May 27, 1969 J. W. ANDERSEN 3,446,661

GLASS FABRIC STRUCTURE AND METHOD OF MAKING THE SAME

Filed Jan. 22, 1964

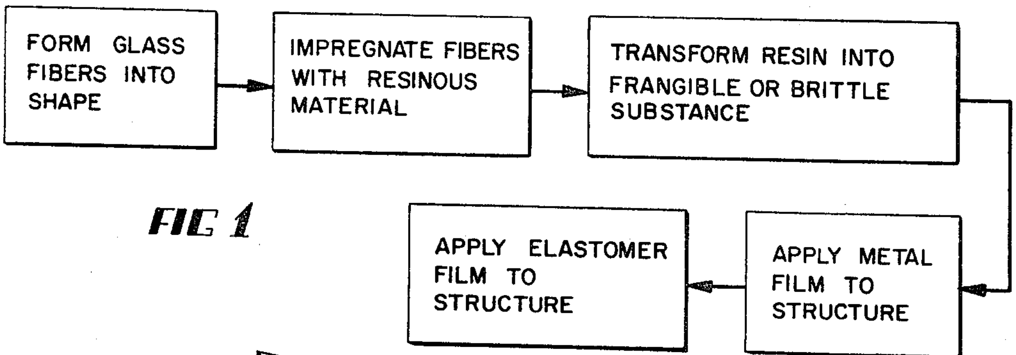

FIG 1

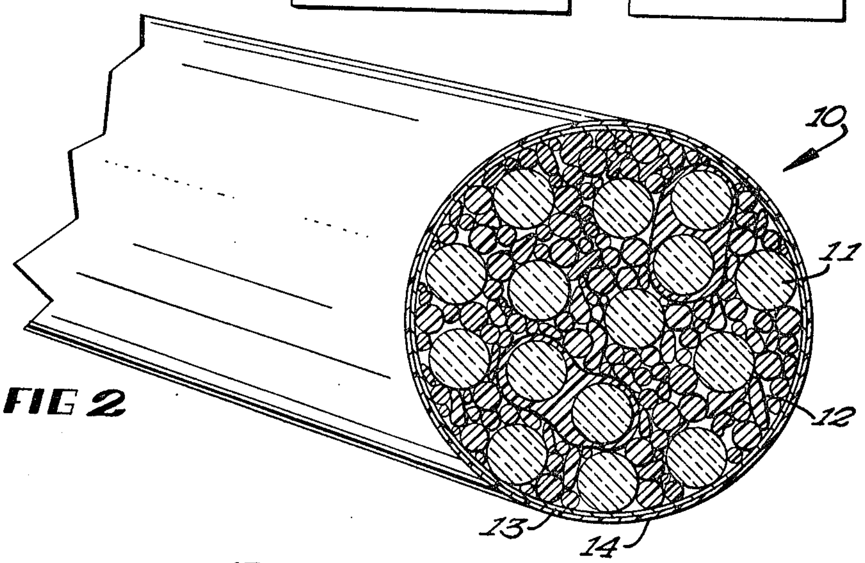

FIG 2

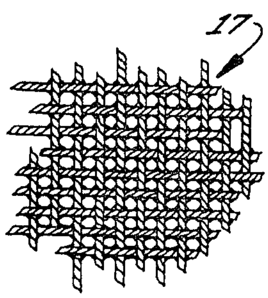

FIG 3

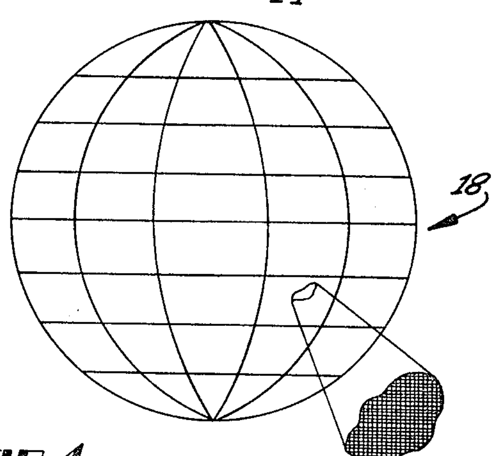

FIG 4

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GLASS FABRIC STRUCTURE AND METHOD OF MAKING THE SAME

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Filed Jan. 22, 1964, Ser. No. 339,482
Int. Cl. B44d 1/18; B32b 17/02; G01s 17/00
U.S. Cl. 117—227 6 Claims

ABSTRACT OF THE DISCLOSURE

An improved fabric structure prepared from bundles of glass filaments bonded together with a frangible binding substance, the binding substance being present in the bundles or fibers within the interstices between the filaments forming said bundles. This improved fabric is thereafter coated with a film of an electrically conductive material, preferably metallic, in order to render structures formed therefrom electrically conductive, and particularly adaptable for use as communications satellites.

This invention relates generally to an improved multifilament glass fiber, and to a spherical structure formed therefrom, the structure being particularly adaptable for use as a radio wave reflecting satellite which may be self-erecting as a satellite is put into orbit.

Because of the high resistance of atmospheric air, it is impractical if not impossible to attempt the launching of a mesh spherical structure at the speeds required to reach outer space. It is thus known that flexible self-erecting thick web mesh spheres of the order of 450 feet in diameter can be folded compactly into a cylindrical canister which is positioned at the nose of an outer space projectile and subsequently be caused to be ejected from the canister and the unit will then assume an orbital path around the earth. The self-erecting capability of the device will cause it to expand from the folded condition into a spherical configuration. There is no need for providing residual air or other materials which will inflate an otherwise closed structure inasmuch as the unit is self-erecting. Inasmuch as there is very little gas pressure at the altitudes normally employed, wind or air resistance is essentially non-existent. This distance is usually in the range of from 500 to 1,000 miles for the radio reflective purposes intended, and the sphere is then caused to circle the earth in a prescribed path at satellite velocities in the order of 18,000 miles per hour.

Collisions with cosmic dust and the natural environment at these altitudes and at these velocities will not create any problem with the configuration maintained by the sphere. The structure will tend to keep its distended configuration at all times, since a minimum area is presented to the main deforming force, that is, solar pressure. It has been found that a mesh or grid type structure will give the largest RF reflecting surface for a minimum weight, and a spherical shape is most frequently desired for this application.

A mesh structure fabricated from glass fibers may be metallized and made to be self-erecting. Glass has a modulus of elasticity of 10 p.s.i., and thus can be conveniently folded and packed in a container without exceeding the yield point. The material will not retain a fold memory, and when released from a container, it will spring back to its original shape. The high modulus of the glass makes it an efficient material to withstand the normal deforming forces found in space.

In accordance with the present invention, a self-erecting fabric structure is utilized which comprises a plurality of elongated glass filaments which are arranged together to

form fibers. The fibers are retained together as individual strands by means of a brittle binder which bonds certain of the adjacent filaments, one to another, along the extent thereof. The resultant structure may be annealed, if desired, and accordingly the material will have a sufficient memory to be self-erecting to the spherical structure desired.

Therefore, it is an object of the present invention to provide an improved self-erecting fabric structure which is fabricated from glass fibers which are prepared to have a high modulus, and which can be folded and packed without inducing a fold memory therein.

It is a further object of the present invention to provide an improved self-erecting fabric which includes a brittle binder which permits the fabric to be subjected to high stresses, the fabric being capable of avoiding stress concentrations which may exceed the yield point along the areas where these high stresses are present.

It is yet a further object of the present invention to provide an improved self-erecting glass fabric structure having a metallized coating thereon, the structure being particularly adaptable for use as a reflector for electromagnetic radiation.

It is still a further object of the present invention to provide a foldable mesh spherical structure which is self-erecting, light in weight, and which will be sufficiently rigid in outer space to resist deforming forces which may be present.

A still further object of the present invention is to provide an improved self-erecting structure specifically adapted for space application, the structure comprising a glass fabric of mesh configuration, and being subject to only a portion of the solar pressure.

Other and further objects of the present invention will become apparent to those skilled in the art upon a study of the following specification, appended claims, and accompanying drawings wherein:

FIGURE 1 is a flow diagram illustrating the various steps which are normally employed in preparing a fabric in connection with certain aspects of the present invention;

FIGURE 2 is a detail view, and an enlarged scale, showing a plurality of glass filaments which have been incorporated to form a typical glass strand, bundle or fiber which has been treated in accordance with certain aspects of the present invention;

FIGURE 3 is a detail plan view of a woven mesh fabric prepared in accordance with certain aspects of the present invention; and,

FIGURE 4 is a plan view of a spherical structure fabricated in accordance with the present invention.

In accordance with the preferred modification of the present invention and with particular attention directed to FIGURE 2 of the drawings, it will be observed that the fiber generally designated **10** includes a plurality of individual filaments **11** along with a frangible binder, size, or the like as at **12**. A particularly suitable material for the size is neoprene rubber. The fiber has a metallic coating **13** adjacent the outer periphery thereof, along with a coating of an elastomer or flexible coating **14**. While an elastomer is particularly desirable, it is understood that other protective coatings may be employed as well, the only requirement being that they are flexible and will not take a set when folded. In FIGURE 3, a woven structure is shown with the individual fibers being arranged in a basket weave configuration as shown at **17**, FIGURE 4 illustrating the spherical structure generally designated **18** fabricated from a material woven as indicated in FIGURE 3. Individual segments or gores are initially prepared, and heat treated at a temperature which is substantially equal to the annealing temperature of the glass. The individual gores therefore will achieve a relaxed configuration which is substantially that of a spherical segment.

While the individual fibers may be twisted, if desired, it will be appreciated that a fiber may be employed which does not utilize a twist. The twisted fibers provide for a greater degree of rigidity in a finished structure, however this may occur with a sacrifice of uniformity in surface configuration.

In accordance with one aspect of the present invention, particular attention is directed to FIGURE 1 which is a flow diagram of one fiber preparation technique which has been found desirable in preparing a self-erecting glass fabric. In this connection, a glass fiber is selected, such as E glass comprised of filaments of about 0.00025 inch up to about 0.00100 inch diameter. A filament of 0.0005 inch diameter is preferred. This material is commercially available. Of course, soda glass, high modulus glass, Refrasil glass, quartz glass, and the like may also be utilized. These materials are also commercially available. An important factor in the selection of raw material is the strength and rigidity thereof per unit weight, as well as the resistance to permanent deformation as a result of folding, bending, or the like. In the fiber glass material selection, a pattern having from between about 30% and 70% open weave is desirable, this range having been found to provide the required rigidity.

In the fiber glass weave, a material having a thread density of between four threads per inch and twenty threads per inch is useful. In this regard, a material having ten threads per inch in the warp and ten threads per inch in the weft may be used, with the warp threads being 0.012 inch in diameter and the weft threads being 30 mil by 10 mil rectangle. In addition to basket weave material, leno weave fabric may also be utilized successfully. In this regard, the rectangular configuration in the weft threads assists in stabilizing the fabric by limiting or controlling relative movement between the warp and the weft. Two or more rectangular threads may be utilized in the weft, if desired, this structure further controlling the relative movement occurring between the warp and the weft.

The fiber glass weave includes a binder coating or size as is conventional in the art. In accordance with the present invention, the binder must be thin and be capable of being rendered brittle. In this regard, any of the thermo-setting binders such as polyester adhesives, neoprene rubber, latex rubber materials, or the like may be employed. After treatment, the binder will attach to individual filaments in the fibers in order to form small relatively movable bundles. The filaments bundles are accordingly free to move relative to one another. In this regard, the fibers are also free to move relative to one another.

In order to render the binder material brittle, the woven fabric is passed through a heat treating zone wherein a temperature of between about 450° F. and 600° F. is maintained for a period of about fifteen minutes. This treatment has been found to be satisfactory to render a neoprene rubber binder sufficiently brittle and charred. Polyester adhesives and other commercially available binders will also become brittle and may char at this temperature. The treatment is substantially at the annealing temperature for the glass, and hence the heat treatment is preferably conducted over a mandril or the like in order to provide the desired form, configuration, or the like, in the finished fabric.

Subsequent to the heat treatment, the fiber surface is coated with a film of an electrical conductor, such as, for example, copper or the like. Other metallic conductors may be used, if desired, such as aluminum, nickel, or the like. Vacuum deposition techniques have been found to be entirely satisfactory for this operation, and a copper deposit of between about 2 and 4 micro-inches has been found satisfactory to maintain electrical continuity through the cloth in all directions. If desired, a

protective coating such as an elastomeric or flexible coating, may be utilized to coat the metallic coated filaments. While vapor deposition techniques have been indicated as being useful for the metallic coating, it is also possible to use electroless plating techniques. Alternatively, the fiber may be suitable loaded with a conductive material being incorporated as a filler in the binder.

For a sphere having a diameter of 450 feet, with a maximum opening between fibers of 0.15 inch, and using E glass with 0.0005 inch diameter filaments, (the modulus of elasticity of the glass being 10^7 p.s.i.) the calculated buckling loads are substantially in excess of the calculated requirements as determined by the solar pressure. In this connection, the rigidity requirements are eighty times the theoretical requirements when a solar pressure of 1.3 times 10^{-9} p.s.i. is expected to be encountered. The weight of a sphere based on the information above is only twenty-three pounds, however, for most requirements, particularly where greater weight may be tolerated, the sphere may employ glass having a substantially heavier fiber of greater density. This will increase reliability and make the unit easier to handle.

The self-erecting feature of the structure is believed to be achieved by means of the brittleness of the binder or size material. The binder becomes frangible in nature, and as such is instrumental in avoiding stress concentrations when the structure is folded, bent, or otherwise distorted. A binder density ranging from between about 3% to 15% by weight of the glass fiber has been found to be satisfactory. A sphere of this material provides a radio cross-section equivalent to over 95% of a solid reflecting surface of the same configuration for frequencies ranging up to 8.5 kilomegacycles.

EXAMPLE I

A basket weave of fiber glass, fabricated from soda glass, having a thread density of twenty threads per inch in the warp and ten threads per inch in the weft was selected. The warp threads were 12 mils in diameter, and the weft threads were 30 mil by 10 mil rectangles. The pattern was about 50% open. A neoprene rubber binder or size was employed the size being 10% by weight of the fabric. The material was cut in the form of gores, and placed over a mandril, the material being retained on the mandril and placed in an oven for a period of fifteen minutes at a temperature of 600° F. This was sufficient to render the binder substantially brittle and somewhat charred. The individual gores were then placed in a zone for deposition of copper metal thereon, the copper being vacuum deposited onto the fabric until a thickness of 4 micro-inches was achieved. Electrical continuity was available through the cloth in each direction. The fibers were then spray coated with a thin film of silicone rubber. In this regard, the silicone coating designated by code number RTV-11 and sold by Silicone Products Department of General Electric Co. of Waterford, N.Y. was extremely thin, being in the range of about ½ mil, with a substantially greater quantity of silicone rubber being retained at the intersection points of the individual threads in the weave. Following preparation, the individual gores were secured together, one to another, by using a polyester adhesive. The adhesive is not critical, and epoxy or other commercially available resinous adhesives may be used.

In addition to the plain basket weave and the leno weave, a non-woven configuration may be utilized. The non-woven configuration is made up of deposited layers of fibers which are held generally in place by a slip set material. The non-woven material is particularly advantageous due to its lack of distortion which may otherwise be introduced in the fabric as a result of the weaving operation.

It will be appreciated that other fabrication techniques may be employed. For example, the entire sphere may be prepared from a continuously woven material, the technique being to perform the weaving operation on the surface of a sphere forming mandril. In this connection the only seals necessary will be the final longitudinal seal and the end cap seals after removal of the mandril. The result in this regard is a homogeneous, one piece sphere with a minimum seam area. This would be desirable from the standpoint of eliminating spherical distortion.

What is claimed is:

1. A self-erecting fabric fabricated from a plurality of fibers woven together to form said fabric, each fiber comprising a plurality of elongated glass filaments arranged together in bundles forming the fiber structure, and a mechanically brittle carbonaceous binder being incorporated within the bundles forming the fibers of said fabric and bonding certain of said filaments together, one to another, the bond extending along at least a portion of the extent of said filaments, said fibers having a metallic coating disposed over and enclosing the outer peripheral surface thereof.

2. The structure as defined in claim 1 being particularly characterized in that said metallic coating is copper.

3. A self-erecting fabric structure fabricated from a plurality of fibers woven together to form said fabric, each fiber comprising a plurality of elongated glass filaments arranged together in bundles to form a fiber, and a mechanically brittle carbonaceous binder incorporated within said bundles forming the fibers for bonding adjacent filaments together along the extent thereof, said fibers having a metallic coating disposed and enclosing the outer peripheral surface thereof and being woven together to form a fabric structure in the form of a spherical segment.

4. The self-erecting fabric structure as defined in claim 3 being particularly characterized in that said spherical segment is annealed.

5. A self-erecting fabric fabricated from a plurality of fibers woven together to form said fabric, each fiber com-

prising a plurality of elongated filaments arranged together in bundles forming the fibers of said fabric, and a mechanically brittle carbonaceous binder being included in the bundles of filaments forming said fabric and bonding certain of said filaments together, one to another, the bond extending along at least a portion of the extent of said filaments, said filaments having a modulus of elasticity in the range of about 10^7 p.s.i., and an electrically conductive film being disposed along the surface of said fibers.

6. The method of preparing a self-erecting glass fiber fabric structure for reflecting electromagnetic wave radiation which includes the steps of weaving together a plurality of glass fibers formed from bundles of glass filaments to form a fabric structure, impregnating said glass fabric structure with a thermo-setting size, heating said impregnated fabric until said size is rendered frangible, and then coating the surface of said fibers with a metallic film.

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U.S. Cl. X.R.

117—46, 71, 126, 217, 229; 161—93, 196; 343—18