METHOD AND APPARATUS FOR THE PRODUCTION OF FIBERS

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INVENTOR

BY Anton Formhals

ATTORNEY
UNITED STATES PATENT OFFICE

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METHOD AND APPARATUS FOR THE PRODUCTION OF FIBERS

Anton Fernhals, Mainz, Germany, assignor of forty-five one-hundredths to Richard Schreiber-Gastell, Mainz, Germany

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This invention relates to the production of a continuous fiber band of artificial filaments by the electric splitting up or shattering of a stream of a solution or dispersion of filament forming material, and, will therefore, for convenience, be referred to as “electrical splitting of fibers”. More particularly the invention relates to an improved process and apparatus for the electric splitting of fibers between electrodes, one of which moves relative to the other and upon one of which the fibers are collected in the form of a continuous coherent fiber band, or sliver. Reference is made to the applicant's copending application, Serial No. 88,428, filed July 1, 1936, relating to a new article of manufacture.

In accordance with the electrical splitting of fibers as disclosed in the U. S. Letters Patent to Fernhals No. 1,975,504 of October 2, 1934, a spinning solution is introduced between a stationary electrode, in the form of a serrated wheel immersed in the spinning solution, and an oppositely charged movable electrode which may be in the form of a revolving wheel, ring, belt, bobbin or drum. The high electric tension between the electrodes causes dispersion or shattering of the splitting solution into a plurality of fine filaments or fibers which are attracted to the movable electrode and temporarily collected thereon.

The method and apparatus disclosed by the above said patent has certain limitations and disadvantages as regards the usable form in which the fibers are collected, and also as regards the quantity of fibers produced at any one time.

In the method described hereinabove one encounters trouble with the spun fibers adhering to the surfaces of the moving collecting belts, drums, wheels, and the like, thereby making it difficult or impossible to remove them satisfactorily in the form of a continuous compact bundle without their damage. Likewise, and especially when it is desired to spin a large mass of fibers as to yield a commercial self-sustaining sliver for direct processing into threads or yarns of good quality, it is found that the fibers themselves tend to be so stuck to one another as to prevent their free separation and “drawing out” in the subsequent textile spinning operation. This sticking together becomes increasingly bothersome with average fiber diameters of several denier per filament and upwards. Furthermore, these sticking phenomena have served to greatly limit the number of spinning jets or streams which may be used with a single given collecting electrode.

In addition to the above recited disadvantages the prior art collecting devices are open to the further objections that they have not served to collect the fibers at once into a compact coherent form with the fibers arranged substantially parallel to each other. The moving electrodes have heretofore exhibited plane or curved continuous surfaces. The entire force area of these electrodes was charged electrically and the charge became uniformly distributed thereover. Thus the fibers tended to collect and distribute themselves more or less at random over these surfaces, rather than to concentrate noticeably in any particular fashion. A compact organization of the fibers in good parallelism on the collector has not been heretofore achieved. While special devices were suggested to assemble the spun fiber masses from the previous collectors in a compact organized form, these devices have damaged the filaments in the process of loosening them from the continuous surface of the collector and at the same time have tended to cause entanglement thereof.

The fiber masses heretofore produced have thus been relatively disorganized, weak, tangled, and badly stuck together, which faults have prevented them from being directly processed into spun threads or yarns of good strength and quality without intermediate textile operations such as opening, carding, combing and the like.

It is the object of the present invention to overcome the above and other limitations, and to yield an artificial fibrous band or sliver capable of being commercially processed to a strong twisted thread, yarn and the like, without intermediate textile operations intervening between the electrical splitting of the sliver and thread spinning operation.

Another object of this invention is to produce a fiber band in which a high degree of parallelism exists between the individual fibers. A further object of the invention pertains to the production, by an electrical splitting process, of a large quantity of fibers, in a continuous, compact, coherent form, while permitting rapid drying of the fibers, eliminating substantial adherence of the fibers not only to each other but to the electrode collecting device as well, and permitting an easy removal of the fiber band from the collecting device without damage to the fibers or the parallel construction of the fiber band. It is a further object of the invention to produce a parallel, coherent fiber band which will be easy to “draw”, 


that is, one in which the individual filaments are relatively disentangled and are free to slide or move relative to each other without substantial damage.

Other objects of the invention will appear hereinafter. The objects of the invention may be accomplished according to one embodiment thereof by delivering a spinning solution from a plurality of nozzles connected to a feed pipe, said nozzles delivering streams of spinning solution into a high potential electrical field created between the nozzles and a moving collecting device, thereby causing said streams to shatter or disperse into a plurality of fibers, collecting the thus formed fibers on a moving collecting device which constitutes one pole of the field, the collecting device being provided with projecting elements or prongs substantially separated from each other and acting as successive individual electrodes which receive the fibers and support them substantially parallel and in the form of a continuous fiber band at or near the points of said electrodes, the space between the prongs permitting the evaporation of the solvent in the fibers and making possible the easy removal of the continuous fiber band from the electrodes by means of any suitable device, such as, for example, the stripping device described below, after which it may be wound onto reels and the like. The prongs are furthermore arranged in generally the same direction permitting the building up of an organized bundle or sliver of substantial dimensions which can be continuously removed from the collector. The threads, due to the large amount of air or other gaseous drying agent coming in contact therewith from all sides, dry out thoroughly and do not adhere to each other to any substantial extent, even though the quantity of fiber spun is large, per unit of time, in comparison with previously known spinning methods.

The stripping device which permits a continuous removal of the formed sliver from the collector generally comprises a disc provided on its circumference with finger-like or lobe-like projections which are adapted to mesh with the electrode prongs on the collector in such a way that the fingers or lobe-like projections of the disc are inserted in the spaces of the belt between the prongs and close to the belt and upon revolution of the disc the lobes move further and farther away from the belt to the extremities of the prong-like electrodes thereby stripping the sliver from the collector, so that the electrodes of the collecting device upon being moved again under the nozzles, are ready to receive another mass or bundle of fibers.

For a further understanding of the invention, reference is made to the following detailed description taken in connection with the accompanying drawings of one specific embodiment of the invention in which:

Figure 1 is a diagrammatic perspective view of a continuous belt-electrode collector.

Figure 2 is an end elevational view showing one form of stripping disc.

Figure 3 is an end view of the endless belt collector and stripping disc.

Referring to the drawing, a plurality of metal nozzles 10 are connected with a pipe 11 which may or may not be metal, and are supplied with spinning solution from the storage tank 12. The nozzles and pipe are electrically connected in circuit with a device 13 for producing high potential electric current. Device 13 may be a transformer and rotary converter for changing ordinary line current such as 110 volt, 60 cycle alternating electric current into a high voltage pulsating direct current or 13 may be any suitable device for producing a high potential direct current. For obtaining special effects in the shattering of a stream of spinning solution, 13 may be a suitable device for producing an alternating current of high potential of any desired or varying frequency. Spaced from the nozzles is a long endless belt 14 preferably comprising rubber or any other suitable non-conductive material, although an electrically conducting material such as a metal may be used. The belt is provided with spaced metal prongs or lugs 15 which are fastened to the belt so as to project from at least one side thereof. The lugs 15 are disposed substantially within the plane of the belt with the projecting ends extending perpendicularly from the side of the said belt. The projecting portions or ends of the lugs are preferably pointed as shown. These lugs constitute the individual electrodes to which the fibers are attracted and the solvent is removed from the fibers and by the lugs from the fiber band at intervals. It is to be understood, however, that the individual prongs may be electrically connected with each other, in which case an electric charge will nevertheless be accumulated on the individual prongs. The belt is driven by pulleys 16 and 17 which are preferably composed of wood or some other suitably electrically non-conducting material. Positioned parallel to the under surface of the belt is shown a long conductor wire 18 attached by means of a conductor 19 to the circuit which includes the high potential source 13. Conductor 18 is spaced from the belt, the spacing of wires 18 receiving a charge from the wire 18 through the air gap therebetween. The potential between the nozzles and the electrodes 15 is maintained between 10,000 up to 100,000 volts and preferably at least 30,000 volts.

The high potential electric charge on the electrodes 15 is of opposite polarity to that imparted to the spinning solution and is preferably lower in potential than that imparted to the said solution so as to prevent undesirable flying about of fibers due to a repelling action of said electrodes. It is furthermore possible to spin with the electrodes 15 grounded so that they are at zero potential, and it is to be understood that such type of apparatus is intended to be included within the broad scope of the invention.

A potential stabilizing and directing means 30 such as a concave curved screen or other wire network is preferably positioned in back of the nozzles 16 and is connected to a charge of high potential electricity of the same polarity as the potential imparted to the spinning solution. The directing means serves primarily to direct the fibers toward the prongs and in addition serves to repel any fibers toward the belt from which occasional fibers sometimes tend to fly back to the spinning nozzles.

The fibers, during the spinning operation, are attracted to and electrostatically adhere to the electrode prongs 15 and travel with the belt supported by the prongs. The fibers form a sliver which is preferably removed continuously at one end of the belt collector by means of a stripping device 20 mounted on a shaft 21 the axis of which is inclined towards the axis of the shaft of pulley 17, so that the lobes of the disc move outwardly as the disc revolves thereby scraping off
the sliver from the collector, the sliver being continuously wound up on a suitable reel 22 or other collecting device.

The greatest electrostatic charge present on the prongs 15 appears to be at the points of the projecting ends thereof. Due to this condition the fibers will usually collect in the form of a continuous band at the tips of the said projecting ends. When the band leaves the room between the ends of the prongs and the belt for insertion of the lobes of the stripping device 20.

It is not necessary for the electrodes 15 to be connected with each other in apparatus of the type shown in Figure 1, since they individually act as electrodes and acquire a charge from the spaced elongated conductor 18 whether they are connected together or not.

The present invention is advantageously applied to the spinning of solutions of cellulose acetate in organic solvents, for example of cellulose acetate in acetone. Splatnig solutions containing different solvents behave differently when spun in accordance with the present invention. The use of certain solvents in the spinning solution will cause a greater or lesser stretching of the stream of liquid, than others, and some solutions will require a higher potential than others for the satisfactory breaking up of the stream and formation of fibers. Other cellulose derivative solutions may also be spun in the same way, for example solutions of cellulose ethers such as ethyl cellulose and butyl cellulose. Generally, solutions of resins and other materials which can be formed into fibers may be spun according to the present invention.

Example

A solution consisting of 200 grams commercial cellulose acetate, 700 grams acetone and 400 grams mono methyl ether of ethylene glycol is forced through single hole nozzles the orifice diameter of which is approximately .010". A potential difference of approximately 57,000 volts is maintained between the nozzle and the conductor wire 18 as illustrated in the drawing. The voltage is obtained from a source supplying pulsating direct current. The streams of cellulose acetate solution are split under the influence of the high potential field into numerous fine filaments which are deposited and then carried away supported by the prongs attached to the moving belt at or near the points thereof. The streams of solution and the fibers therefrom are properly directed to the prongs by means of the high potential between the nozzles and the prongs which electric field is suitably modified and shaped by means of the screen positioned in back of the nozzles said screen possessing an electrical charge of the same polarity as that of the nozzle.

During the splitting of the stream of solution and deposition of the fibers the solvent evaporates, the fibers quickly drying as they are carried away from the spinning zone. The fibers are thus oriented in a position substantially parallel to the direction of travel of the belt and due to their rapid drying adhere neither to the collecting device nor to one another to any objectionable degree.

The continuous sliver or fiber band thus formed is removed by the stripping device and deposited in a suitable container or wound on a reel. The fibers in the fiber band at this point are sufficiently loose and free, of one another, and lie substantially parallel in a compact sliver as to permit said sliver to be directly drawn and twisted into threads or yarns of good quality and strength. Prior to drafting and twisting, the sliver may be preferably treated with a suitable textile finish in a manner similar to the treatment of wool rovings to facilitate ease and smoothness of drafting. The sliver treated with a suitable textile finish is drawn and/or twisted to yield a yarn of any weight desired.

The sliver as formed by this process possesses outstanding properties as regards the relative freedom from sticking together of the individual fibers, due to the fact that the fiber band collects at, and is supported as such by the points or near the points of the electrodes, thus permitting free access, from all sides, of the air to the freshly spun fibers, assisting in drying. Previous devices have been continuous flat or curved surfaces, to which the fibers could stick, and which would permit drying out of the fiber from one side only, thus decreasing the rate of solvent evaporation and causing sticking together of the mass. The compactness of sliver is also increased by the fact that the electrical charge on the prongs of the collecting device tends to be more concentrated at the tips or points and thus attracts the fibers to these points, thereby concentrating and organizing them at once into a narrow band suspended from the prongs, thus forming a coherent sliver easily removed and substantially free from entanglement both as laid down and as removed from the electrodes. Furthermore, the compactness of fiber band is accompanied by an improved and excellent parallelism of the individual fibers. This feature not only adds strength to the fiber band, but taken together with the freedom of the individual fibers, is particularly important when the sliver band is later processed into threads as by drawing or twisting equipment.

With the fiber band or sliver of the instant invention it is thus possible to dispense with the usual combing or carding operations, thereby greatly simplifying and cheapening manufacture of the final twisted threads or yarns. The desirable construction of my sliver also tends to favor smoothness of operation in drawing and/or twisting as well as toward good uniformity in the final yarn.

It is preferred that the electrode-collector be a continuous belt with prongs, but it will be understood that it may also be a wheel or other device provided in a similar fashion with electrode prongs around its circumference, which prongs are adapted to mesh with a suitable means for removing the fiber band from the wheel-collector. If desired suitably positioned air jets may be used to remove the fiber band, or may be used in conjunction with various mechanical devices in removing the sliver from the collector.

The moving collecting device, on which the fibers are collected in a continuous sliver, may be driven at any desired speed to obtain varying effects. However, when it is desired to collect the fibers in a compact, coherent fiber band in which the fibers are arranged substantially parallel to each other which fiber band may be directly drawn and twisted into a yarn or thread, it is essential that the linear speed of the collecting device is at least as high, and preferably slightly higher, than the speed of the freshly formed fibers in their travel toward the collecting device.

The size of the sliver delivered from the machine may be regulated by a number of factors either singly or in suitable combination with each.
other. The chief factors include the number of spinning nozzles in operation at any one time, the volume of solution delivered by the nozzles unit time, the concentration of solids in the spinning solution, and the speed of the collecting device. With the type of equipment here described, one may choose the number of nozzles, speed of collecting device, etc., so as to yield a wide range of sizes of the sliver band to be removed by the stripping device, without damage or rupture. I have found that a convenient size sliver weighs between 0.1 gram and 0.25 gram per meter length. Slivers either much larger or somewhat smaller may be produced as desired.

While slivers of quite large size may be produced by using an even larger number of nozzles and a longer belt, there is a lower limit to the size of the sliver as determined by the fact that it must be sufficiently coherent to permit winding, unwinding, and handling. This means that the rate of deposition of fibers on the collecting device must be such that for each revolution of the belt (or 1/2 revolution when two stripping devices and two rows of nozzles are used) there is formed a sliver of sufficient weight to be coherent for the purposes of winding and handling without breaking. I thus use a plurality of nozzles with one collecting device. The number may vary from 10 or 20 to upwards of several hundred, or even more per collecting device.

The sliver, in addition to possessing good, coherent, uniform and parallel construction, contains filaments of good strength. When cellulose acetate is used as the filament forming material, I have obtained threads after drawing and twisting showing good strength comparable to that of wool yarns. Another desirable property of my sliver is its long staple as compared to the staple of cotton and the shorter staple wool. I may vary my average staple length from 2 or 3 inches up to 12 inches or even higher. The somewhat longer staple is advantageous for most purposes because of the added strength that results in the twisted yarn thereby. Natural fibers such as cotton and wool are limited in staple length by the nature of their source.

While I may spin lustrous fibers, I am not limited thereby, but may introduce into the spinning solution suitable delustering agents, such as pigments, oils, organic solids, and other materials known and used in the art to achieve delustered, semi-lustrous, and other effects. Likewise, I may spin dyed filaments by introducing suitable dyes or other coloring matters into the spinning solution.

I may exercise control over the average filament diameter and produce fibers as small as one denier per filament or even smaller, or I may produce relatively coarse filaments of 3, 5, 10 or even greater average denier per filament. This is accomplished by varying the solids content and/or viscosity of my spinning solution, and will also be influenced to a certain extent by the voltage potential employed, and size of the nozzle orifice.

In general, a fine filament sliver will be produced with the lower solids and/or viscosities, the higher voltages, and the smaller nozzle orifices. Heavier filaments, in general, go with higher solids, and/or viscosities, lower voltages, and larger nozzle orifices. These and other factors may influence the filament size as well as the filament length. I thus have considerable latitude in the choice of conditions to produce slivers of greatly varying properties according to the use to which I put the material.
wool in many respects. They are likewise admirably adapted to mixture with wool. It will be thus apparent that my fiber band or siler is of new and novel construction. The individual fibers of my product are heterogeneous as compared to the homogeneous character of pinted staple fibers. Furthermore, the fibers of the instant invention are already built, constructed, and organized into a coherent, compact, free drawing fiber band showing a high degree of parallelism, which siler may be processed at once into twisted yarns. Artificial staple fibers, on the other hand, mean for imparting to said elements an electrical charge of high potential of opposite polarity to the charge on said nozzle, and means for continuously removing fibers collected on said elements.

6. In an apparatus for the electrical spinning of fibers, a nozzle, means for imparting an electrical charge of high potential to said nozzle, a continuously movable supporting means spaced from said nozzle, a plurality of elements fixed to said supports means, said elements spaced from said nozzle, a plurality of elements fixed to said supporting means spaced from said nozzle, a plurality of elements spaced from each other, means for imparting to said elements an electrical charge of high potential of opposite polarity to the charge on said nozzle, and means cooperatively connected to said elements for continuously removing fibers collected on said elements.

7. In an apparatus for the electrical spinning of fibers, a nozzle, means for imparting an electrical charge of high potential to said nozzle, a continuously movable supporting means spaced from said nozzle, a plurality of elements fixed to said supporting means spaced from said nozzle, and means for continuously removing fibers collected on said elements.

8. In a method for the electrical spinning of fibers, the steps comprising electrically dispersing a stream of spinning solution into fibers, collecting said electrically dispersed fibers in the form of a sliver and moving said sliver through the surrounding atmosphere until substantially dry, said sliver, during said collecting and drying thereof, being at all times supported in such a manner as to be completely surrounded by the atmosphere substantially along the length thereof, whereby to prevent objectionable adherence of the fibers to each other, continuously removing said sliver from the drying atmosphere and winding it in the form of a package.

9. In a method for the electrical spinning of fibers, the steps comprising electrically dispersing a stream of spinning solution into fibers, collecting said electrically dispersed fibers in the form of a sliver, drying said sliver during the forming and collecting thereof by suspending the same at spaced portions thereof in such a manner as to be completely surrounded by the atmosphere substantially along the length thereof during said collecting and drying thereof whereby to obtain a substantially dry, compact, coherent sliver in which the individual fibers are substantially free from each other and continuously removing said sliver from the drying atmosphere and winding it in the form of a package.

10. In a method for the electrical spinning of fibers, the steps comprising electrically dispersing a stream of spinning solution into fibers, collecting said electrically dispersed fibers in the form of a sliver and drying said sliver during the forming and collecting thereof by moving the sliver, suspended at spaced portions thereof in such a manner as to be completely surrounded by the atmosphere substantially along the length thereof during said collecting and drying thereof, continuously removing said sliver and treating the same with a finishing composition prior to any drawing or twisting thereof.

11. In an apparatus for the electrical spinning of fibers, a nozzle, a continuously movable supporting means spaced from said nozzle, said supporting means, said elements spaced from each other, means for imparting to said elements an electrical charge of high potential of opposite polarity to the charge on said nozzle, and means for continuously removing fibers collected on said elements.
porting means being constructed in such a manner as to permit fibers collected thereon to be surrounded by the atmosphere substantially along the length of the supporting means, and means for maintaining a high electrical potential between said elements and said nozzle.

12. In an apparatus for the electrical spinning of fibers, means for forming a stream of spinning solution, a continuously movable supporting means spaced from said means, a plurality of spaced elements on said supporting means, electrical means connected relative to said stream of solution and said spaced elements to maintain a high electrical potential therebetween whereby to electrically disperse said stream of spinning solution to fibers and collect the fibers on said elements in the form of a compact coherent sliver in which the individual fibers are substantially free from each other.

13. In an apparatus for the electrical spinning of fibers, a nozzle for forming a stream of spinning solution, means for imparting to said stream of spinning solution an electrical charge of high potential, a continuously movable supporting means spaced from said nozzle, a plurality of elements fixed to said supporting means, said elements spaced from each other, means for imparting to said elements an electrical charge of high potential of opposite polarity to the charge on said stream of spinning solution.

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