United States Patent

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[54] **INEXTENSIBLE FILAMENTARY STRUCTURES, AND FABRICS WOVEN THEREFROM**
2 Claims, 4 Drawing Figs.

[52] **U.S. Cl.** **139/426,** 57/140, 57/144, 87/6, 139/425
[51] **Int. Cl.** **D03d 15/00,** D02g 3/16, D02g 3/26
[50] **Field of Search** ..... 139/420, 426, 425, 420 (A)—420 (D); 57/139, 140, 140 (B), 140 (Coated), 144—146, 160—162; 87/6, 7

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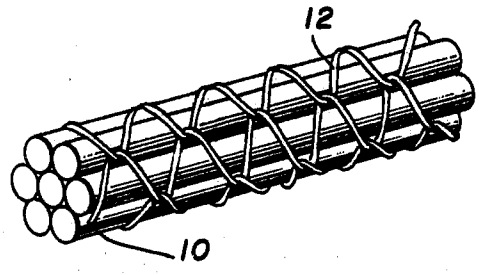
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ABSTRACT: Strands of brittle, highly inextensible filamentary materials are collimated into a bundle and wrapped or braided covering applied to form a composite yarn structure having sufficient flexibility and mechanical stability to permit the yarn to be woven as the warp of a fabric, the fill yarn being any conventional fibrous material. The inextensible filamentary materials include, among others, boron, boron carbide, silicon, silicon carbide, carbon, quartz, and similar inorganic refractory fibers which are characterized by high strength and modulus, brittleness, and inextensibility.



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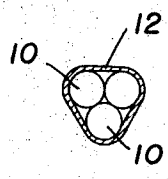


FIG. 1

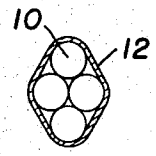


FIG. 2

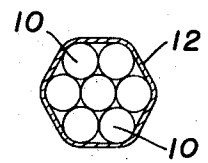


FIG. 3

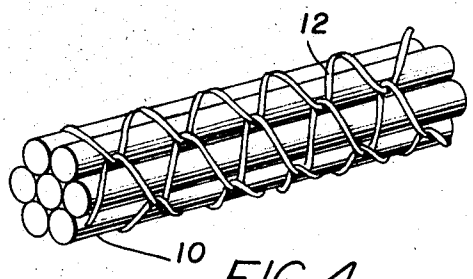


FIG. 4

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INEXTENSIBLE FILAMENTARY STRUCTURES, AND FABRICS WOVEN THEREFROM

BACKGROUND OF THE INVENTION

1. Field in the Invention

This invention relates to a method of weaving fabrics from brittle and highly inextensible filamentary materials. More particularly, this invention relates to a method for forming a composite yarn structure from inorganic refractory fibers and utilizing this composite as the warp yarn in waving a fabric.

2. Description of Prior Art

Recent developments in the field of high strength, temperature resistant materials have included the use of inorganic refractory fibers, such as boron, boron nitride, boron carbide, silicon, silicon carbide, alumina, alumina-silica, carbon, glass, and quartz to fabricate reinforced composite structures having outstanding stiffness and strength-to-weight ratios. These inorganic refractory fibers are characterized by high strength modulus, brittleness, limited flexibility, and by essentially zero elongation as defined by the term "inextensible."

Although many of these refractory fibers are presently available only in short lengths or as whiskers, efforts are being made to produce the materials in continuous filament form. Continuous filament boron formed by the vapor deposition of boron on a fine wire tungsten substrate is now commercially available.

High-strength reinforced structures are generally fabricated generally by filament winding or by sheet layup. In filament winding, strands of reinforcement are oriented directly onto surfaces which control their form. In sheet layup, the strands are first formed into sheets, and the sheets are laid up and laminated to provide the desired form and orientation. While these methods are useful, composites made by these processes do not possess the cross-reinforcement provided by a woven structure. For this reason, it is desirable to prepare woven fabrics of the inextensible materials as reinforcement for composite structures.

Although the art of weaving is ancient, the inextensible and brittle nature of the inorganic refractory fibers make it extremely difficult to weave these materials in a conventional manner. Conventional textile yarns have a reasonable amount of elongation due to the intrinsic properties of the fibers used and due to the generally twisted yarn structure. Consequently, such yarns are capable of absorbing energy to fairly high strain levels, without breaking. They may also be bent to very short radii of curvature without damage.

Filaments of the inorganic refractory fibers presently available conform to none of these conditions. The high filament modulus, in combination with a relatively large filament diameter, results in a gross stiffness and consequent fabrication difficulties. Since the bending moment of a circular rod is proportional to the fourth power of the radius of the rod, it is apparent that the intrinsic stiffness of the material is augmented by its geometry. Attempts at weaving individual monofilaments into the warp of a fabric have resulted in frequent breakage of the brittle filaments. A method for handling and weaving these materials was clearly needed if the advantages of the woven fabric in reinforced composited structures were to be obtained.

SUMMARY OF THE INVENTION

It has been discovered that a multiplicity of high-modulus, high-strength, brittle, and highly inextensible filaments may be collimated into a bundle and covered to hold the bundle as a unit for further processing. The preferred covering is a braid since braid structures are torque-free and braid-covering density may be varied with ease. However, other conventional methods for covering yarns may be successfully used.

The inextensible filaments which may be used in the practice of this invention are the inorganic refractory fibers which have a tensile strength of at least 50,000 p.s.i. and an elastic modulus of at least 4 million p.s.i. Included among others are boron, boron nitride, boron carbide, silicon, silicon carbide, alumina, alumina-silica, carbon, and quartz. The filament may also be a composite structure consisting for example of a tungsten wire core with a sheath of boron, boron carbide, or titanium diboride.

The covered bundles can be handled with relative ease and can be woven into tapes, ribbons, or fabrics using the bundles as warp ends. The advantage of the bundle structure arises from the freedom of the component filaments to move with respect to the others, particularly in bending, and to assume a position of minimum strain. Furthermore, should one or more individual filaments be broken, the integrity of the bundle is maintained by the cover. Yet further, the cover is exposed to and absorbs much of the abrasion of the weaving process, sparing the brittle filaments this attrition.

The density of the braid covering can be varied to suit filament length. Thus, for covering long continuous strands of filamentary material, the braid may be of a relatively open nature, while for covering shorter lengths of from 2 to about 8 inches, a fairly close braid would be desired.

The covering yarn may be spun cotton, spun wool, spun rayon, spun acetate, spun polyamide, spun polyester, spun acrylic, spun polyolefin, continuous filament rayon, continuous filament acetate, continuous filament polyamide, continuous filament polyester, continuous filament acrylic, continuous polyolefin, continuous filament glass, continuous filament quartz or other suitable supple textile material. In some instances where the presence of the foreign fiber may be undesirable in the ultimate composite, the covered bundle may be woven and the covering yarn may subsequently be removed by dissolving it from the fabric prior to making the ultimate composite structure.

Filling yarns for weaving the collimated bundle warp fabric may be selected from a wide variety of available materials, including glass, cotton, wool, and organic manmade fibers. If the transverse properties of the fabric reinforcement in the ultimate composite are not critical, it is convenient to use synthetic organic fiber yarns, such as nylon, polyester polyacrylonitrile, or polyolefin. If, however, the transverse properties are of consequence, high-performance synthetic organic fibers, glass, quartz and other available materials may be used.

Collimated bundle fabrics made from high-modulus, high-strength, brittle, and highly inextensible filaments may be incorporated in resin matrices to produce high-performance composite. The reinforcing filaments are present in high density, and their intrinsic filament properties are unimpared by the geometry of the fabric. Therefore, the composite has a high strenght-to-weight ratio, high modulus, and high stiffness.

DESCRIPTION OF DRAWING

FIGS. 1, 2, and 3 show three typical cross-sectional views of the braid-covered composite yarn structure. The inextensible filaments are designated by numeral 10, and the braid material by number 12.

FIG. 4 shows a representative side view of a braid-covered composite yarn structure produced in accordance with the instant invention.

DESCRIPTION OF PREFERRED EMBODIMENTS

In the practice of the present invention, a plurality of the inextensible inorganic refractory fibers are collimated into a bundle and bound together in a parallel and substantially untwisted relationship by wrapping or braiding a thread around the bundle to maintain its integrity. Generally, the bundle will be comprised from three to seven essentially continuous inextensible monofilaments of 100 yards or greater length. The bundle may also be comprised of an arrangement of an inextensible filament having shorter lengths of from 2 to about 8 inches, or longer. Generally, 2 inches is the practical minimum length which can be used in accordance with this invention.

For ease of handling, and for superior product characteristics, the continuous monofilaments are preferred. Excellent results are obtained using the commercially available filaments produced by vapor deposition of boron on a very fine tungsten wire substrate. These filaments have a tensile strength of about 400,000 p.s.i., an elastic modulus of about 60×10^6 p.s.i., and an upper temperature limit of about 2,000° C. in an inert atmosphere. Three to seven of these composite monofilaments, bound by a widely spaced nylon braid covering, are easily handled and can be used as warp ends to weave a fabric having in the warp direction the same high strength and modulus as the boron-tungsten filaments.

Although a number of commercial machines may be used to place the braided cover about the inextensible filament bundle, good results have been obtained using a No. 1 Braider having eight carriers manufactured by New England Butt Company, Providence, Rhode Island.

The covered composite yarns can be handled with relative ease and with little danger of breaking any of the inextensible filaments if reasonable precautions are taken to avoid folding or bending the yarn about a very small radius. Although the composite yarns are generally used as warp ends in constructing the fabric, they may also be used as fill if it is preferred. In this case, the inextensible filaments are most conveniently cut to a length corresponding to the width of the fabric, and individually placed through the warp shed during the weaving process. When using the inextensible filaments as fill, it is generally advisable to use a flexible textile yarn as the warp.

The following examples will serve to further illustrate the invention:

EXAMPLE I

Seven ends of continuous boron-tungsten sheath-core composite monofilament 8 mills in diameter were collimated and passed through the center of an eight-carrier braider where a covering braid of 50 denier nylon was applied at 8 braids/inch to form a composite yarn structure. A woven fabric was prepared by using 80 braid bundles per inch of width as warp ends and a single 189 denier fiberglass yarn as the fill. The resulting fabric was completely flexible in the fill direction and sufficiently flexible in the warp direction to bend around a 2-inch radius mandrel with no fracture of boron filaments.

EXAMPLE II

Three boron-tungsten monofilaments were covered with a braiding of 20 denier acetate yarn according to the procedure of example I. The composite was very flexible and easily woven into a fabric having 120 braid covered bundles per inch as warp ends with a single 189 denier fiberglass yarn as fill. The lightweight fabric had excellent flexibility. The acetate braid covering could be removed by washing the fabric with acetone, thereby producing a fabric comprised solely of boron and glass fibers.

It will be apparent from the foregoing description and examples that this invention provides a novel method for preparing yarns and fabrics from highly inextensible filamentary materials. As many widely different embodiments of this invention may be made without departing from the spirit and scope thereof, it is to be understood that this invention is not to be limited to the specific embodiments thereof, except as defined in the appended claims.

We claim:

1. A composite filamentary structure comprising a central core of a plurality of essentially straight and parallel inextensible filaments comprising a tungsten wire core and a sheath selected from the group consisting of boron, boron nitride and boron carbide and an outer covering of a flexible fiber selected from the group consisting of cotton, rayon, acetate, polyamide, polyester, acrylics, polyolefins, glass and quartz.

2. A woven fabric the fill of which being a flexible textile material selected from the group consisting of glass, cotton, wool and organic manmade fibers, and each warp of which being comprised of a plurality of essentially straight and parallel inextensible filaments selected from the group consisting of boron, boron nitride and boron carbide and having a covering fiber selected from the group consisting of cotton, wool, rayon, acetate, polyamide, polyesters, acrylics, polyolefins, glass and quartz forming an integral bundle therewith.