United States Patent

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[72] Inventors **Malcolm Basche**
West Hartford;
Urban E. Kuntz, East Hartford, both of, Conn.

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[73] Assignee **United Aircraft Corporation**
East Hartford, Conn.

[54] **METHOD OF COLLIMATING FIBERS**
1 Claim, 3 Drawing Figs.

[52] **U.S. Cl.** ..... **226/196,** 19/65 T, 156/161, 156/181
[51] **Int. Cl.** **B65h 23/26,** D01h 13/02, B65h 57/14
[50] **Field of Search** ..... 156/181, 166, 169, 161, 436, 441; 226/196, 197, 198, 199, 200; 19/65 T

[56] **References Cited**

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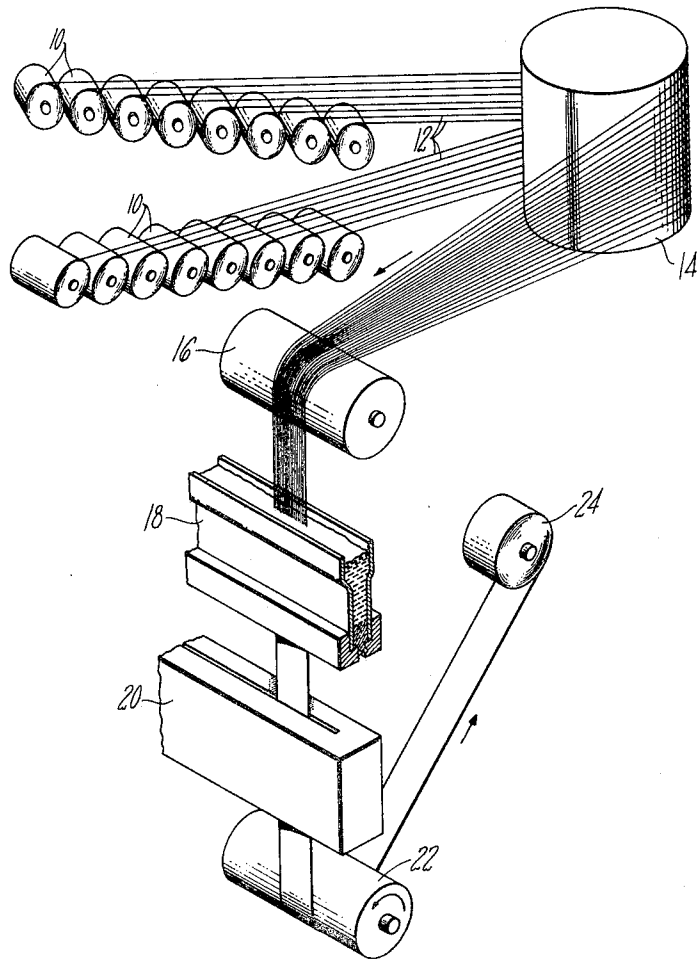
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Primary Examiner—Carl D. Quarforth
Assistant Examiner—Roger S. Gaither
Attorney—John D. Del Ponti

ABSTRACT: A method for collimating a plurality of filaments into parallel, side-by-side contiguous relation including passing the filaments around first and second rollers, the rollers having their axes perpendicular to, but noncoplanar with, each other whereby all but one filament will be subjected to sidewise forces.

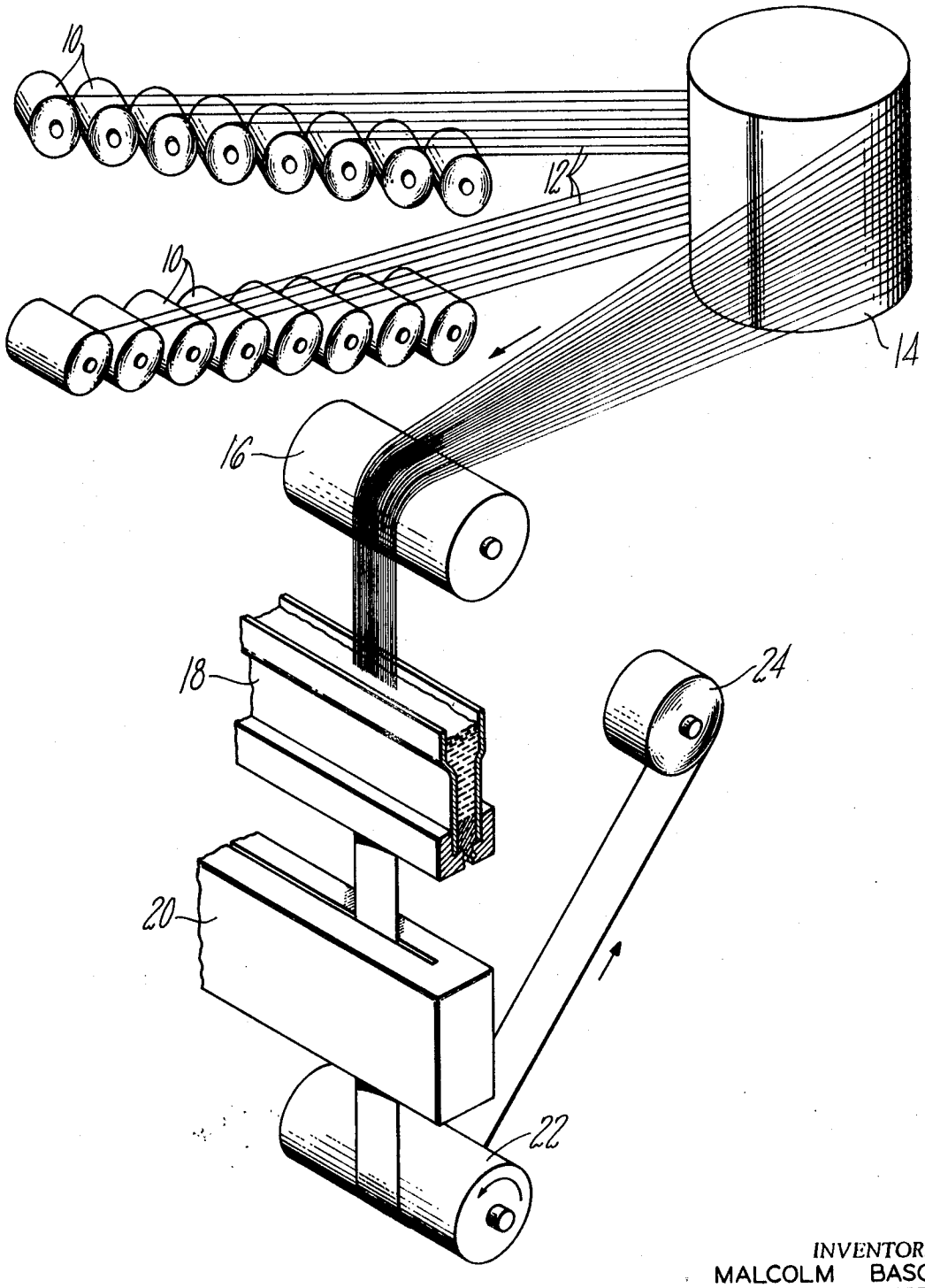


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SHEET 1 OF 2

FIG. 1



INVENTORS
MALCOLM BASCHE
URBAN E. KUNTZ

BY John D. DeLuca

ATTORNEY

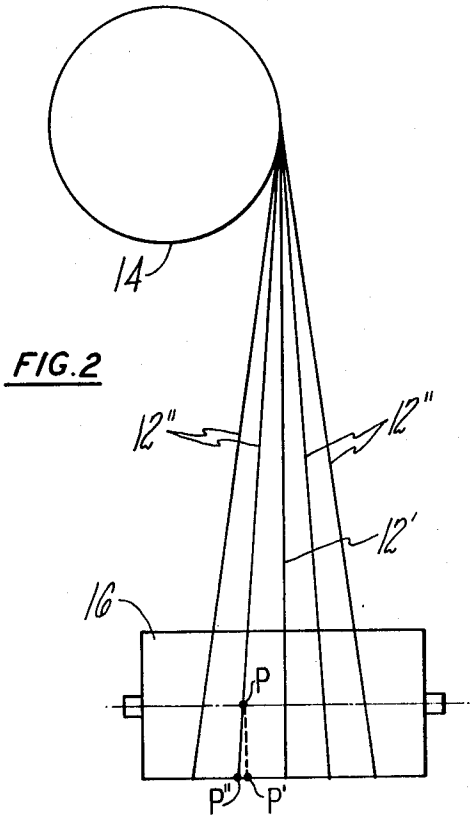


FIG. 2

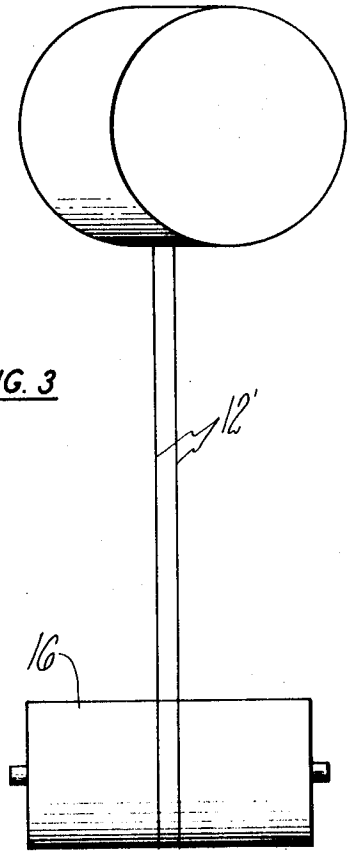


FIG. 3

METHOD OF COLLIMATING FIBERS

BACKGROUND OF THE INVENTION

This invention relates to the production of multiple fiber composite tape and more particularly relates to means for collimating a plurality of individual filaments into a parallel side-by-side relationship to facilitate the production of unidirectional fiber-reinforced composites.

It is known that fiber strengthening offers the potential of significant improvements in the fabrication of composite materials. The concept of fiber strengthening is based on the fact that materials produced in fibrous form frequently exhibit a higher elastic modulus and a higher strength than the corresponding materials in bulk. In order to exploit the attractive physical properties of continuous filamentary materials however, it is necessary to gather the fibers together into a composite structure in such a way that failure in several isolated fibers will not be transmitted to the surrounding fibers and further, to distribute the load with reasonable uniformity over the entire fiber bundle. One method of achieving this result is to gather the fibers into a collimated relationship and infiltrate them with matrix material to form a monolayer tape.

One of the paramount problems in continuously producing unidirectionally reinforced composite tapes resides in the inherent difficulty of incorporating the fibers into the matrix material. There are basically two ways in which continuous filaments may be incorporated into the matrix in a parallel, uniformly spaced fashion. One way is to precision align the filaments in noncontacting relation prior to encasement and to control their spacing by tension means until the matrix material is applied. Because of the elaborate and intricate equipment necessary to maintain exact spacing, this procedure is unsatisfactory and is generally considered commercially unattractive. The other general method involves precoating each individual filament with matrix material so that the fibers can subsequently be aligned in side-by-side contacting relation with the filaments being spaced apart by the thickness of the coatings. Although this procedure has done away with the problem of spacing maintenance it has generated new problems, one of which is the assiduous requirement that the apparatus be capable of causing the individual, precoated filaments to continuously assume and maintain intimate side-by-side contact in a monoplanar configuration. The prior art has shown apparatus for collimating filaments together into a ribbon, however, these prior techniques incorporate specialized components, often unreliable, as for example concave roller or toothed comb elements in order to achieve the aforesaid collimation.

Exemplary of the prior art teachings are those shown in Letters Patent U.S. Pat. No. 3,009,512 issued to Guay on Nov. 21, 1961 and U.S. Pat. No. 3,258,378 issued to Kelsey on June 28, 1966. The Guay patent teaches the use of a concave highly polished roll across which a plurality of filaments are pulled under tension in order that the filaments will come together under the influence of a sidewise pressure. Unfortunately, the operation of the Guay device frequently resulted in the filaments riding one over the other. One of the disadvantages of the Guay device can be traced to the use therein of a collimating roller with a nonconstant diameter so that adjacent fibers, in passing thereover, are subjected to different circumferential speeds and hence imbalances in filament tension and sidewise pressure effects. The Kelsey patent, in an effort to resolve the problems of the Guay device, taught that a tiltable comb could be utilized, in conjunction with a tension inducing roller pair, to position the filaments adjacent to each other without the generation of any sideways pressure at all. The Kelsey teaching requires that the toothed comb be maintained at a precise inclination so that the cosine of the angle of tilt of the comb multiplied by the spacing of the threads be equal to the widths of the threads. To this end, a micrometric screw adjustment was provided.

The present invention, while utilizing some of the concepts underlying both the Guay and the Kelsey processes, produces monolayer tapes by a distinct and different process and by an improved and simplified apparatus without the necessity for concave rollers, adjustable toothed combs or any other specialized equipment at all.

SUMMARY OF THE INVENTION

The present invention relates to a means for collimating a plurality of filaments into a parallel side-by-side relationship preparatory to integration into monolayer tape product without necessitating the use of concave roller or toothed comb elements. The technique includes an improved process and apparatus whereby adjacent filaments initiating from diverse sources are automatically made to assume a continuous contacting relation by the exertion of a sidewise pressure induced by the juxtaposed relation of a sequence of rollers.

According to one aspect of this invention, a plurality of continuous filaments each issuing from a separate feed source are sequentially passed around a pair of cylindrical rollers, the rollers being so located with respect to each other that the filaments issuing from the first roller are subjected to sidewise forces and are naturally made to assume an intimate state of contact whereby high quality is assured without the necessity for critical production control. One advantageous feature of the present apparatus is the fact that substantially all contact with the fibers during the orientation period is a rolling contact so that the likelihood of wear and damage to both the fiber and the equipment is minimized.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic perspective view of typical apparatus used in the practice of the invention;

FIG. 2 is a plan view of a portion of the apparatus shown in FIG. 1; and

FIG. 3 is a plan view of the rollers shown in FIG. 2 but with their axes in a nonperpendicular orientation.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to the drawings, wherein like numbers indicate like elements, a series of supply rolls or spools **10** are provided as a convenient source of filaments **12**. The filaments **12** assume a rolling contact with a pair of cylindrical rollers **14** and **16** and pass therearound as shown. The roller **14** acts as a spacing idler or guide roller while the roller **16** acts as a collimating roller when the rollers are critically disposed in a particular angular relationship, as hereinafter described, so that the filaments are induced to issue from the roller **16** as a monolayer of contiguous and coplanar collimated fibers. The fibers are subsequently transfixed into permanently collimated relation by means of a matrix overcoat applied by passage through a resin pot **18** and curing furnace **20**. A detailed example of a practical coating apparatus is described in copending application Ser. No. 752,080 entitled "Process for Coating Filaments with a Resin and Apparatus Therefor" filed Aug. 12, 1968 and sharing a common assignee with the instant invention. After coating and curing, the resulting unidirectional fiber reinforced tape is passed over a guide roller **22** and stored on a takeup reel **24**.

The spools **10** are preferably arranged in banks with each bank of spools having the spools positioned with their axes parallel but at staggered elevations as shown in the drawings. However, it will be appreciated that so long as the spools **10** are sufficiently staggered to prevent filament interference, they may be arranged in any practical configuration. The number of supply spools utilized is a matter of choice with an upper quantity limit being determined by the axial length of the rollers **14** and **16**.

As hereinbefore suggested, the angular relation of the idler **14** and the collimating roller **16** is precise and crucial. The two rollers must be disposed so that a sidewise pressure will be exerted on all but one of the filaments. In particular, the rollers

must be disposed with their axes perpendicular to each other. Such a relationship assures that all of the filaments **12** will automatically be made to assume side-by-side contact on the collimating roller **16**. It will be appreciated that one of the advantages of the instant invention is that if one of the filaments breaks during the operation, the remaining fibers will seek intimacy and close the gap created thereby, thus salvaging what would otherwise be unacceptable tape. That two common rollers could produce such dramatic results in terms of collimating efficiency was a discovery totally unexpected, particularly in view of the prior art techniques. The discovery is best explained with reference to FIG. **2** wherein is shown the two rollers positioned with their axes mutually perpendicular but not coplanar. Because of this roller relationship, only one of the filaments, designated by the numeral **12'**, can make an angle of 90° with the axis of the collimating roller **16**. All of the other filaments **12''** make angles which are either less than or greater than 90°. As the filaments are pulled over the collimator **16** and cause it to rotate, a point P representing the point of initial contact between the roller and the filament **12''** is caused to move. As the roller rotates, the point P on the roller moves to P' while the corresponding point P on the filament moves to P''. There is thus a relative axial slip P'–P'' which, since there is friction between the filament and the roller, will cause a sidewise force to act on each filament **12''** tending to displace them towards the base fiber **12'**. As the filaments come together into a monolayer of parallel fibers, the sidewise forces will diminish but will nevertheless act to maintain the fibers in abutting contact since the filament diameter, while small, is still finite and all but the base filament will have an angle with the axis of roller by which it differs slightly from 90°. As can be seen from the foregoing, one of the advantages inherent in the system resides in the fact that the automatic diminution of sliding contact between fiber and roller acts as a safeguard to keep the fibers from riding up over one another.

In contrast to the aforesaid concept and, as can be seen in FIG. **3**, when the axes of rollers **14** and **16** are not mutually perpendicular, there exists a situation where more than one filament can be simultaneously perpendicular to the axis of the roller **16**. As a result, the filaments will not seek intimacy with each other and will instead be spaced apart by an exact amount dependent upon the departure from mutual perpendicularity of the rollers **14** and **16**. It is only when the rollers are disposed in the critical relation as heretofore described that all of the filaments will assume, in a monolayer, a continuously contacting collimated relation.

In one investigation with the apparatus as shown in FIG. **1**, 10 fibers of 4 mil boron filament precoated with a 0.2–0.4 mil coating of polyimide resin were passed through a rod-sealed mercury wipe resin pot at a speed of 400–800 ft./hour. The precoated boron filaments assumed a contiguous collimated relation with no spacing detectable therebetween so that after the application of the resin overcoat, the resulting tape displayed fibers that were evenly and uniformly spaced with no boron to boron contact. The tape was tested and had a tensile strength of 198,000 p.s.i. and a 36×10^6 p.s.i. modulus.

While for the sake of clarity and brevity, the foregoing description has been made with respect to specific examples, processes and parameters, these specific embodiments will be understood to be illustrative only, and no limitation is intended thereby. It should for example be understood that the instant method and apparatus for collimating fibers is applicable to all kinds of filaments whether or not precoated. Various other modifications and alternatives will be evident to those skilled in the art within the true spirit and scope of the invention as set forth in the appended claims.

What is claimed is:

1. A method of collimating a plurality of continuous filaments into parallel side-by-side contiguous relationship which comprises,

providing first and second cylindrical rollers with the axis of one roller perpendicular to, but not coplanar, with the axis of the other roller,

supplying a plurality of at least three individual and noncontiguous filaments to be guided around each roller under tension,

passing the tensioned filaments around the first roller in a generally parallel, side-by-side relationship such that no one tensioned filament overlays any other tensioned filament when passing around the first roller,

extending the tensioned filaments towards said second roller whereby only one of the filaments extending from said first roller to said second roller will be perpendicular to the axis of the second roller and the remaining extended filaments on either side of said one filament will be urged towards a 90° relationship with the axis of the second roller,

and further passing the extended filaments around the second roller to form a monolayer of parallel filaments.