

[54] **NOVEL YARN AND PROCESS**
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57/34, 12

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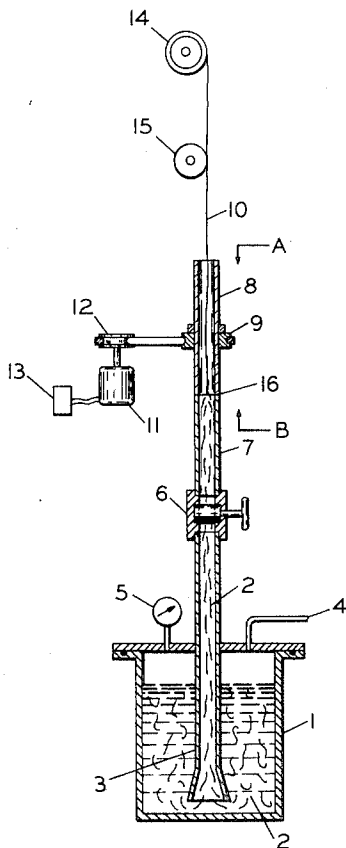
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[57] **ABSTRACT**

A fluid vortex spinning process for yarn in which a dispersion of high-modulus refractory fibers and lower modulus fibers in a viscous carrier liquid as a flowing stream is rotated about its axis to produce a composite staple fiber yarn of axially aligned high-modulus refractory fibers intermixed with and intertwined by lower modulus fibers and the composite yarns so produced.

19 Claims, 2 Drawing Figures



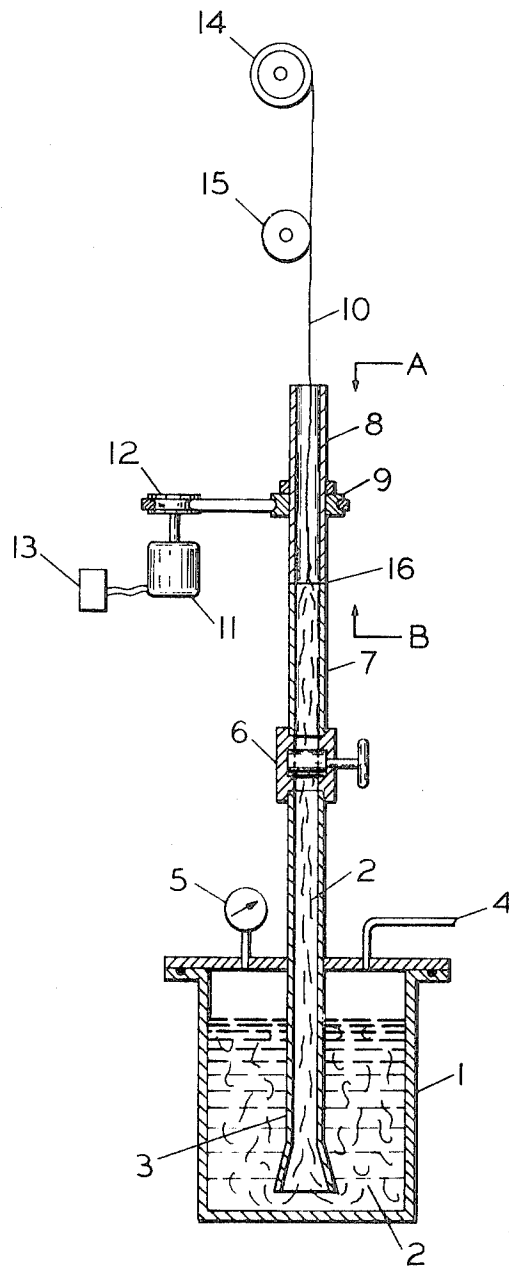


FIGURE 1

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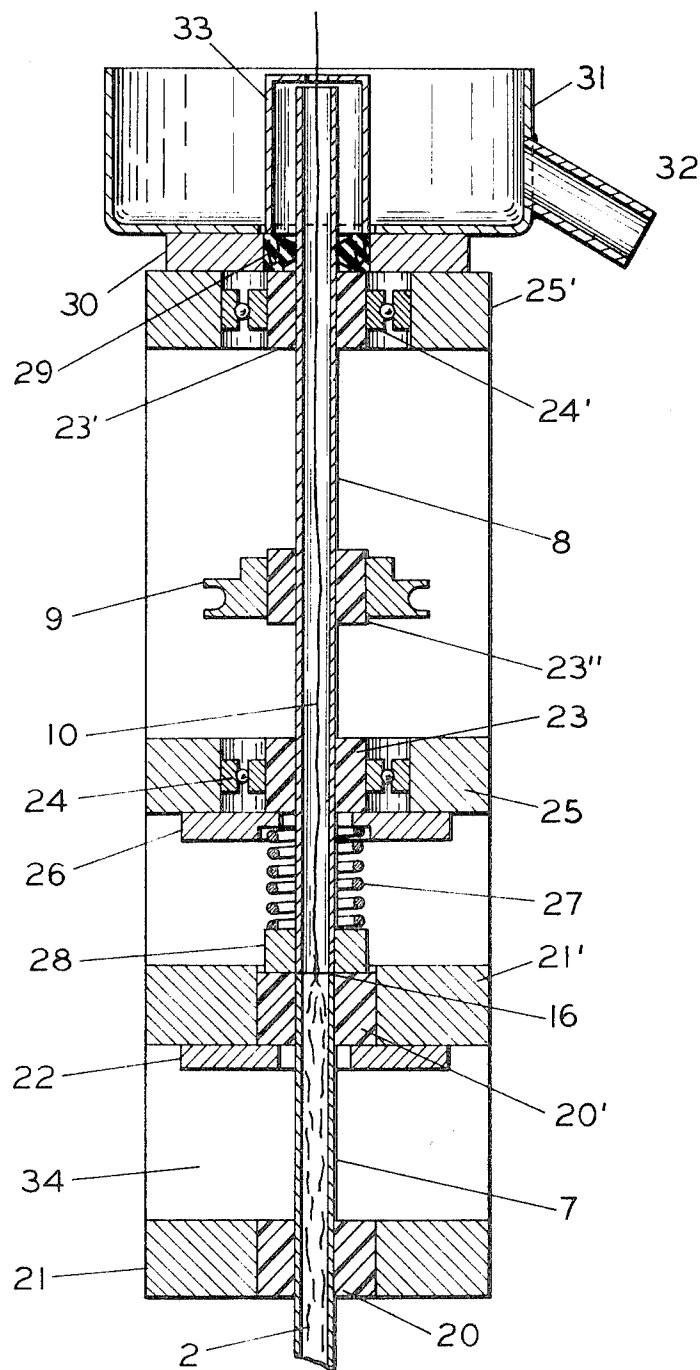


FIGURE 2

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NOVEL YARN AND PROCESS

The invention described herein was made in the course of or under a contract or subcontract thereunder with the U.S. Department of Defense, Office of Naval Research.

BACKGROUND OF THE INVENTION

The field of the invention is that of yarns of low and high modulus staple fibers suited for use in the preparation of reinforced composites and the process of preparing such yarns with axial alignment of the high modulus fibers.

Reinforced composites produced generally by molding a matrix material have been reinforced with a variety of high modulus fibers and filaments for increased strength and stiffness. But the greatest increases are only realized when the high modulus reinforcing fibers or filaments are aligned in the direction in which the greatest strength and stiffness are desired. When continuous high modulus filaments are employed this can generally be achieved by known methods. However, when high modulus staple fibers are to be employed their alignment in the desired direction or directions is much more difficult. It is particularly difficult when employing the very brittle and fragile whisker fibers of silicon carbide and other metal carbides and nitrides, graphite and the like. In fact short of fully aligning such whisker fibers by laborious hand operations and then infusing the arrangement with a setting liquid to fix the whiskers in their alignment no fully successful method for their use as aligned reinforcing fibers has been developed.

It would be very desirable if such high modulus staple fibers and particularly whisker fibers could be aligned in a continuous yarn which yarn could then be employed directly in producing a molding lay-up for later infusion with a moldable matrix material, resinous, metallic or ceramic, or in which the lay-up produced could be charred and the carrier fibers volatilized so that the fired lay-up could then be infused with the desired matrix material. Such a yarn has been produced by the present invention.

Although conventional textile processes cannot be used to produce such yarns, it was previously known to produce yarns from one or more textile type fibers of generally low modulus by various methods generally described as open-end spinning where a yarn is produced from staple fibers directly. Open-end spinning processes employ several different modes of collecting and assembling fibers including a fluid vortex, twisting by a mechanical rotating element from a collecting zone, overlapping of tufts of fibers on a collecting drum and twisting them as withdrawn, and collection on a rotating collecting surface and twisting onto a seed yarn as in so-called "pot spinners." None of these methods are adapted to handle short, stiff or fragile high modulus fibers since most of them require well crimped fibers of relatively low modulus. The fluid vortex spinning systems have not employed sufficiently strong hydrodynamic forces to handle such short, stiff or fragile uncrimped fibers.

One such fluid vortex system employing liquids such as water as a fluid has been described in which yarns of low modulus crimped textile type fibers could be produced by means of the vortex produced in a two-part tube with a rotating terminal portion. However, such processes are unsuccessful when attempts are made to spin yarns comprised of high modulus short, stiff or fragile fibers as well as textile type fibers.

It has now been found that blended yarns of low and high modulus fibers including high modulus fibers of whisker type and in which the high modulus fibers are controlled in axial alignment can be produced by a fluid vortex method. The yarns are suited for use in preparing preforms for infusion by liquid or molten matrices and thereafter for molding or otherwise forming to form reinforced composite structures of increased strength and stiffness in controlled desired directions. A fluid vortex method has been found by which such yarn can be produced which is subject to control in the alignment of the

high modulus fibers and for the production of multicomponent yarns which previously could not be produced either by conventional textile processes or the so called open-end spinning technique.

BRIEF DESCRIPTION OF THE INVENTION

The present invention embraces a process of fluid vortex spinning of yarns comprising forming a dispersion of discrete high modulus refractory fibers and low modulus fibers in a viscous carrier liquid, establishing a flowing stream of said liquid dispersion through a passage whose end portion at least is straight, rotating about its axis the terminal portion of said stream thereby to produce a yarn, and separating the carrier liquid from the yarn so produced.

It also embraces a yarn product comprising a composite yarn of aligned high modulus refractory fibers and wrapped low modulus fibers in yarn form which can be used as reinforcing agent in composite matrices. The viscous carrier liquid used is a liquid in which the two types of fibers are dispersible and which is sufficiently viscous to produce relatively high hydrodynamic forces in the flowing and rotating stream formed.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic drawing of certain apparatus suitable for carrying out the process of the invention.

FIG. 2 is an enlarged sectional view of that portion of the apparatus of FIG. 1 from points A to B of FIG. 1 with fluid effluent pot shown.

DETAILED DESCRIPTION OF INVENTION

The present invention is of a novel yarn structure and a process for producing such yarn by fluid vortex spinning. Basically the process comprises forming a dispersion of discrete high modulus refractory fibers and low modulus fibers in a viscous carrier liquid, establishing a flowing stream of said liquid dispersion through a passage whose end portion at least is straight, rotating about its axis the terminal portion of said stream to produce a yarn, and separating the carrier liquid from the yarn so produced.

The fibers utilized in the process and forming the yarn are of two general types, high modulus refractory fibers and low modulus fibers. The high modulus fibers are all those of high strength and stiffness useful as reinforcing fibers in composites with resinous, metallic, ceramic or other moldable matrices. They include staple fibers of glass, metal such as boron, steel, aluminum and the like, graphite and high temperature resistant polymers such as aromatic polyamides and other resins as well as those occurring generally in the form of "whiskers" such as silica, silicon carbide, silicon nitride, and the carbides and nitrides of other metals of very high stiffness and strength. In general the staple fibers most useful are those of lengths from about one-fourth to 1.5 inch or somewhat longer. Likewise the whisker fibers of lengths of about one-fourth to 1 inch or greater are most useful. Fibers and whiskers of lengths less than the internal diameter of the passage leading to the rotating portion of the apparatus can be employed, but will generally not be as well aligned with the axis of the resulting yarn, but more generally dispersed at all radii throughout same and at more or less random angles of incidence to such axis. Hence, the yarns produced therefrom afford less control of the strength and stiffness in a given desired direction of composites made therefrom.

The low modulus fibers may generally comprise any staple fiber of textile type which is of a length that will not plug the passage of the apparatus used. The preferred lengths of such low modulus fibers range from about three-eighths to 1½ inch or longer and generally it is preferred to use low modulus fibers somewhat longer than the high modulus fibers used. Such low modulus fibers will normally possess aspect ratios ranging from about 100 to 1,000 or greater. The diameter of the low modulus fibers is not critical but may embrace any size

generally useful in the production of textiles. Large diameter filaments are useful but are not preferred because of the increase in size of the yarn and the lower volume percent of high modulus fibers in the resulting yarn. The low modulus fibers can be crimped or uncrimped.

The viscous carrier liquids which can be used are any in which the fibers are dispersible, are chemically inert thereto, and which will produce relatively high hydrodynamic forces in the flowing and rotating stream form. Fluids with viscosities of from about 30 to about 20,000 poise or higher can be used. Preferably fluids of from about 50 to 2,000 poise are used. Also it is desirable to employ liquids which are easily separated from the yarns produced and such are preferred. Many viscous liquids can be employed including glycerol, and polyglycols of high molecular weight, silicone oils of suitable viscosities, polymeric carboxylic acid esters of suitable viscosities, sugar solutions such as glucose, sucrose and the like, corn syrups of various viscosities, mineral oils of various viscosities such as white mineral oil, vegetable oils such as peanut oil, rape oil, castor oil and epoxidized corn oil, soya oil and the like and other liquids and mixtures thereof falling within the above viscosity range. The sugar and corn syrups and polyglycols are particularly preferred because of the ease with which they can be washed from the yarn product with water only. The viscosity of the viscous liquid can be controlled by varying the dilution varying the temperature or by blending different liquids or different viscosities of the same liquid to obtain intermediate viscosities.

The dispersion of the staple fibers in the viscous carrier liquid may be accomplished in any convenient manner, such as by stirring, kneading or other form of agitation or by blending an already prepared master batch in a miscible liquid or the same liquid. With the high modulus fibers employed it is generally sufficient to simply stir the fibers which have been deposited on the surface or in the carrier liquid for a short time at a few hundred r.p.m. to substantially disperse the fibers in a relatively homogenous manner. Likewise the same procedure can be employed with a low modulus or textile type fiber. However, with some of the longer fibers, particularly the longer low modulus fibers, the use of a rotating stirrer whether round or in other form frequently results in a balling up of the longer fibers between the stirrer and the walls of the vessel containing the dispersion. When this happens such balls of fiber have to be removed from the dispersion and additional fiber added to make up the desired concentration. A convenient method for dispersing fragile fibers and such longer fibers is to deposit groups of the fibers on the surface of the viscous liquid and thereafter knead them by repeated vertical working of a stirring rod or cylinder so that these fibers gradually disperse downward into the viscous liquid. This avoids any balling up effect from rotational dispersion. If desired, dispersing aids such as wetting agents or other form of dispersant may be added to the fibers or the liquids to assist in obtaining relatively homogenous dispersions thereof.

With reference to the drawing an apparatus for carrying out the process is schematically illustrated in FIG. 1 thereof. Basically such apparatus consists of a pressure vessel or tank 1 for receiving the dispersion 2 of fibers in the viscous carrier liquid and which is fitted with an exit conduit or tube 3. This tube may conveniently be adapted with a flared or funnel shaped lower end to assist in entraining the dispersed fibers with the carrier liquid. It will likewise be supplied with a source of gas pressure 4 and a gauge 5 to determine the pressure applied. The exit conduit or tube 3 which is desirably fitted with a valve 6 to control flow therethrough, is not necessarily a straight conduit as shown but may take any position except that the latter portion thereof where it joins a rotating conduit tube 8 should be straight. The rotating tube 8 mounted in flexible sleeves and mounts is supplied with a pulley 9 adapted to be driven by a motor 11 with a pulley 12 through a belt, cable, chain or V-belt drive and the speed of the motor controlled by controller 13. The rotating conduit or tube is thus adapted for rotation at speeds varying from 100 to 4,000 to 5,000 r.p.m.

Yarn 10 formed therein is taken up on a reel 14 which is preferably perforated and desirably traverses a snubber roll 15 prior to its final take-up.

The details of the rotating tube assembly are shown in FIG. 2 of the drawing. Reference is made to FIG. 2 showing the end portion of the fixed tube 7 and the entirety of the rotating tube 8 and the manner of their mounting and sealing. Fixed tube 7 is pressed through flexible sleeves 20 and 20' preferably of Teflon or other sealing materials and the seals 20 and 20' in turn mounted in mounts 21 and 21'. The mounts are in turn fixed to a frame 34 which serves to fix same. The rotating tube 8 is likewise carried in seals 23 and 23' of Teflon or other sealing material which in turn are mounted in bearings 24 and 24' carried by mounts 25 and 25'. At approximately the middle of the rotating tube 8 seal 23'' is carried within a pulley 9 adapted for rotation of the tube. In order that a good seal against the fixed tube is maintained the abutting end of the rotating tube 8 is supplied with a rotating seal 28 of Teflon or even more elastic sealing material and a spring 27 which rests on metallic plate 26 carried by the mount 25. A reciprocal plate 22 carried by mount 21' serves to fix and stabilize the Teflon seal 20' of the fixed tube so that constant spring biasing pressure is maintained at the abutted sealed junction 16 of the fixed tube 7 with the rotating tube 8. At the opposite or free end of the rotating tube 8 there is placed an oil seal 29 within mount 30 serving to prevent the effluent carrier liquid from running back down the rotating tube. The mount 30 serves to separate from the top bearing mount 25' the effluent pot 31 fitted about the exit end of the rotating tube 8. This pot 31 is supplied with an exit conduit 32 to a receptacle, not shown, for the separated carrier fluid. In order to prevent the yarn 10 exiting from the rotating tube 8 from catching and wrapping about the end of the tube, the exit end of the rotating tube is supplied with a stationary cap 33 with an exit aperture just smaller or equal to the internal diameter of the rotating tube 8.

The apparatus described above was employed in all of the examples of the process and to produce the yarn of the invention. Other equivalent apparatus of somewhat different design could likewise be employed in the present process. This form of the apparatus was illustrated as vertically arranged which was done to minimize the gravitational effects on the spinning process and the viscous liquid employed. However this is not essential in carrying out the process and any other arrangement of the relative parts of the apparatus could likewise be employed including horizontal disposition.

The process of the present invention will hereinafter be described with reference to the apparatus described above for convenience but it is understood that some variations would be adopted when other similar apparatus of different arrangement were employed. The process is carried out by means of charging the pressure vessel 1 with a dispersion 2 of both high modulus and low modulus fibers in the highly viscous carrier liquid. The spinning is initiated by pressuring the pressure vessel 1 by means of gas pressure inlet 4 to establish a flowing stream of the liquid dispersion 2 through the fixed tube 3 and, upon opening of valve 6, through the rotating tube 8. The rotating tube 8 is rotated by means of motor 11 and associated controller 13 through pulleys 12 and 9 at a speed correlated with the flow induced by pressuring the vessel 1. Generally spinning has been successful at speeds of from 800 to 3,000 to 4,000 r.p.m. Higher rotational speeds are desirable and can be effected in equipment designed to sustain such rotational forces.

The dispersion 2 of high and low modulus fibers in viscous carrier liquid is caused to flow through the fixed tube 3 and by establishing such flow both types of fibers are axially aligned across the flowing stream of viscous fluid. It is essential that laminar flow in the stream be maintained so that areas of turbulence will not be developed since these will adversely affect the axial alignment of the fibers within the dispersion. Contrary to the teachings in some of the prior art processes, in the viscous fluids employed and the distances traversed through tube 3 there is little or no progression of fibers to the axis of

the flowing stream and fibers aligned with the axis are found at all radii of the stream.

Near the interface 16 with the rotating tube 8 a vortex in the flowing stream of viscous fluid is formed and the hydrodynamic forces induced thereby cause the condensation of the entrained fibers into a yarn. This yarn 10 near the vortex is comprised of axially aligned high modulus fibers distributed across the diameter of the yarn and intertwined loosely by the low modulus fibers of the dispersion. The helix angle and amount of twist of the low modulus fibers increases during progression through the remaining portion of the rotating tube 8. There is no sharp demarcation between the two types of fibers due to their more or less general occurrence throughout the dispersion 2 and the yarns 10 consist of an intermingling of high modulus and low modulus fibers. However, due to their greater stiffness the high modulus fibers tend to maintain their axial alignment while the low modulus fibers are more readily twisted about them. Some high modulus fibers occur at the periphery of the yarn bundle, but when their lengths are longer than the internal diameter of the fixed tube 7 they are generally in axial alignment and demonstrate relatively low angles of incidence with the axis of the yarn 10.

In spinning the viscous carrier liquid in most part separates from the yarn as it exits from the end of the rotating tube and such fluid is trapped by the effluent pot 31 and directed by conduit 32 to a receptacle, not shown. The stationary cap 33 with its opening no larger than the internal diameter of the rotating tube 8 prevents the raw yarn catching thereon and wrapping about the end of the rotating tube. Additional small amounts of the viscous fluid will be thrown or drained off the yarn during its passage about the snubbing roll 15 and its take-up on the take-up reel 14. This take-up reel 14 is desirably a perforated reel, generally metal, which is adapted for draining away entrained viscous fluid and for subsequent thorough washing of the yarn taken up for removal of the final amounts of entrained fluid. The speed of the take-up reel is generally controlled to match that of production and exit of the yarn produced by the rotating tube assembly so as not to apply unusual forces to the yarn during its formation. The flow rate from the receptacle 1 is likewise adapted to maintain this yarn velocity constant.

In the apparatus described above the conduit or tube 3 from the receptacle 1 to the valve 6 comprised a $\frac{3}{8}$ -inch tube. The valve was fitted with a reducer to one-fourth inch size so as to receive the 6-mm. tube fitted thereto. The internal diameter of the fixed tube 7 and of the rotating tube 8 were 4 mm. and the relative lengths thereof were 4 inches of fixed tube 7 and 6 inches of rotating tube 8. These sizes however are not limitations on the apparatus in general but were used for convenience in the apparatus assembled. Larger and somewhat smaller tubes can be successfully employed in the apparatus described above with suitable adaptations in the sizes of seals and motor drives.

The yarns of this invention produced by the process described above demonstrate a high degree of alignment of the high modulus fibers with an intertwining of the low modulus fibers about the high modulus fibers. These high modulus fibers are at varying radii within the yarn although aligned axially therein. Such yarns are produced from crimped or uncrimped textile length low modulus fibers and straight, stiff high modulus fibers including whisker fibers. In all of the yarns produced the degree of alignment is such that the yarns are very suited for use as reinforcing members for composite matrices both directly in the case of some of the low modulus fibers employed and after charring and burn-out of the low modulus fibers in other cases. Not only do the yarns afford a much easier physical form for producing lay-ups and preforms for subsequent infusion with matrix materials, but they also afford a higher degree of alignment of the reinforcing high modulus fibers than is obtainable by other textile, mechanical or production means. Thus such yarns meet a real need in the art of producing fiber reinforced composites in a more efficacious manner and at reduced cost.

The present invention will be more fully comprehended from the examples which follow.

EXAMPLE 1

A slurry or dispersion of fibers in corn syrup was prepared from 8 grams of glass fiber 0.57 mil diameter and chopped to a staple length of one-half inch which had been fired at 600° C. for 23 minutes to remove the size added to 1,400 ml. of a corn syrup with a viscosity of approximately 130 poise at room temperature. These fibers were dispersed by rotating a 2-inch diameter Teflon cylinder at 300 r.p.m. for 20 minutes. The dispersion was essentially complete and quite homogenous. Thereafter the dispersion of glass fibers in corn syrup was heated to 60° C. in a heating mantle and the low modulus fibers dispersed therein. The low modulus fibers were bicomponent acrylic fibers of 0.7 mil average diameter cut to three-fourths inch staple length. They were dispersed by gradually placing groups of fibers on the surface of the heated corn syrup and stroking them into the syrup by a vertical motion with a glass rod. When addition was completed a brief stirring with the 2-inch diameter Teflon cylinder evenly dispersed the low modulus fibers without causing balling. The dispersion of both types of fibers appeared to be homogenous. The dispersion was cooled to room temperature for spinning.

The dispersion prepared as above was spun into yarn employing the apparatus described herein, which consisted of a $\frac{3}{8}$ -inch exit conduit from the slurry receptacle, a 4-inch fixed section of 6-mm. tube and a 6-inch rotating section of 6-mm. tube, both tubes having an internal diameter of approximately 4 mm. Spinning of yarn through the apparatus was initiated by pressuring the vessel containing the dispersion to 20 p.s.i. and opening the valve. The take-up reel was driven at a rate of 0.66 inch per second and the rotating tube driven at a rotation of 2,000 r.p.m. When flow of the corn syrup dispersion appeared at the effluent cup, probing of the cup with a stirring rod picked up the yarn and it was lead over the snubbing roll and to the take-up reel. Continuous spinning was established and a 7-foot sample of yarn was spun. Qualitative inspection of the yarn under a microscope revealed excellent axial alignment of the glass fibers throughout the yarn with the low modulus fibers intertwined thereabout at a low helix angle. The yarn produced was suitable for use in molding reinforced composites. A $\frac{1}{4} \times 4 \times 0.06$ -inch sample of a curable epoxide resin and curing agent containing such yarn as reinforcement has good flexural strength and modulus in the direction of lay of the yarn demonstrating effective reinforcement by the yarn.

EXAMPLE 2

In this example an additional composite yarn employing silicon carbide "whisker" fibers was prepared employing the same apparatus as described hereinbefore. In the same manner as detailed in Example 1 above 0.7 gram of dark green "long" silicon carbide whiskers which had been harvested from a random ball of such whiskers and of average length of approximately one-half inch were placed in tufts in a 1,000 ml. of corn syrup of viscosity of approximately 130 poise. Rotation of the 2-inch Teflon cylinder at about 350 r.p.m. easily dispersed the whiskers. Thereafter 7 grams of the bicomponent acrylic fibers employed in Example 1 were dispersed by the vertical kneading procedure there described while the corn syrup dispersion was heated to 60° C. Thereafter the dispersion was cooled to room temperature and spun.

The yarn was spun in the same apparatus described above. Flow was initiated by pressuring the vessel containing the dispersion of fibers at 17 p.s.i., driving the rotating tube at 1,800 r.p.m. and driving the take-up reel at 0.66 inch per second. A yarn was produced upon initiation of flow and continuous yarn production ensued for a total take-up of 80 feet of composite yarn. Upon microscopic examination of the yarn it was found that all the whisker fibers longer than the internal diameter of the fixed and rotating tubes, approximately 4 mm., were aligned axially in the yarn and intertwined with the

low modulus acrylic fibers which were at a low helix angle. Some breakage of the long carbide whisker fibers occurred and those short fibers shorter than the internal diameter of the rotating tube were found to be dispersed at random angles throughout the yarn. The yarn was quite suitable for use in preparing molding lay-ups and in reinforcing molded composite samples.

This example demonstrates the efficacy of the present process for the production of yarns of carbide and other whisker type fibers in a form which facilitates their alignment and use in producing directionally reinforced composites.

EXAMPLE 3

This example illustrates the utility of cellulosic fibers as low modulus fibers in the present process. Rayon fibers of 0.36 mil diameter cut to three-fourths inch staple length are employed to form a yarn with the same ½-inch glass staple fibers of Example 1. The dispersion of 4 grams of the glass fibers and 7 grams of rayon fibers in 1,400 ml. of corn syrup of 100 poise viscosity is prepared as in Example 1. When spun through the apparatus described above with fixed and rotating tubes of 6 mm. internal diameter at a pressure of 20 p.s.i. on the dispersion, the rotating tube driven at 1,650 r.p.m. and the yarn take-up reel driven at a speed of 0.8 in./sec. a yarn with no breaks is secured with continuous spinning until the dispersion is exhausted. A uniform yarn is produced with the glass fibers axially aligned and intertwined by the rayon fibers.

It will be understood that the foregoing details of apparatus and process of the invention are given by way of example only and that modifications can be made to suit the requirements of various fibers and viscous fluids without departing from the scope of the invention as defined by the claims.

I claim:

1. A process of fluid vortex spinning which comprises forming a dispersion of discrete high modulus refractory staple fibers and lower modulus staple fibers in a viscous carrier liquid having a viscosity of from 30 to about 20,000 poise, establishing a flowing stream of said liquid dispersion through a passage whose end portion at least is straight, rotating about its axis the terminal portion of said stream thereby to produce a yarn, and separating the carrier liquid from the yarn so produced.

2. The process of fluid vortex spinning of claim 1 wherein the high modulus refractory fibers have a staple length of from

one-fourth inch to about 1.5 inches.

3. The process of fluid vortex spinning of claim 1 wherein the high modulus refractory fibers are glass.

4. The process of fluid vortex spinning of claim 1 wherein the high modulus refractory fibers are whisker fibers.

5. The process of fluid vortex spinning of claim 1 wherein the high modulus refractory fibers are silicon carbide whisker fibers.

6. The process of fluid vortex spinning of claim 1 wherein the lower modulus fibers have a staple length of from three-eighths inch to about 1.5 inches.

7. The process of fluid vortex spinning of claim 1 wherein the lower modulus fibers are synthetic cellulosic or polymeric staple fibers.

8. The process of fluid vortex spinning of claim 1 wherein the lower modulus fibers are acrylic staple fibers.

9. The process of fluid vortex spinning of claim 1 wherein the lower modulus fibers are cellulosic staple fibers.

10. The process of fluid vortex spinning of claim 1 wherein the carrier liquid is corn syrup.

11. A composite staple fiber yarn of high modulus refractory fibers and lower modulus fibers, which yarn comprises axially aligned high modulus refractory staple fibers intermixed with and intertwined by lower modulus staple fibers.

12. The composite staple fiber yarn of claim 11 wherein the high modulus refractory fibers have a staple length of from about one-fourth inch to about 1.5 inches.

13. The composite staple fiber yarn of claim 11 wherein the high modulus refractory fibers are whisker fibers.

14. The composite staple fiber yarn of claim 11 wherein the high modulus refractory fibers are glass.

15. The composite staple fiber yarn of claim 11 wherein the high modulus refractory fibers are silicon carbide whisker fibers.

16. The composite staple fiber yarn of claim 11 wherein the lower modulus fibers have a staple length of from three-eighths inch to about 1.5 inches.

17. The composite staple fiber yarn of claim 11 wherein the lower modulus fibers are synthetic cellulosic or polymeric fibers.

18. The composite staple fiber yarns of claim 11 wherein the lower modulus fibers are cellulosic fibers.

19. The composite staple fiber yarn of claim 11 wherein the lower modulus fibers are acrylic fibers.

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