatings; Pyrolytic deposition of materials; Processing and properties of ceramics for radomes; Metal-ceramic composites as engineering materials.

111. New ceramic-metal composites.
MATERIALS PROTECTION, p. 80-81, April 1962

Nucerite is a family of ceramic-metal composites, each composite consisting of a specifically formulated ceramic component chemically bonded to a structural base metal.

112. Otto, W.H., Duft, B., and Dharmarajan, S.
POTENTIAL OF FILAMENT WOUND COMPOSITES.
Narmco Industries, Inc., San Diego, Calif.
June 61, 6p. (Contract NOw-61-0623-c) ASTIA AD-259 544

Expressions are derived for computing stresses at the interlamination. These are based on certain simplifying assumptions regarding the elastic constants for a laminate made up of two laminations, oriented at different angles with respect to the principal axis of the laminate.

113. Paprocki, S.J., Hodge, E.S., and Gripshover, P.J.
GAS-PRESSURE BONDING, Defense Metals Information Center, Battelle Memorial Inst., Columbus, Ohio. DMIC rept. no. 159 ,43p., 25 Sep 61.
(Contract AF 33(616)-7747) ASTIA AD-265 133

Solid-state bonding by the gas-pressure-bonding process employs a gas at high pressure and elevated temperature in order to fabricate metallic or ceramic materials. The process has been used to produce metallurgical bonds between similar and dissimilar metals, ceramics, and cermet materials. It appears to be ideal for fabricating brittle materials of widely differing properties. Consolidation of metallic and ceramic powders to densities approaching theoretical is readily accomplished by gas-pressure bonding at temperatures well below those normally required in sintering operations, and the resulting grain growth is held to a minimum. Numerous configurations have been fabricated from Be and Nb by the gas-pressure-bonding process. Examples are cited of typical nuclear fuel elements and various structural components of interest for aircraft and missile application.

114. Parikh, N.M., and Fisher, J. I.
AN INVESTIGATION OF METAL-CERAMIC COMPOSITES FOR HIGH-TEMPERATURE APPLICATIONS. Armour Research Foundation, Chicago, Ill. Final rept. 14 Apr 59-14, Apr 60, Rept. no. ARF 2175-12 ,18 May 60. (Contract DA 11-022-505-ORD-3038, Proj. TB4-004) ASTIA AD-238 137

Fiber metal reinforced-ceramic materials were investigated to determine the nature and strength of the bond between metal and ceramics, and the residual thermal stresses resulting from hot pressing. Conical interface shear tests showed that, in vacuo, there is no chemical or diffusion bond formed between Al_2O_3 and any of the refractory metals (W, Ta, or Mo) at any temperatures. In the case of Ni-TiC system, there was no bond formation below the eutectic temperature. Above the eutectic temperature the molten metal wets the carbide and the bond is stronger than the carbide at the density to which the carbide was consolidated. These conic interface shear tests indicate that, reinforcement of the ceramic oxides by metal fibers is primarily due to mechanical interlocking. The study of metal fiber-ceramic systems demonstrated the marked dependence of a variety of properties and measurements (electrical conductivity, thermal expansivity, amount of residual stress, and strength) on the orientation of the test specimen with respect to the pressing direction. The most improved property of a ceramic occasioned by metal fiber reinforcement was thermal shock resistance. Reinforced specimens could not be harmed by severe thermal shocks(e.g., from 1500° C) regardless of the orientation of the specimen with respect to the pressing direction, although unreinforced specimens shattered under the same test conditions.

115. Parikh, N.M., Fisher, J.I., and Rostoker, W.
FIBER REINFORCED METALS AND ALLOYS.
Armour Research Foundation, Chicago, Ill.
Bi-monthly rept. no. 1, 19 Feb - 18 Apr 60,
17 May 60, 4p. ARF rept. no. 2193-1
(Contract NOa(s) 60-6081-c) ASTIA AD-238 510

The experimental program of this project is subdivided into 3 distinct stages: (1) the preparation of fiber reinforced composite samples and selection of the method of preparation which yields samples of uniform density, (2) the measurement of various mechanical and electrical properties of the composites, and (3) the formulation of general rules that govern the nature of reinforcement of metals by fibers. The mild steel-silver system appears to be most suitable in that the components are mutually insoluble and do not form any compounds. Also, fibers of low-carbon steel are commercially available in a broad range of diameters. Another system which will be simultaneously investigated is magnesium reinforced with steel fibers. Prior to the measurement of any of the properties of the composites, a series of measurements are being made on the fiber metal component; these are electrical conductivity measurements on steel wires at various temperatures, resistance of the bond formed by sintering wires together, and elastic properties of the wires. These measurements will provide the necessary data for correlation with the composite properties.

116. Parikh, N.M. and Fisher, J.I.
FIBER REINFORCED METALS AND ALLOYS.
Armour Research Foundation, Chicago, Ill.
Bimonthly rept. no. 2, 19 Apr - 18 June 60,
Rept. no. ARF 2193-2 , 13 July 60.
(Contract NOa(s) 60-6081-c) ASTIA AD-240 395

116. (cont'd)
Steel-silver composites were prepared by infiltrating compressed steel fiber felts 2 in. high by 2 in. in diameter with molten Ag in vacuo at 1100° C for 1 hr. Half of the felts were sintered in H at 2100° F and the other half were not sintered. Test pieces, 2 x 0.135 x 0.125 in., were machined both perpendicular to the axis (x-direction) and axially (y-direction) for determining density, resistivity, elastic modulus, yield strength, elongation, ultimate tensile strength, and Poisson's ratio. The resistivity of samples cut from the y-direction was low and independent of composition. The resistivity of samples cut from the X-direction was proportional to the composition and independent of the initial condition of the felt, sintered or unsintered. The yield strength of the x-direction specimens was independent of the use of sintered or unsintered felts, but the ultimate tensile strengths of composites with unsintered felts were much greater than those with sintered felts. Samples cut from the x-direction had much greater yield and ultimate tensile strengths than those cut from the y-direction. The sintered felts showed much greater fiber-to-fiber contact than the unsintered felts. The Poisson's ratio and elastic moduli were independent of composition and were very close to the values for pure Ag.

117. Parikh, N.M. and Fisher, J.I.
FIBER-REINFORCED METALS AND ALLOYS.
Armour Research Foundation of Illinois Institute of Technology., Chicago, Illinois. Third Bimonthly Report, September 12, 1960, (Contract No. NOas 60-6081-C) ASTIA AD 246023

The purpose of the program is to investigate the basic criteria concerning the reinforcement of metals by a continuous three-dimensional network of metal fibers.

118. Parikh, N.M. and Fisher, J.I.
FIBER-REINFORCED METALS AND ALLOYS.
Armour Research Foundation, Chicago, Ill.
Bimonthly rept. no. 5, 19 Oct - 18 Dec 60,
(Rept. no. ARF 2193-5) 13 Jan 61, 7p.
(Contract NOa(s) 60-6081-c) ASTIA AD-253 022

No appreciable strength increase was obtained by heat treating and quenching from 1700F of Ag reinforced with type 430 stainless steel fibers. Heat-treated samples of Ag reinforced with 17-4 PH fibers were less ductile than the as-impregnated samples. The elastic moduli of all the composites were much lower than those calculated by assuming an additive relationship.

119. Parikh, N. M.
FIBER-REINFORCED METALS AND ALLOYS
Armour Research Foundation, Chicago, Ill.
Final rept. 19 Feb 60 - 18 Feb 61, (Rept. no. ARF 2193-6), 22 Mar 61, 43p.
(Contract NOa(s) 60-6081-c) ASTIA AD-255 992

Fiber felts prepared from short, kinked metal fibers were impregnated with weaker metals. The average concentrations of fibers in matrix metal were 10 to 50 vol-%. It was found that the felting operation itself markedly influenced the mechanical properties of the composites. The fiber diameter also had distinct effects on the degree of reinforcement. In all cases the strength of the composites are directly related to the interfiber spacings and, until some critical value of this parameter is reached, there is very little reinforcement of the matrix by fibers. The incorporation of brittle fibers in a ductile matrix generally results in decrease in elongation and notch-toughness. The experimentally measured elastic moduli compare favorably with values predicted from the theory of elasticity. The degree of reinforcement of matrix by fibers of identical lengths and diameters depends upon the nature of the fibers.

120. Pearl, H. A., Nowak, J. M., and Conti, J. C.
REFRACTORY INORGANIC MATERIALS FOR STRUCTURAL APPLICATIONS. PART II.
Bell Aircraft Corp., Buffalo. Report WADC TR 59-432, July 60, (Contract AF 33(616)5930)

The object of the second year's work, Part II, is to develop techniques for fabricating flat, simple, and complex curvature ceramic honeycomb panels, each measuring at least 1 square foot. The detailed generalized objectives were: (1) To establish areas where ceramic and refractory inorganic materials might be used in advanced weapon systems; (2) To select geometric shapes representing advanced-weapon-system applications; (3) To fabricate geometric shapes using the basic techniques developed in the first year's work; (4) To evaluate the fabrication methods by determining selected properties on test specimens. Limited exploratory examinations were to be preformed on techniques for fabricating other sandwich constructions, reinforced, and composite solid ceramics. A process was developed for making both small and large, simple and complex curvature geometric shapes from honeycomb ceramic sandwich constructions.

121. Peterson, G. P.
OPTIMUM FILAMENT WOUND COMPOSITES.
Nonmetallic Materials Lab., Wright Air Development Div., Wright-Patterson AFB, Ohio. (WADD TN 61-50), June 61, 7p.
ASTIA AD-264 178

121. (cont'd)
A review of the present Air Force program to obtain optimum filament wound composites is presented. The basic philosophy involves research in four major areas; (1) reinforcement and finishes, (2) matrix materials, (3) winding patterns, and (4) fabrication and processing techniques. The latter two are directly related to filament winding and are treated as an integral unit in this review.

122. Peterson, G. P.
HIGH MODULUS GLASS FIBERS FOR REINFORCED PLASTICS. Dayton U. Research Inst., Ohio. Rept. on nonmetallic and composite materials., Sep 61, 80p. (WADD TR 60-735). (Contract AF 33(616)-5500, Proj. 7340) ASTIA AD-268 902

Contents: Properties of high-modulus reinforced plastics, by George P. Peterson; High-modulus glass fibers for structural plastics, by Ralph L. Tiede; Processing and fabrication techniques for reinforcing plastics with YM-31A fibrous glass, by Allan B. Isham; Structural efficiency of sandwich as affected by elastic modulus and weight of facing, by E. W. Luenzi; Safety precautions for handling and fabrication of high-modulus glass fibers for structural plastics, by L. J. Schafer and L. H. Miller; Potential uses of high-modulus glass fibers, by P. Dayton; Marketing and availability of high-modulus glass fibers, by W. M. Keller.

123. Plant, H. T., Girard, R. T., and Wisely, H. R.
Fiber-Reinforced Ceramics. MATERIALS IN DESIGN ENG. v. 53, p. 14-16, April 1961.

An inorganic materials system based on aluminum phosphate and fused silica fibers has the physical and electrical properties of reinforced plastics and can be processed by low pressure, low temperature techniques similar to those used for reinforced plastics.

124. Plant, H. T. and Jordan, T. J.
NON-METALLIC FIBER REINFORCED CERAMICS. General Electric, Engrg. Lab. Paper presented at the Fall Meeting, Society of Aircraft Materials and Process Engineers, 17 Nov 1959

The Bureau of Aeronautics, Department of the Navy, aware of the oncoming need for high-temperature dielectric materials for radome applications authorized the General Engineering Laboratory of the General Electric Company to undertake a two-year investigative program to study and develop an inorganic-fiber-reinforced, ceramic system. In addition to specifying that the physical and electrical properties of such a system be essentially equivalent to a glass-fiber-reinforced plastic after exposure to 1000 F, a request was included that the material system developed be of such nature that it could be processed by techniques essentially similar to those presently used by the reinforced plastics industry. This then was the author's motive in undertaking this project. At the start of this work, it was decided that a major emphasis should be placed upon the ascertaining and understanding of the various parameters and interactions which are involved in a fiber-reinforced ceramic, so as to establish a bench mark from which progress might be measured. This study with its radome oriented requirements was limited to nonmetallic fiberous reinforcements. With respect to potential binder systems, two basic approaches were undertaken, the first based upon the use of glassy-phased binders or sintered crystalline binders using hot-pressing techniques. The second was the use of a ceramic cement obtained by solution reaction at elevated temperatures.

125. Plant, H. T. and Jordan, T. J.
NON-METALLIC FIBER REINFORCED
CERAMIC LAMINATES. Paper presented at
the Society of Aircraft Materials and Process
Engineers Filament Winding Conference, March
28-30, 1961, Pasadena, Calif.

This paper outlines the investigations carried out to develop readily-processed fiber-reinforced ceramic compositions for operation at 1000F. As a result of this work, a silica filament-reinforced aluminum-phosphate system has been developed which has good physical and electrical properties at temperatures in excess of 1000F.

126. PLASTIC MATERIAL, GLASS FIBER BASE,
FILAMENT WOUND. General Motors Corporation, Allison Division, Military Specification
MIL-P-27327, Sep 1961.

This specification covers the requirements for three types of glass-fiber base filament-wound composites to be used for structural parts and other applications.

127. Poulos, N. E., Murphy, C. A., et al
FUSED SILICA ROCKET NOZZLES.
Georgia Inst. of Tech. Engineering Experiment Station, Atlanta. Final summary rept, 1 Sep 60 31 Aug 61, 31 Aug 61, 94p. (Contract NOrd-18564)
ASTIA AD-265 856

Plasma arc sprayed refractory coatings for rocket nozzle throats were evaluated. Apparatus and techniques were developed for arc-spraying. The spraying parameters investigated included powder particle size, moisture content, method of powder feed for uniform rate of feed, stand-off distance, and substrate temperature and preheating. Stresses set up by thermal expansion characteristics of the refractory coating materials were found to limit the size and shape which could be coated satisfactorily. Graphite was the most satisfactory material for the entrance and exit cones, with attention then directed to the evaluation of materials for arc-sprayed coatings on the throat insert where maximum heat and erosion effects are encountered. Investigations were carried out with nozzle throat insert coatings of Cr2C4, A1203, W, HfC, Hf02, and a composite coating of W and Zf02. The composite coating of W-Zr02 was found to give a uniform coating with a composition in close agreement with the composition desired and controlled by the feed rates of the 2 separate powders.

128. Process makes better cermets at lower cost.
STEEL v. 144, n. 4, p. 84, Jan 26, 1957

Electrophoretic deposition process developed by Vitro Corp. of America, New York, features deposition and bonding of refractory metal or ceramic coatings on metal body in graded layers; part to be coated becomes one of two electrodes immersed in suspension of charged particles which adhere to it while within electrostatic field; deposits are uniform in composition and thickness even on irregular shapes.

129. Raynes, B. C.
STUDIES OF THE REINFORCEMENT OF METALS WITH ULTRA HIGH STRENGTH FIBERS (WHISKERS).
Bimonthly engineering prog rept no 2, 21 Jan - 24 Mar 61, 31 Mar 61, 11p. (Contract NOw 61-0207-c) ASTIA AD-254 778

Studies of the reinforcement of metals with ultra high strength fibers (whiskers), continued with the preparation of high strength alumina fibers. A practical means for incorporation of these alumina fibers into metal matrices was developed. This method involves the dispersion of alumina fibers; the pre-wetting of these fibers with a metal alloy by a brazing technique; the thorough mixing of the fibers with powdered metal comprising the matrix material; the extrusion of this mixture with a minimum of organic binder and with an area reduction sufficient to insure fiber alignment within the extruded piece; sintering of the extrusion to appropriate density; and metal working thereafter to a finished part.

130. Raynes, B. C.
STUDIES OF THE REINFORCEMENT OF METALS WITH ULTRA HIGH STRENGTH FIBERS (WHISKERS).
Horizons, Inc., Cleveland, Ohio. Bimonthly engineering progress rept no. 3, 24 Mar - 31 May 61; 5 June 61, 8p. (Contract NOw-61-0207-c) ASTIA AD-259 767

In studies of the reinforcement of high temperature metals and alloys with ultra high strength fibers (whiskers), the problem of developing a useful bond between the whisker and the metal matrix was the subject of primary concern. A procedure for incorporation of the fibers into the matrix has been developed. However, no significant improvements in tensile strengths have been observed in composites, indicating that the bond between the matrix and the reinforcing whisker is not transmitting the applied stress to the very much stronger fiber. Metallographic examination of the composites also reveals that no bond is being obtained. Means for improving the metal-to-fiber bond are now being studied.

131. Raynes, B. C.
STUDIES OF THE REINFORCEMENT OF METALS WITH ULTRA HIGH STRENGTH FIBERS (WHISKERS).
Bimonthly engineering progress rept no. 4, 1 June - 31 July 61, 2 Aug 61, 10p. (Contract NOw 61-0207-c) ASTIA AD-261 528

Effort was directed toward developing a useful bond between the metal matrix and the whisker in a composite. Among several approaches being taken, an examination of certain high temperature brazing alloys was begun. A simplified means for obtaining elevated temperature tensile strengths of wires and small diameter bars is being worked out.

132. Raynes, B. C.
STUDIES OF THE REINFORCEMENT OF METALS WITH ULTRA HIGH STRENGTH FIBERS (WHISKERS).
Horizons, Inc., Cleveland, Ohio. Final rept. 28 Oct 60 - 27 Aug 61, 27 Nov 61. (Contract NOw 61-0207-c) ASTIA AD-267 891

132. (cont'd)
The feasibility of reinforcing Nichrome or other high temperature alloys with high strength A1203 fibers (whiskers) was examined experimentally. The primary problems were the development of a strong bond between the metal matrix and the fibrous non-metallic reinforcing phases, and the development of a method to produce dense composites useful ultimately as structural shapes in which the reinforcing fibers are oriented with respect to stress. An extrusion process for producing such composites with oriented structures was developed. The process can be utilized in commercial practice at an anticipated reasonable cost for production of wire, sheet, bar, and uniform cross section of rod stock. Heat treatment in air of a composite containing excess Cr metal resulted in the most significant findings with respect to bond development and a survey. An A1203-Cr203 Nichrome bond producing useful strength was formed at least in part.

133. Raynes, B. C., and Kelsey, R.H.
STUDIES OF THE REINFORCEMENT OF METALS
WITH ULTRA HIGH STRENGTH FIBERS (WHISKERS).
Interim Report 1, 28 Apr 61 - 21 Jan 62, Jan 29, 62, 20p.
(Contract NOw-62-0235-c)

Emphasis was placed on developing a bond between the metal matrix and the reinforcing alumina whiskers. The extrusion-sintering composite preparation technique developed in the first portion of this work has been adopted as a standard approach. The phenomenon of reinforcement requires extremely precise control of the processes of diffusion in order to produce a chemical bond between the ceramic fiber and the metal matrix. Active agents which accomplish this bonding have been chosen which are expected to remain in a fluid state in order that these diffusion processes will be made more uniform. Halides of various metals either present in the original metal alloy or deliberately added are under study. Reinforcement of a Nichrome V alloy, consisting of an increase of almost 50 percent in measured tensile strength on a cold-worked composite, has been achieved in this present program. Cold-worked Nichrome, prepared by the extrusion-sintering process, usually exhibits a room temperature tensile strength of about 210,000 psi; the composite specimen, reinforced overall with only 2-1/2 percent by weight of alumina whiskers, showed room temperature tensile strength of just over 300,000 psi.

134. Raynes, B. C., and Kelsey, R. H.
STUDIES OF THE REINFORCEMENT OF METALS
WITH ULTRA HIGH STRENGTH FIBERS (WHISKERS).
Horizons, Inc., Cleveland, Ohio. Interim rept. no. 2,
21 Jan - 31 Mar 62, 23 Apr 62, 15p. (Contract
NOw 62-0235-c) ASTIA AD-275 341

134. (cont'd)

In a project dealing with the reinforcement of high-temperature metals with high-strength fibers, the main emphasis was on the refinement of techniques for mixing, extruding and sintering 80/20 Ni-Cr alloy with CaC12 to produce composites with more reliable and consistent tensile strengths. Marked reinforcement of the alloy occurred with A1203 whiskers, using CaC12 as a wetting agent. Vacuum treatment of the raw mix did not reduce the variability significantly. A double sintering process yielded reliable tensile strength data, but the parameter which causes variability in softening points was not found.

135. Read, R. H., et al
Fiber metallurgy. PRECISION METAL MOLDING,
v. 16, p. 25-6, 53, 58, April 1958.

Includes information on fiber metal base composite materials.

136. Reeder, R. G.
GLASS FIBER REINFORCED PLASTICS FOR XQ-10
DEVELOPMENT PROGRAM. Northrop Corporation,
Radioplane Division, AMC Technical Report No.
59-7-263, Oct 12 53 - Mar 1 59. (Contract
AF 33(600)-25933) AD 156073

The purpose of this final report is to combine and present the findings of all previously submitted material pertinent to the plastic-target-drone project, Air Force Contract No. 33(600)-25933. The main objective of the plastic-drone project was to prove the feasibility and desirability of glass-fiber-reinforced plastic laminates in airframe structures. The XQ-10 version of the OQ-19 target drone was chosen as the demonstration medium. This report presents the finalization of all engineering, production services, materials, and processes that were utilized in this program. An additional objective was to determine the extent that glass-fiber-reinforced plastics could be used or substituted for aluminum in a target drone without impairing flight performance. The results of the program proved that it was feasible and practical to design and fabricate airframe structural (load carrying) components out of glass-reinforced plastics. Flight tests indicated that the final design tested of the XQ-10 was proven satisfactory and superior to the metal OQ-19D counterpart. The production prototype was especially adaptable to rough usage and simple repair important for field use. The XQ-10 was considered to be producible economically in large quantities. The simple fabrication methods would provide low man-hours per unit, and low material and tooling costs.

137. Roberts, D. A.
REVIEW OF RECENT DEVELOPMENTS IN THE TECHNOLOGY OF NICKEL-BASE AND COBALT-BASE ALLOYS. Defense Metals Information Center, Battelle Memorial Inst., Columbus, Ohio. Rept. 1 May - 31 July 61, 4 Aug 61, 4p. (DMIC memo. no. 122). ASTIA AD-261-292

A practical method for incorporating ultrahigh-strength fibers (Al whiskers) into metal matrices was developed. Fibers, pre-wetted with an alloy by a brazing technique are mixed with metal powders, extruded, sintered and worked into finished parts.

138. Rolston, J. A.
LITERATURE SURVEY ON FILAMENT-WOUND COMPOSITE STRUCTURES, Directorate of Materials and Processes, Aeronautical Systems Division, Wright-Patterson Air Force Base, Ohio. Sept. 1961, 24p. (ASD TR 61-215)

Filament Winding is the newest phase in the state-of-the-art of structural reinforced plastics. This report brings together abstracts of existing literature relating to filament winding.

139. Rudiger, O., Stickforth, J., and Lohrke, G.
Boral as protective material against thermal neutrons, TECHNISCHE MITTEILUNGEN KRUPP, v. 19, Nov 1961, p. 154-172, (IN GERMAN)

Technology of "Boral," an Al sheet clad with an alloy consisting of a suspension of B_4C in an Al matrix. Manufacture by the alloy in ingot or powder form, to the Al sheet. Data are given for physical properties, neutron absorption, mechanical properties and microstructure.

140. Sabanas, M.
Metal fiber composites. PRODUCT ENGINEERING, v. 31, n. 22, May 30, 1960, p 57-61.

140. (cont'd)
A good static seal material for high-temperature, high-pressure service requires an unusual array of properties. Along with resilience, compressibility under moderate load, and recovery upon load release, such a material must offer zero porosity when compressed, and resistance to the latest industrial fluids. At 1000F and above, metallic composites are the only materials that have these properties. Here are latest data on this new series of hybrids--hard metal-fiber felts impregnated with soft metals or polymers.

141. Sabanas, M.
COMPOSITE INORGANIC RESILIENT SEAL MATERIALS, Armour Research Foundation, Chicago, Ill. Rept on Non-Metallic and composite materials, May 58 - May 59, Oct 59, 87p. (Contract AF 33(616)-5793) (WADC TN 59-338, vol. 1), ASTIA AD-231 003.

Research was conducted on essentially inorganic seal materials exhibiting the desirable characteristics common to elastomers combined with temperature and fluid resistance to at least 1000° F. Materials exhibiting this behavior are a prerequisite to the design concept of power transmission systems for future flight vehicles. Experimental screening tests were performed on composite refractory materials to provide leads for new materials for ultimate static and dynamic seal applications. Of the numerous refractory material composites tested, the graphite and molybdenum disulfide combination approached the target objectives, but were rapidly oxidized in an air atmosphere at 1000° F. Materials consisting of stainless steel and molybdenum fibers made into a bonded skelton of the desired shape and impregnated with various soft ductile phases, were fabricated and their properties studied. The properties of these composites differ from the base metals from which they are made, since the geometrical configuration imparts an elastomeric like behavior to the composite. A longer period of research would be required for further experimental study to explore all the possibilities that these new composite materials offer.

142. Sabanas, M.
COMPOSITE INORGANIC RESILIENT SEAL MATERIALS, Armour Research Foundation, Chicago, Ill. Rept. for Dec 58 - Dec 59 on non-metallic and composite materials, Apr 60, 34p. (WADC TR 59-338, vol. 2) (Contract AF 33(616)-5793) ASTIA AD-238 020

142. (cont'd)
The principal objective of this research program is to investigate and develop new concepts for novel and unconventional material combinations which would have resilience, recovery, strength, and chemical resistance at temperatures up to 1000° F. Major emphasis was given to configurations that would enable these materials to be used as static and dynamic reciprocating shaft seals. Composite material combinations consisting of stainless steel and molybdenum fibers impregnated with tin, indium, magnesium, silver, and polymeric materials were produced. Composites made of molybdenum fibers impregnated with silver were evaluated as static seals and showed good ability to seal air heated to 1000° F and retained pulsating pressures from zero to 5000 psi. The relationship between the fiber structure, impregnant, and final composite were studied. Impregnation techniques and secondary work processes like machining are outlined in this report.

143. Sadowsky, M. A.
TRANSFER OF FORCE BY HIGH-STRENGTH FLAKES IN A COMPOSITE MATERIAL. Watervliet Arsenal, N. Y., Technical rept. no. WVT RR 6105-R June 61, 65p. ASTIA AD-263 969

Isolated microfibers and isolated microflakes do not contribute to strengthening of the composite material. Stress concentrations arising at the ends of isolated microelements will easily reach proportions threatening to destroy the surface bond between microelement and matrix. Whenever this happens the end portions of the microelements become totally inactive. The same kind of inefficiency is inherent in a sequence of microelements aligned along a common line (plane). Such arrangements will not help to build a strong composite material. It was intuitionally recognized, and has now been confirmed by mathematical elasticity analysis that the basis of strength of the composite lies in the staggered arrangement as shown in illustrations in the report and in force transfer by means of shearing stresses.

144. Scala, E.
COMPOSITE MATERIALS. Avco Corp., Wilmington, Mass. American Rocket Society Structural Design of Space Vehicles Conference, Santa Barbara, Calif., Preprint ARS 1098-60, 1960

Homogeneous materials have rarely met structural requirements as well as have the composites, although the latter are generally more expensive to produce. Often included in the term composite are: (1) Honeycomb and corrugated structures; (2) Cellular or foam structures; (3) Infiltrated and aggregate structures; (4) Coatings and laminates; (5) Flake, fiber, and particle reinforced structures; (6) Multiple-phase alloys and ceramics. There was no attempt to review the last item which is on a microscale and encompasses virtually the entire fields of metallurgy and ceramics. Examples of all the above structures can be found in missiles currently in production or under development – in wings, fins, skins, casings, tanks, nose cones, and nozzles. Examples of some of the more recent developments are reviewed, wherein many of the composites must serve several purposes beyond their use as structure, for example, thermal insulation and protection, vibration, aerodynamic control, and shock absorption.

145. Schmidt, F.
REPORT FOR REFRACTORY COMPOSITE GROUP.
General Electric Co., Phila. Pa. Paper presented at the Fourth Meeting of the Refractory Composite Working Group, Cincinnati, Ohio, Nov. 14-17, 1960.

This report treats the possible improvements in strength-to-weight ratios by use of fiber-reinforced materials, especially by the use of single crystal whiskers bonded in matrix form.

146. Schoerch, H.
SPACE STRUCTURE DESIGN WITH COMPOSITE MATERIALS. Astronautical Research Corp., Santa Barbara, Calif., American Rocket Society, Conference on Structural Design of Space Vehicles, Apr 6-8, 1960, Santa Barbara, Calif. Preprint ARS 1096-60, 1960.

The present discussion confines itself to identifying some general objectives that might be encountered in the design of advanced space structures, and reviews the possibilities vested in approaches involving composite structural materials. Typical problem areas associated with the design and materials are also discussed.

147. Scruggs, D. M.
Metal-ceramic composite materials, MACHINE DESIGN, v. 34, p. 192, 194, 197-198, Jan 18, 1962.

Ceramic constituents are arrayed in Cu, W and Cr matrices to provide a structural continuous phase and improve oxidation and wear resistances, high temperature strength, thermal conductivity and ductility. Comparison with the various geometries and amounts of graphite in gray, malleable and ductile iron.

148. SHEET BERYLLIUM COMPOSITE.
Aeronautical Systems Division, Wright-Patterson
Air Force Base, Ohio. Rept. no. ASD-TR-7-845 (1),
Interim Progress Report, 1 Oct 61 - 31 Dec 61

This program involves design, development of manufacturing processes, testing and evaluation of reinforced ceramic heat shields combined with honeycomb panel load bearing structure. The ceramic heat shield is designed to reject approximately 90% of the incident heat flux by radiation at the surface and is capable of withstanding environments in excess of 3000° F. for one hour. The load bearing semi-monocoque structure operates in temperature ranges suitable for stainless steels, super alloys and beryllium. A 90" long test section representing a portion of a typical lifting body re-entry vehicle will be fabricated and tested.

149. SHEET BERYLLIUM COMPOSITE STRUCTURES.
Aeronautical Systems Division, Wright-Patterson
Air Force Base, Ohio. Rept. No. ASD-TR-7-845 (2),
Interim Progress Report, 1 Jan 62 - 31 Mar 62.

This program is directed toward the design, development of manufacturing processes, testing, and evaluation of reinforced ceramic heat shields combined with load bearing honeycomb panel structure. The composite structure will be capable of withstanding surface temperatures in excess of 3000° F for one hour. The load bearing semi-monocoque structure will operate in temperature ranges suitable for beryllium, stainless steels, and super alloys. The predominant development effort is in the application of beryllium to the load bearing structure. A ninety-inch section of a typical lifting body re-entry vehicle will be fabricated for test under a simulated super-orbital re-entry environment. Preliminary work has been performed in the definition of environment, design analysis, materials selection, and component testing.

150. Sklarew, S.
REINFORCED INORGANIC REFRACTORY CERAMIC
COATINGS. The Marquardt Corp., Van Nuys, Calif.
Paper presented at the 6th Meeting of the Refractory
Composites Working Group, Dayton, Ohio, June 16-19,
62. (Summarized in DMIC Rept 175)

Several composite systems of metal-reinforced inorganic refractory-ceramic coatings have been developed for thermal protection of structures exposed to elevated-temperature environments up to plus 4000F. The discussion includes stable, self-supporting systems as well as systems in which the reinforcing media are attached to the structural-metallic substrate. The coating systems afford appreciable thermal drops for long time intervals from the thermally exposed ceramic to the substrate structure, thus preserving the structural integrity and load carrying capabilities of the substrate.

151. Smith, L. L.
COMPOSITE INORGANIC RESILIENT SEAL
MATERIALS. Armour Research Foundation,
WADC TR-59-338, Part 3, March 1961

Composite materials suitable for use as static and dynamic seals at temperatures ranging from cyrogenic to 1200° F and pressures up to 5000 psi were investigated. Friction, wear, resiliency and the effects of fiber orientation and radiation were determined. The materials were grouped as follows: (1) fibrous metal skeletons with pure metal impregnated with silver and/or indium which gave promising results at temperatures of 1000° F for reciprocating shaft seals and -424 F for static seals. (2) Fibrous skeletons with other impregnants. These included metal skeletons filled with Teflon, silicone, inorganic rubber, and various ceramic compositions. (3) Nonfibrous ceramic composites containing talc or glass.

152. Smith, L. L.
COMPOSITE INORGANIC RESILIENT SEAL MATERIAL.
Armour Research Foundation, Chicago, Ill., Rept. for
Mar-Nov 61 on Nonmetallic and Composite Materials.
WADC TR 59-338, Pt. 4, Dec 61., 59p. (Contract
AF 33(616)7310, Proj. 7340) ASTIA AD-273 606

The principal objective of this research is the evaluation of composite materials suitable for use as static and dynamic seals at temperatures ranging from cryogenic to 1500F and pressures up to 5000 psi. Composites made of stainless steel or Mo skeletons impregnated with babbitt for cryogenic temperatures and Cu for elevated temperatures were obtained, using carbon molds for casting. Static Seals: Studies were made of low and high pressure seals for space vehicles. In testing six-inch diameter Mo-Ag seals, spring-types such as C-rings were found to require less clamping force than solid types such as O-rings. Babbitt and In fillers for cryogenic seals were successfully employed with Mo and stainless steel skeletons at -319F to retain 2000 psi helium pressure. Dynamic Seals: The sealing of rotating and reciprocating shafts with metallic composite seals is discussed, as well as dynamic test fixtures. Using a stainless steel-Ag seal with a rotating shaft flame-sprayed with chromium carbide, successful sealing was obtained at 84 and 757 F, 5000 RPM, and pressures of up to 4000 psi.

153. Sonneborn, R.H., Isham, A.B., and Wagner, R.H.
CONTROL OF VARIABLES IN HEAT RESISTANT GLASS REINFORCED PLASTICS, Owens-Corning Fiberglas Corp., Ashton, Rhode Island, AMC Tech. Rept. No. 59-7-589 Vol. 1-11, Jan 1959, ASTIA AD 156069, Contract AF 33(600)-35031

The final report on this contract work is divided into two volumes: I. Summary, II, Engineering Report. Volume II contains the engineering details of the esperimental work, all data, and their interpretations. Table of Contents for Volume II: (1) Reinforcement Variability; (2) Resin Variability; (3) Glass Surface Treatments; (4) Materials Control Testing; (5) Process Variability; (6) Molding Process Descriptions; (7) Test and Inspection Techniques; (8) Statistical Methods Employed on Contract.

154. Stegler, R. E.
Composite-adhesive bonds cases for solid-fuel rocket motors. IRON AGE. v. 185, n. 19, May 12, 1960, p. 146-147.

This article presents a threefold process to eliminate trouble spots and reduce cost and weight by 50%.

155. Sterry, W.M.
STUDIES OF REFRACTORY COATINGS, METAL-CERAMIC COMPOSITES AND THERMAL PROTECTION SYSTEMS. Boeing Airplane Co., Seattle, Wash. Paper presented at the Fourth Meeting of the Refractory Composites Working Group, Cincinnati, Ohio, Nov 15-17, 1960.

This paper constitutes a progress report on activities of the Boeing Airplane Company Aero-Space Division on studies of protective coatings, metal ceramic composites, and refractory foams used for thermal-protection systems.

156. Sterry, W. M.
CERAMIC AND COMPOSITE CERAMIC-METAL MATERIALS SYSTEMS APPLICABLE TO RE-ENTRY STRUCTURES. Symposium on Processing Materials for Re-Entry Structures, May 1960, WADD TR 60-58, ASTIA AD 241597

156. (cont'd)
This paper was presented at a symposium held in Dayton, Ohio, May 1960, by the Society of Aerospace Materials and Process Engineers, and discusses a number of metal-ceramic composites and pure ceramic material systems having application to re-entry structures and to related propulsion system hot components.

157. Stevens, D.
ESTABLISHMENT OF THE POTENTIAL OF FLAKE REINFORCED COMPOSITES AS ENGINEERING STRUCTURAL MATERIALS, Narmco Industries, Inc., San Diego, Calif. Quarterly progress rept. no. 4, 1 Sep - 30 Nov 61, Jan 62, 22p. (Contract NOw-61-0305-c)
ASTIA AD-270-502

Increase in strength over flake alone, or fiber alone, for flake-fiber combinations are reviewed. Techniques for centrifugally casting flake cylinders are reported. A continuation of studies on the notch sensitivity of flake composites still shows their relative insensitivity to concentrators. Data on mica flake-glass fiber combinations are presented. Significant increases in the modulus of flake composites with a carbon black filler are discussed, along with some applications of flake.

158. Stover, E.R., and Cacciotti, J. J.
CARBIDE AND CARBON COMPOSITES FOR OXIDATION RESISTANCE ABOVE 4000°F. General Elec., Schnectady, N.Y., American Ceramic Society Annual Meeting, April 1961, Preprint No. 61-RL-2821M, 1961

A comparison was made of loss in dimensions during exposure to an oxy-acetylene torch at 4000F surface temperature, and results were correlated with microstructures. In contrast to previous studies by others, SiC and SiC-C composites showed no significant superiority over the most resistant commercial graphites, and there was little influence of SiC content, residual Si, or grain structure except in samples subject to excessive spalling. TaC-C mixtures, which also formed liquid oxides at the testing temperature, had loss rates similar to the best SiC-C samples. NbC-C mixtures had much higher loss rates due to formation of greater amounts of liquid. Flat deposits of pyrolytic graphite, having the edges of the planes exposed to the torch, had significently lower rates of dimensional loss than any other samples, although oxidation along cracks between some layers resulted in greater weight loss than external dimensions would indicate. Pitting resulted from spalling of units of the microstructure on basal plane surfaces (parallel to the deposition surface), and samples having basal plane surfaces with small radii of curvature exposed to the flame had loss rates higher than those found in flat deposits.

159. Stowell, E. Z., and Liu, Tien-Shih
PARAMETRIC STUDIES OF METAL FIBER REINFORCED CERAMIC COMPOSITE MATERIALS,
Southwest Research Inst., San Antonio, Texas.
Interim rept. no. 1, 8 Jan - 7 Mar 60, 8 Mar 60,
7 p. (Contract NOa(s) 60-6077-c) ASTIA AD-234-887

Work in two areas was started. To describe structural factors influencing the expected mechanical properties of compatible systems, a study was made on the effects of fiber geometry, their distribution and mechanical properties on a MFRC body. In this connection, the embedded metallic fibers are regarded as discontinuities and/or inclusions in a homogeneous ceramic matrix. To interpret theoretical deductions in terms of actual ceramics-metal fiber systems, work was started on a comprehensive survey of pertinent physical and mechanical properties of ceramic materials and metallic elements with melting temperatures above 1650° C (3000° F). The following conclusions may be drawn from the theoretical discussion: If the composite material is to carry tension, the metallic fibers should be aligned in the direction of the tension. The resulting composite material will of course be orthotropic. The ratio E'/E should be as large as possible, (where E and E' are the elastic moduli, respectively, of the matrix and metallic inclusion). A ratio of 2 would be desirable and is possible of achievement. For example, a mullite-tungsten combination would yield a ratio of $E'/E = 2.3$ approximately. The curves of stress distribution indicate that the fibers may be fairly closely spaced without impairing their stress-carrying power too heavily. They may probably be spaced a distance apart of the order of the diameter. An isotropic material can be achieved by a random orientation of metallic fibers, but probably at a sacrifice of the exceptional ability to carry undirectional tension which results when the fibers are aligned.

160. Stowell, E. Z., and Liu, Tien-Shih
PARAMETRIC STUDIES OF METAL FIBER REINFORCED CERAMIC COMPOSITE MATERIALS,
Southwest Research Inst., San Antonio, Texas.
Interim rept. no. 2, 8 Mar- 7 May 60, 18p.
9 May 60. (Contract NOa(s) 60-6077-c)
ASTIA AD-238 710

Theoretical strength of a matrix reinforced with metallic fibers: A qualitative analysis is presented of the strength of a composite material (a matrix interspersed with metallic fibers) on the basis of perfect elasticity. It was assumed that (1) the metallic fibers are inclusions which are perfectly bonded to the matrix and which suffer the same strains as the matrix, (2) the fibers all have the same diameter and breaking stress, differing only in length, (3) the fibers are aligned in the direction of the applied tension, (4) the elastic modulus of the fibers is greater than that of the matrix, (5) the stress inside a fiber is uniform and equal to the stress implied by the stress concentration factor,

160. (cont'd)
(6) the fiber spacing is large enough so that each fiber acts individually, (7) when a fiber breaks it becomes completely ineffective, and (8) the matrix does not break before the fibers break. Property survey of ceramic materials: Physical properties are tabulated for NiO, SiO_2, SrO, Ta_2O_5, ThO_2, SnO_2, TiO_2, WO_3, UO_2m V_2O_3, Y_2O_3, ZnO, and ZrO_2.

161. Stowell, E. Z., and Liu, Tien-Shih
PARAMETRIC STUDIES OF METAL FIBER REINFORCED CERAMIC COMPOSITE MATERIALS, Southwest Research Inst., San Antonio, Texas. Bimonthly rept. no. 3, 8 May - 7 July 60, 8 July 60, 11p. (Contract NOa(s) 60-6077-c)
ASTIA AD-240-135.

Estimated strength of composite material when stressed at an angle to the fibers: Two cases are considered, one with a set of fibers aligned in the X-direction and one with 2 sets of fibers at right angles. When the stress is lined up in the direction of a set of fibers, the strength of the composite is governed by the strength of that set of fibers. When the stress is applied at a small angle to a set of fibers, the strength of those fibers probably still controls the strength of the material up to a certain angle. Beyond this angle, failure may occur by excessive shear stress. Refractory oxides at high temperatures: Short-time strength data are presented for a number of nominally pure oxide materials; a typical feature is a sharp decrease in short-time tensile strengths at a temperature corresponding to a transion in fracture characteristics from trans-crystalline to intergranular grain-boundary fractures. For poly-crystalline oxides, grain-boundary creep is the major long-time elevated-temperature deformation process. The creep rate is dependent on grain size and the minor constituents which affect the structure of the boundary material. The stability of refractories in contact with metals is dependent on physical factors as well as thermodynamic properties.

162. Stowell, E. Z., and Liu, Tien-Shih
PARAMETRIC STUDIES OF METAL FIBER REIN-FORCED CERAMIC COMPOSITE MATERIALS, Southwest Research Inst., San Antonio, Texas. Bimonthly rept. no. 4, 8 July - 7 Sep 60, 8 Sep 60, 8p. (Contract NOa(s) 60-6077-c)
ASTIA AD-244-305

The mechanical behavior of ceramic materials at elevated temperatures is described from a phenomenological standpoint. The viscoelastic characteristics of both the ceramic materials and the metals at elevated temperatures makes possible the prediction of their behavior. Summary tables on pertinent physical, mechanical and thermodynamic properties are presented for carbides, nitrides and borides.

163. Strauss, E. L.
SUMMARY OF MARTIN INVESTIGATIONS OF REFRACTORY COMPOSITES. The Martin Co., Baltimore, Md., Paper presented at the Fourth Meeting of Refractory Composites Working Group, Cincinnati, Ohio, Nov 14-17, 1960

Research findings on oxidation-resistant coatings, low-temperature ablators, and ductile ceramics with special emphasis on highly porous ceramics are included in this report.

164. Strauss, E. L.
RECENT MARTIN INVESTIGATIONS OF REFRACTORY COMPOSITES. The Martin Co., Baltimore, Md., Paper presented at the Fifth Meeting of the Refractory Composites Working Group, Dallas, Texas, August 10, 1961. (Summarized in DMIC Rept. 167)

The Martin Company has continued materials investigations in three distinct areas: Evaluation of Coatings for Molybdenum. The investigation was made to evaluate the performance of coatings for molybdenum under conditions, relevant to re-entry vehicle environments, that would serve to aid in the establishment of design criteria. High-Temperature Composite Structure. The purpose of this program is the design, development, fabrication, test, and evaluation of a nose-cone-type heat shield, capable of efficient operation with surface temperatures in the range of 3000 to 4000 F. Resin-Impregnated Porous Ceramics. This effort involves the continuation of research to develop effective heat-shield materials which will thermally protect the body of glide and lifting re-entry vehicles without undergoing a change in shape.

165. Strauss, I.
DEVELOPMENT OF COMPOSITE ROCKET NOZZLES, General Telephone and Electronics Labs., Inc., Bayside, N. Y. Final rept., 31 Aug 61, 63p. (Rept. no. TR 61-109.8) (Contract NOw 61-0479-c) ASTIA AD-262 775

A material for rocket nozzles, consisting of a tantalum carbide matrix with embedded reinforcing tungsten wires, has been developed. The fabrication method is such that reactions between carbide and tungsten wires were prevented and the tungsten wires retained their ductility at room temperature. Plasma-flame spraying is used for the deposition of the carbide matrix. After a discussion of the general reinforcement

165. (cont'd)
effect produced by ductile wires in a brittle matrix, the advantages and disadvantages of a number of wire frameworks and refractory matrix materials are outlined. Tantalum carbide was selected as the main matrix material to be studied because of its extremely high melting point. A wire structure, consisting of circumferential windings supported and kept in place by longitudinal coils, was considered to be the optimum configuration for reinforcing a rocket nozzle. A method was developed to spray carbides in an inert atmosphere chamber. This kept the carbon content of the material close to the theoretical amount, but the deposition of a fully stoichiometric carbide proved not to be feasible. A number of tensile and other tests were performed to investigate the effectiveness of reinforcing structures.

166. Suffredini, L. P.
ESTABLISHMENT OF THE POTENTIAL OF FLAKE REINFORCED COMPOSITES AS ENGINEERING STRUCTURAL MATERIALS, Narmco Industries, Inc., San Diego, Calif. Quarterly rept. no. 1, 1 Jan - 31 Jan 61, Apr 61, 24p. (Contract NOw 61-0305-c) ASTIA AD-265 192

An analysis of the moment distribution on a uniformly loaded circular plate with edges overhanging the support is presented. The equations developed are used to calculate the maximum tensile stress and deflection in such a loaded plate. These equations are intended for the evaluation of the flexural strength of flake reinforced plastic laminates under biaxial stress. The notched tensile strength of flake laminates is reported. The results are interpreted in terms of built-in stress raisers caused by local variations in the distribution of flake. Tensile stress at root of the notch has reached a level of 58,000 psi.

167. Suffredini, L. P. and Duft, B. L.
ESTABLISHMENT OF THE POTENTIAL OF FLAKE REINFORCED COMPOSITES AS ENGINEERING STRUCTURAL MATERIALS, Narmco, Inc., San Diego, Calif. Quarterly rept. no. 3, 1 Jan - 31 Mar 60, Apr 60, 1 v. (Contract NOa(s) 59-6255-c) ASTIA AD-239-751

A theoretical analysis of the behavior under stress of circular glass flake reinforcing elements in a resin matrix is presented. The ultimate compressive strength is shown to be a function of the ratio of specimen and flake thickness. Lower limit values of ultimate strength have been estimated from reasonable glass and resin properties. Methods for determining the mechanical properties of the flake and resin are described. A calculation of the stress induced in a flake composite from thermal effects has been

167. (cont'd)
made. Because of the large difference in thermal contraction between resin and glass, a tensile stress in the range of 7000 to 29000 psi may develop during cooling of the composite from cure temperature to room temperature. The thermal stress is a function of localized structure within the composite. A method of testing the tensile strength of the individual circular glass flake being produced in this program has been developed and verified. The average tensile strength of the flakes tested falls in the range of 150,000 to 200,000 psi. The flake formed from Pyrex glass can be made as thin as 0.5 mils with a diameter-to-thickness ratio (d/t) of 250. Theoretical calculations based on reasonable glass and resin properties indicate a minimum d/t of 220 is required. A statistical criterion for the selection of a non-arbitrary flake slenderness ratio is suggested.

168. Suffredini, L. P. and Stevens, D. W.
ESTABLISHMENT OF THE POTENTIAL OF FLAKE REINFORCED COMPOSITES AS ENGINEERING STRUCTURAL MATERIALS, Narmco Industries, Inc., San Diego, Calif. Quarterly rept. no. 4, 1 Apr - 30 June 60, July 60, 1v. (Contract NOa(s) 59-6255-c)
ASTIA AD-240 725

A statistical analysis of the variation of flake distribution within a flake reinforced composite has been performed and verified by an experimental evaluation of cross sections taken at random throughout the composite. No correlation has been found between the variance in flake proportion in a cross section and the variance in mechanical test data. The predicted variance is much smaller than is observed from the scatter in test results. The thermal stresses developed in a glass-resin composite, because of the large difference in thermal expansion between the components, have been examined using a photoelastic technique. Thermally induced shear stresses as large as 400 psi have been observed. The room temperature bending strength of epoxy-Filmglas laminates is not altered by exposure to liquid nitrogen temperatures. Model laminates prepared from thin heat treated 17-7 PH stainless steel circular flakes have been tested in tension to check a prediction of composite strength as deduced from a theoretical stress analysis. Preliminary results indicated good agreement between observed and calculated values. A strength-to-weight analysis for plates and cylindrical elements in compression has demonstrated the superiority of present day glass flake laminates over aluminum and steel for application where the principal mode of loading is compression.

169. Suffredini, L. P., and Stevens, D. W.
ESTABLISHMENT OF THE POTENTIAL OF FLAKE REINFORCED COMPOSITES AS ENGINEERING STRUCTURAL MATERIALS, Narmco Industries, Inc., San Diego, Calif. Summary technical rept., 1 July - 1 Oct 59, Oct 60, 79p. (Contract NOa(s) 59-6255-c)
ASTIA AD-265 929

The stress-strain behavior of highly idealized model flake composites, composed of disc shaped flake of uniform size and mechanical properties, was considered. An analysis of such a composite under a uniaxial tensile stress was performed, considering the reinforcing elements to act independent of their nearest neighbors. This analysis was then modified to consider interactions between adjacent flakes. For the case where the flakes act independently of one another, the results show that the upper limit of strength available is only approximately 48% of the inherent strength of the reinforcement. A consideration of flake interaction reveals that a larger fraction of the reinforcement strength can be developed under load. Techniques for making disc shaped glass flake are given and the limitations of the methods are discussed. Methods for improving the reinforcement efficiency of the flake by altering the geometrical shape from a simple disc to a lenticular form are also considered.

170. Sutton, W. H.
Development of composite structural materials for space vehicle applications. ARS JOURNAL, v. 32, Apr 1962, p. 593-599.

Results of experimental study of single filamentory crystals of ZrO_2 used for reinforcing Al. Structural considerations for filament reinforcement and factors affecting reinforcing capabilities of whiskers in a composite. Theoretical basis for predicting composite strength. Calculated strength-density ratios of alloy F-48 reinforced with Al_2O_3 whiskers at temperatures above 3000° F.

171. Sutton, W. H.
DEVELOPMENT OF WHISKER-REINFORCED METALLIC COMPOSITES, General Electric Co., Philad., Pa. Paper prepared for the fifth meeting of the Refractory Composite Working Group, Dallas, Texas, Aug 10, 1961. (Summarized in DMIC Rept. 167)

171. (cont'd)
A study has been conducted to investigate the feasibility of whisker reinforcement. Sapphire (α - Al_2O_3) whiskers were selected because of their refractory characteristics, chemical compatibility with metals at elevated temperatures, and because they retain a considerable portion of their strength at temperatures near their melting point (3750 F). The program was divided into three areas of investigation and are covered in this paper; (1) Whisker growth; (2) Structural analyses; (3) Composite fabrication.

172. Sutton, W. H.
DEVELOPMENT OF COMPOSITE STRUCTURAL MATERIALS FOR SPACE VEHICLE APPLICATIONS, General Electric Co., Philad., Pa. American Rocket Society Conference, April 4-6, 1961, Palm Springs, Calif. Preprint ARS 1685-61, 1961

The increasing demand for higher operating temperatures of structural components for air and space craft has created an acute materials problem. Since it is unlikely that the high-temperature strength of materials commercially available today can be increased by more than a small increment, the development of new materials and new techniques becomes imperative. The concept of utilizing the extremely high strength of filamentary crystals (whiskers) for reinforcing metals is presented. Structural considerations of filament reinforcement and the problems of attaining the full reinforcing capabilities of whiskers are now discussed. An example is given for predicting the strengths of a composite consisting of a columbium alloy (F-48) reinforced with sapphire (Al_2O_3) whiskers. The preliminary results of an experimental program concerned with the development of composites of aluminum reinforced with Al_2O_3 whiskers and Zr O2 fibers are discussed. It is concluded that the crux of utilizing the full reinforcing potential of whiskers lies in the careful orientation, wetting, and bonding of the whiskers in the metal phase.

173. Sutton, W. H., Gatti, A., and Brenner, S. S.
DEVELOPMENT OF COMPOSITE STRUCTURAL MATERIALS FOR HIGH TEMPERATURE APPLICATIONS, General Electric Co., Phila., Pa., GE 0465-QR-1, July 1960, (Contract NOw 60-0465-D)

This study is concerned primarily with a demonstration of the feasibility of whisker reinforcement by developing a refractory, whisker-reinforced metal composite. A program is undertaken to demonstrate the feasibility of whisker-reinforcement in metal/alloy structural composites. The ultimate goal of this program is the development of a composite which has a strength-to-weight ratio of 600,000 inches at 200 F. In this report, a discussion of the nature of whiskers (filamentary crystals) included. Since it is intended to use sapphire (Al_2O_3) whiskers as reinforcing media, considerations are given on growth mechanisms and methods, and also on theoretical expectations of what a composite containing these whiskers might achieve in the way of high-temperature strength. An experimental program was set up for growing sapphire whiskers from an aluminum melt in a hydrogen atmosphere. The effects of temperature, time, and gas-moisture content (dew point) were studied.

174. Sutton, W.H., Talento, A., and Chorne, J.
DEVELOPMENT OF COMPOSITE STRUCTURAL MATERIALS FOR HIGH TEMPERATURE APPLICATIONS, Space Sciences Lab., General Electric Co., Philadelphia, Pa. Progress rept. no. 5, 1 May - 31 Aug 61, on Materials Studies Operation, Aug 61, 30p. (Contract NOw-60-0465-d) ASTIA AD-263 814

Studies were made of the feasibility of making whisker-reinforcement of metal composites for structural applications. The ultimate goal is a composite with a strength-to-density ratio of 600,000 in. at 2000F. The growth of sapphire (A1203) whiskers was optimized to produce length-to-diam ratios of 1000 or better. Studies are underway to improve the wettability and adherence between the sapphire whiskers and silver matrix. Wire specimens of silver, 0.030 in. in diam and reinforced with A1203-whiskers, were fabricated by centrifugal casting methods. This method yields composites of nearly 100% density, and results in greatly improved penetration of the silver into the whisker bundles, even though the latter were not metallized.

175. Sutton, W. H., Talento, A., et al
DEVELOPMENT OF COMPOSITE STRUCTURAL MATERIALS FOR HIGH TEMPERATURE APPLICATIONS, Space Sciences Lab., General Electric Co., Philadelphia, Pa. Progress rept. no. 7, 31 Dec 61 - 28 Feb 62, on Materials Studies Operation, 28 Feb 62, 39p. (Contract NOw 60-0465-d) ASTIA AD-272 866L

No abstract.

176. Sutton, W.H., Chorne, J., et al
DEVELOPMENT OF COMPOSITE STRUCTURAL MATERIALS FOR HIGH TEMPERATURE APPLICATIONS.
Space Sciences Lab., General Electric Co., Philadelphia, Pa. Progress rept. no. 8, 1 Mar - 31 May 62, on Materials Studies Operation, 31 May 62, 35p.
(Contract NOw 60-0465-d) ASTIA AD-275 985L

No abstract.

177. Sutton, W.H., Talento, A., and Gatti, A.
DEVELOPMENT OF COMPOSITE STRUCTURAL MATERIALS FOR HIGH TEMPERATURE APPLICATIONS.
General Electric Co., Philad., Pa., GE 0465-QR-2, Oct 1960. (Contract NOw 60-0465-D)

The purpose of this program is to develop, ultimately, a composite material which will have a strength-to-density ratio of 600,000 inches at 2000 F (1093 C). The basic approach is that of reinforcing a metallic phase with filamentary single crystals, commonly referred to as "whiskers." Since such crystal types are the strongest fibers known today, it is intended that the feasibility of their reinforcing capabilities be demonstrated. In this study, sapphire (Al_2O_3) whiskers were selected because of their high melting point, 3780F, and relatively low density, 3.97 gm/cc. This program has been undertaken to demonstrate the feasibility of whisker-reinforced metal/alloy composites for structural applications. The ultimate goal of this investigation is to develop a composite which has a strength-to-density ratio of 600,000 inches at 2000F. The work accomplished during this period included (1) developing a carefully designed furnace for studying whisker growth, (2) continuing studies of the factors which govern the growth rate and types of Al_2O_3 whiskers, (3) making composites of $Al-ZrO_2$, (4) studying fabrication techniques, (5) designing and completing an apparatus for a vacuum-infiltration method for making composites, (6) developing better composites by additional heat treatment; and (7) designing and setting up several pieces of tensile equipment for testing whiskers and composites at various temperatures.

178. Swann, R. T.
COMPOSITE THERMAL PROTECTION SYSTEMS FOR MANNED RE-ENTRY VEHICLES. American Rocket Society 15th Annual Meeting, Wash., D.C., Dec 5-8, 1960.
Preprint ARS 1569-60, 1960.

178. (Cont'd)
Weights and efficiencies of simple and composite thermal protection systems are presented as functions of heating conditions. It is shown that, for nearly all heating conditions, composite systems will require less weight than the simple systems. Heating conditions encountered during entry are discussed, and the minimum weight systems for these conditions are indicated.

179. Swica, J. J., Hoskyns, W. R., et al
METAL FIBER REINFORCED CERAMICS,
New York State Coll. of Ceramics, Alfred U.
Rept. for 1 Sep 58-31 Aug 59 on Ceramic and
Cermet Materials, Jan 60, 41p. (WADC TR 58-452,
Pt. 2) (Contract AF 33(616)5298, Proj. 7350)
ASTIA AD-233 453

The research described in this report was directed toward the accumulation of data which would lead to a better understanding of the effect of the many variables encountered in metal-fiber systems and the reasons why such composites have the unique properties observed. The principal geometric variables involved in ceramic-refractory metal fiber composites were evaluated using thermal-shock resistance as the most important criteria. Several different ceramic-metal fiber composites were investigated. Using the alumina-molybdenum and alumina-mullite-molybdenum fiber systems, the comparative properties of the two basic types of composites were demonstrated. Composites were developed which had flexural strengths exceeding 30,000 psi following four severe thermal-shock cycles.

180. Tinklepaugh, J.R., Goss, B.R., et al
METAL FIBER REINFORCED CERAMICS,
New York State Coll. of Ceramics, Alfred U.
Rept. for 1 Sep 59 - 31 Aug 60, on Ceramic and
Cermet Materials, Nov 60, 77p. (WADC TR 58-452,
Pt. 3) (Contract AF 33(616) 5298, Proj. 7350),
ASTIA AD-251 929

The flexural properties of a ceramic-metal fiber system were studied and it was found that the metal fiber does assume a part of the load which is to some degree in proportion to the relative elasticity moduli of the ceramic and metal. The ceramic fails when its strength is exceeded but the composite does not fail until the metal fibers are broken or pulled out of the ceramic. The test data for the alumina-molybdenum and alumina-mullite-molybdenum systems were extended to 3000F. Hafnium oxide was found to have desirable characteristics for use in a composite system.

181. Truesdale, R.S., Swica, J.J., and Tinklepaugh, J.R.
METAL FIBER REINFORCED CERAMICS, Alfred U., N. Y. Rept. on Ceramic and Cermet Materials, Dec 58, 36p. (WADC Technical rept. no. 58-452) (Contract AF 33(616)5298) ASTIA AD-207 079

Techniques were developed for the sintering and hot pressing of alumina and alumina containing 5 wt. %, 10 wt. % and 20 wt. % molybdenum fibers. The physical and mechanical properties of alumina containing these percentages of 1/8 in. long by 0.002 in. dia. fibers were determined and compared to those of the alumina. The alumina was superior in strength and impact resistance but there was some indication that the aluminas containing 10 and 20 wt. % additions of fiber were superior in thermal shock resistance. All alumina samples containing 10 and 20% additions developed microcracks while only some 5% samples developed these cracks.

182. Tully, T. S.
AN INVESTIGATION OF METAL-CERAMIC COMPOSITES FOR HIGH TEMPERATURE APPLICATIONS. Armour Research Foundation of Illinois Institute of Technology, Chicago, Illinois. Report No. ARF 2175-2, June 15, 1959. (Contract DA-11-022-505-ORD-3038) ASTIA AD 217806

The objective of this work is a study for the generation of basic data necessary to permit structural and special-purpose applications of metal-ceramic composites. Ceramic and metallic materials were chosen on the basis of the ratio of their thermal expansivities. This ratio is a basic factor in determining internal stress in metal-ceramic composites. Values of this ratio greater than 1 place the ceramic in compression and the metal in tension when the composite material is cooled from elevated temperatures. Three material combinations were selected. Choice was made on the basis of availability of materials and from thermal expansivity ratio.

	Metal	Ceramic	Expansivity Ratio, metal/ceramic
I.	Tantalum	Silicon carbide	1.451
II.	Tungsten	Silicon carbide	0.963
III.	Tungsten	Aluminum oxide	0.569

183. Vassallo, F. A., Wahl, N. E., et al
THE STUDY OF ABLATION OF STRUCTURAL PLASTIC MATERIALS. Cornell Aeronautical Lab., Inc. Buffalo, N. Y. Rept. for June 58 - Apr 59 on Non-Metallic and Composite Materials, Dec 59, 1v. (WADC TR 59-368) (Contract AF 33(616)5683, Proj. 7340), ASTIA AD 234779

Results of ablation tests conducted on reinforced plastics at moderately severe heating conditions are reported. The materials tested include laminates of melamine, phenolic, and silicone reinforced with glass fabric as well as phenolic and silicone asbestos laminates. Experimental data are given for rate of material loss, rate of temperature rise at points within the body, depth of heat penetration and loss of material strength both during and after ablation. The test apparatus provides a stream of high temperature nitrogen which is directed onto test specimens in which thermocouples are located. Body shapes considered are 20° wedges and square edged plates. Analysis of the obtained data is presented for dependence of heat penetration on rate of ablation. Rates of ablation and effective heats of ablation over a range of heat flux from 0 to 200 Btu/ft^2-sec. are given for each material tested.

184. Vassallo, F. A., Wahl, N. E., et al
THE STUDY OF ABLATION OF STRUCTURAL PLASTIC MATERIALS, Cornell Aeronautical Lab., Inc., Buffalo, N. Y. Rept. for Apr Dec 59 on Non-Metallic and Composite Materials, Apr 60, 46p. (WADC TR 59-368, pt. 2) (Contract AF 33(616)5683) ASTIA AD-240 636

Results of ablation research are reported on reinforced plastic materials at moderately severe heating conditions. The materials include laminates of melamine,phenolic and silicone resins reinforced with glass fabric as well as phenolic and silicone asbestos laminates. Experimental data are given for rate of material loss, effective heats of ablation, and depth of material degradation. The exposure apparatus provides a stream of high temperature nitrogen which is directed onto test specimens causing ablation to take place. The principal body shape considered is the 0.5-in flat faced dowel. High temperature exposures of composite bodies in which a substrate of high thermal conductivity is bonded to a layer of ablative material are reported. Experimental data include measurements of substrate temperature rise and rate of ablation. Discussion of heat sink effectiveness of the substrate is given.

185. Vogan, J. W.
THERMAL PROTECTIVE SURFACES FOR STRUCTURAL PLASTICS. Bendix Products Div. Bendix Corp., South Bend, Ind. Rept. for Jan-Sep 60 on Non-Metallic and Composite Materials, Mar 61, 68p. (WADD TR 60-110, pt. 2) (Contract AF 33(616)6393, Proj. 7340), ASTIA AD 260209

New insulation composite systems were fabricated for solid fuel rocket engine. The basic structure consisted of an outer refractory surface of multilayer construction and a porous inorganic thermal barrier. These were adhesively bonded to the substrate plastics. Multilayer Ni-zirconia coatings applied by flame and plasma spray techniques were used as the principal erosion resistant surfaces. Composite structures were investigated in test firings of a solid fuel rocket. These firings showed that the composite structures of plastic and a thermal barrier offered improved behavior in tests up to 20 seconds. Various materials were tested as possible mechanical reinforcements for the insulating layer. Metal honeycombs were selected for use in the fabrication studies.

186. Weare, N. E.
REFRACTORY COATING RESEARCH AT ADVANCED TECHNOLOGY LABORATORIES, American Standard, Advanced Technology Lab., Mountain View, Calif. Paper presented at the Fourth Meeting of the Refractory Composites Working Group, Cincinnati, Ohio, Nov 14-17, 1960.

Three research programs are currently being conducted at Advanced Technology Laboratories to develop technology in the field of plasma-jet-sprayed ceramic coatings. In these programs, primary emphasis is placed on development of plasma-sprayed materials for use in nuclear reactors and missiles. Development of clad ceramic fuel plates by spray-coating techniques, study of process variables in plasma-spraying refractory coatings on beryllium, and studies of plasma-jet spraying are presented.

187. Weisert, E. D.
A COMPOSITE MATERIALS SYSTEM FOR RE-ENTRY VEHICLE APPLICATIONS. Marquardt Corp., Van Nuys, Calif., American Society of Mechanical Engineers, Aviation

187. (Cont'd) Conference, Mar 12-16, 61, Los Angeles, Calif.
Preprint ASME 61-AV-47, 1961

A composite materials system has been developed for applications such as severe aerodynamic heating. The system is based on the philosophy of utilizing a good insulator, stable at high temperatures, to protect a basic load-carrying structure. The zirconia-refractory metal system developed is capable of sustained exposures to temperatures in excess of 4000F and has good high-temperature stability, thermal-shock resistance, and erosion resistance. The philosophy of approach is expounded, the materials system development described, and properties of a typical system reported.

188. Young, R. E.
THE APPLICATION POTENTIALS OF FILAMENT-WOUND STRUCTURES. Hercules Powder Co., Wilmington, Dela. Bulletin of the 17th Meeting JANAF-ARPA-NASA, Solid Propellant Group, SPIA-SPG Meeting 17, Denver, Colo., May 23-25, 1961

Structural and functional attributes of filament-wound composite systems based on presently available materials are examined against the requirements for a variety of products. Manufacturing methods are discussed where they directly relate to a specific application. The areas covered are closely associated with solid-fuel rockets and include the cylindrical chamber, end-closure means, nozzle components, interstage structures and junctions, clustering systems, integrally wound chambers formed directly over the propellant grain and insulating components, and very large chambers wound at the launching site. Certain property data are given, and the superiority of epoxy resin-bonded glass fibers is indicated.

189. Yurenka, S. B., Duft, B. L., and Chia, C. Y.
POTENTIAL OF FILAMENT WOUND COMPOSITES, Narmco Research & Development Corp., San Diego, Calif., NARM 623 FR, Final Report, March 1962, (Contract NOw 61-0623-c)

A study was made on the effect of coupling agents and resin coatings on the tensile strength of single E-glass fibers. It was found that Volan E and A-1100, when properly applied to the virgin fiber, do not cause any strength loss in the fiber. The resin coating alone, without any coupling agent, appears to protect the fiber in water immersion as well as the combination of a coupling agent and the resin. The A-1100 appears to improve the fiber strength at 500F and to be more heat resistant than the chrome complex Volan E. Mathematical expressions were derived to predict the probable behavior of composites under loads of tension, compression, and bending. Experimental verification on photoelastic study models showed good correlation between theory and experiment.

190. Zwilsky, K.M., and Grant, N. J.
Metal-metal oxide composites for high-temperature use. METAL PROGRESS, v. 80, no. 2, August 1961 p. 108-111,122.

Given the same base metal, dispersion-strengthened composites are stronger (at higher temperatures and for longer times) than their counterparts in age-hardenable alloys. The superiority of these materials is the result of increased stability which is attributed to their resistance to recrystallization up to temperatures near the melting point of the base metal.

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