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METHOD AND APPARATUS FOR SPINNING

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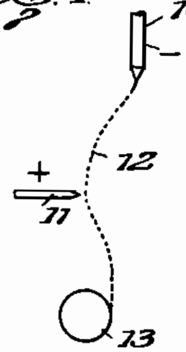
Fig. 1



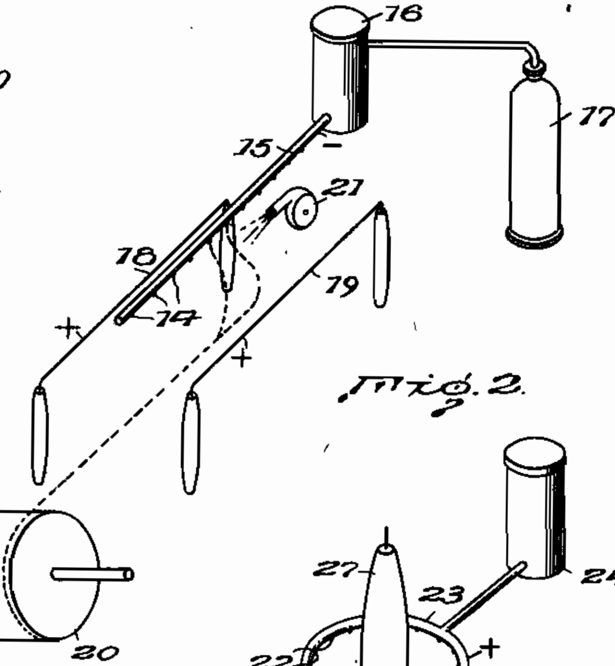


Fig. 2

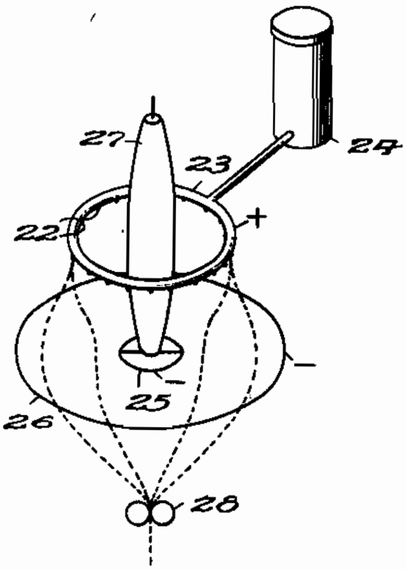


Fig. 3

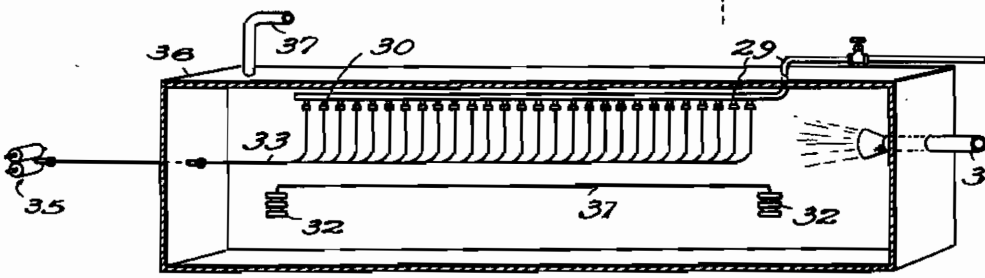


Fig. 4

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METHOD AND APPARATUS FOR SPINNING

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This invention relates to the production of artificial fibers and more particularly it relates to the dispersion or shattering of streams of spinning solution into comparatively fine fibers by means of a high potential electrical field of certain characteristics and collecting said fibers substantially parallel to each other in the form of a continuous fiber band on a moving collecting device. The dispersion of a stream of spinning solution into fibers by a high electrical potential shall hereinafter, for convenience, be referred to as the "electrical spinning" of fibers.

In accordance with previously known apparatus and methods for the electrical spinning of fibers, for example, the apparati and methods disclosed in U. S. Patent 1,975,504 to Formhals, U. S. Patent 705,691 to Morton and U. S. Patent 2,048,651 to Norton, a number of difficulties have been experienced. Due to the comparatively short distance intervening between the solution feeding devices and the fiber collecting devices it was exceedingly difficult to sufficiently completely dry out the formed fibers, and as a result the said fibers would tend to stick not only to the collecting devices but also to each other. Furthermore, in the previous methods the formed fibers would not tend to collect in a compact closely aggregated form. While this was due partly to the fact that the collecting electrodes presented continuous plane or curved surfaces for receiving the fibers and to the use of serrated devices for feeding discontinuous quantities of spinning solution into the high potential electrical field, the apparatus would still not collect the fibers in a compact concentrated fashion even though continuous streams of spinning solution were fed into the electrical field. Particularly when a plurality of spinning nozzles was used it was found that the streams, and the fibers formed from said streams, would take different courses and paths to the collecting device, thus preventing the formation of a closely packed or aggregated fiber band on the collecting device. In other words, while the paths which the streams and fibers might take between the feeding and the collecting devices were determined to an approximate degree by the relative position of these devices to each other, it was not possible to predetermine this path precisely and constantly, nor was it possible to predetermine the paths of all of the streams and fibers therefrom in a perfect manner from the different nozzles.

A further difficulty of previous apparatus and methods was experienced by the bothersome tendency of certain stray fibers to become electrically charged in the proximity of the collecting device, thereby tending to fly back into the field toward the solution feeding device. The occurrence of this phenomenon may be quite troublesome and will seriously interfere with the continuity of operation of the process. Stray fibers which thus fail to attach themselves permanently to the collecting device and tend to fly back into the proximity of the feeding device tend to become attracted and attach themselves to various parts of the solution feeding mechanism, for instance, the spinning nozzles. As the fibers accumulate on and around the spinning nozzle they may amass to a sufficient extent so as to cause serious interference to the free and uninterrupted delivery of spinning solution. In extreme cases they may amass themselves around a spinning nozzle and completely interfere with its satisfactory delivery, thereby necessitating stopping and cleaning of the apparatus.

The above and other difficulties have contributed to the failure to heretofore obtain on a smooth continuous manufacturing basis a continuous, compact, coherent fiber band composed of heterogeneous artificial filaments arranged substantially parallel to each other and being capable, without additional textile operation, of being drawn and twisted into threads or yarns of good quality and strength on standard textile machinery.

In order to overcome the aforesaid difficulties, a method is employed, in accordance with the present invention, which is fundamentally new and which permits the use of simple apparatus similar to the type used in the early days of electrical spinning, when skeins of fiber could not be produced, but only balls of fiber.

In order that the process and apparatus of the present invention be more readily understood, reference is made to the drawings, in which:

Fig. 1 represents a diagrammatic showing of the phenomenon underlying the theory of the invention;

Fig. 2 denotes, in diagrammatic prospective, an alternative system for carrying out the invention;

Fig. 3 shows a further alternative system and

Fig. 4 shows, in part section, a shielding housing which may be employed with either of the systems shown in Figs. 2 and 3.

The physical phenomenon on which the new process is based is shown in Fig. 1. The nozzle 10, preferably negatively charged, delivers a fiber-forming material which, as a result of the force of gravity, tends to fall down vertically. Between the nozzle 10 and the counter-electrode 11, preferably positively charged, there is a high difference of potential, i. e., a high tension field exists between them, which causes the formation of the fibers. Under the conditions previously employed in the prior art fibers formed from the fiber-forming liquid, after they had left the nozzle were attracted by the counter-electrodes around which they collected in the form of a tangled ball. This invention consists essentially in the discovery that by producing a suitably high field intensity on the counter-electrodes relative to the electrode fixed at the point where the liquid is discharged it is possible, shortly before the fibers reach the counter-electrode, to reverse the attracting power of this counter-electrode into a repelling power, so that the fibers do not collect on the counter-electrodes. In order to produce this reverse effect it is only necessary to produce on the counter-electrode a field intensity of such magnitude as will cause the desired reverse effect. This is accomplished by producing high differences of potential and using a counter-electrode which presents a particularly sharp surface.

The reversal effect upon which the present invention is based cannot yet be explained entirely satisfactorily from a scientific point of view. Very probably, however, it is brought about as follows:

When the single fiber leaves the nozzle 10, as shown in Fig. 1, it is under the influence of gravity and also under the influence of the attraction of the electrode 11, since this electrode is of opposite polarity. The fiber therefore moves towards the sharp tip of the electrode 11, where there is the greatest field intensity. From the tip of the electrode 11 ions move towards the fibers 12. This phenomenon is well known in physics as "electric wind" or "ion wind" (cf. for example R. W. Pohl, "Elektrizitätslehre", Berlin 1931, p. 175). The so-called "ion wind" is characterised by the fact that on the one hand charge-carriers move in a given direction, and that on the other hand molecules of gas are carried along with these charge-carriers, so that a directed stream of gas is produced. This stream of gas endeavors to repel the fibers 12 from the electrode 11. At the same time, the charge-carriers emanating from the electrode 11 neutralise the charge on the fibers 12, and then charge the fibers with the same polarity as that of the electrode 11. The mechanical repulsion effect of the "ion wind" is thus strengthened by the electrical repulsion of the fibers 12 from the electrode 11. Under the influence of the purely mechanical action of the "ion wind", and as a result of the alteration in the charge of the fibers 12, the latter cannot collect upon the electrode 11; they approach to within a certain distance and are then repulsed.

If only one nozzle is used, far too little fiber is produced, and it therefore would be expedient, from an economic standpoint, to use a series of nozzles 10 in a row. It would also be necessary to provide a corresponding row of counter-electrodes 11. With this arrangement, the drum 13 would be very wide, and it would be covered with only a few fibers, which would lead to difficulties. These difficulties could be overcome if the fibers 12 were drawn out of the range of the electric field on a flat surface. A moving band of fibers could thus be formed, opposite to the row of electrodes 10, and as the fibers forming this band have received an opposite charge from the electrodes 11, this band of fibers would be of opposite polarity to those fibers whose charge had not yet been reversed. The band of fibers whose charge had been reversed would attract fibers whose charge had not yet been reversed, and would form a support for them.

From the foregoing it will be seen that it is of advantage to remove continuously the fibers which are first attracted and then repelled by the counter-electrode from the range of the electric field, and in such a way that they form a moving support for other fibers reaching them from the point where the liquid is discharged before their charge has been reversed by the counter-electrode.

In the apparatus for the practical operation of this process which is shown in Figs. 2 and 3, a large number of nozzles is provided and on different sides of each nozzle there are two counter-electrodes each of the same polarity, arranged in such a way as to attract to opposite sides the fibers which are formed from the liquid leaving the nozzles. There is such a high field intensity on the counter-electrodes that the fibers cannot collect on them. Instead of consisting of separate tips, both the counter-electrodes of all the nozzles are formed of conductors so fine that there is a point repulsion effect along them, this effect being sufficiently great to prevent the fibers from collecting on them.

Fig. 2 shows an apparatus in which a number of nozzles 14 are arranged along a straight line. The nozzles 14 which are preferably negatively charged, are fixed on a distributing tube 15, and the fiber-forming liquid, which may be cellulose acetate, flows towards this tube from the storage tank 16 under the influence of the pressure which is produced by compressed gas in vessel 17. The pressure is preferably about 2 atm. Insulated conductors 18 and 19 are arranged below the row of nozzles and parallel to it, on either side of it. The revolving device 20, which guides the fibers and which may, for instance, be in the form of a drum, is arranged in such a way that its direction of revolution is in accordance with the direction of the row of nozzles and that of the conductors 18 and 19.

A high difference of potential is produced between the nozzles 14 and the conductors 18 and 19. An example of a successful difference of potential is about 50 KV. The potential of the nozzles 14 to earth is preferably about 55 KV and that of the conductors 18 and 19 to earth is about 5 KV. Conductors 18 and 19 are of extremely thin wires of metal preferably of the piano wire type.

At first the liquid flows from the nozzles 14 in fine streams, falling vertically towards the earth. At the moment when the difference of potential is produced between the nozzles 14 and the wires 18 and 19, fibers begin to be formed, and streams of fiber are produced, flowing in principle in the direction shown in Fig. 2. Since two wires 18 and 19 are present, two streams of fiber are formed, flowing first towards the wire 18 or 19 respectively, then flowing away from these wires and finally falling towards the ground. The ends of the fiber which reach the ground are raised, for instance by means of a rod made of some insulating material, and placed on the revolving drum 20, which then draws them continuously out of the electric field. This forms a belt of moving fibers which is of the same polarity as the counter-electrodes 18 and 19. This belt of fibers forms a moving support for other fibers which have just been formed but which have not yet been repelled and had their charge reversed by the wires.

With the processes of the prior art, the distance between the point where the liquid leaves the nozzle and the fiber support always had to be comparatively small. There was therefore always the danger that when the fibers reached the support they would not be dry enough, and that they would stick. This danger does not exist in the process of the present invention. The device **20** which guides the fibers can be placed far enough from the row of nozzles for the fibers to be completely dry when they reach it.

In order to facilitate the conveyance of the fibers to the drum **20**, a blast apparatus **21** may be provided to blow them towards this drum. The blast apparatus also helps to prevent the undesirable accumulation of the fibers on the electrodes **16** and **19**.

The apparatus shown in Fig. 3 is the same in principle as that shown in Fig. 2, except that the apparatus is curved in shape instead of being modelled on straight lines.

As shown in Fig. 3, a series of nozzles **22** is arranged in a closed curve, for instance in circular form. The nozzles are fixed on to a ring-shaped liquid distributing tube **23**, which is connected to the container **24** in which is a fiber-forming liquid, for example acetyl cellulose. The nozzles **22** are under a high potential, so that they form electrodes at the same time. To each nozzle correspond two electrodes, also arranged in closed curves, which are on opposite sides of the curve on which the nozzles are arranged, but approximately concentric with this curve. Both of the electrodes corresponding to each nozzle could be in the form of separate points.

Actually, in the apparatus illustrated in Fig. 3 all the counter-electrodes corresponding to the nozzles are in the form of conductors **25** and **26**, curving in the same shape as the tube bearing the nozzles—i.e. in this example circular in form. The connection to the annular electrode **25** is surrounded by an insulator **27**, to prevent sparking between it and the tube **23** or the nozzles **22**.

After the fibers have passed between the two annular electrodes **25** and **26** which are below the nozzles **22**, they are drawn through the device **28**, stretched in another apparatus and then spun.

On the device **28** for guiding or drawing off the fibers is formed a tube-shaped fibrous structure, which is very easy to spin.

In the types of apparatus illustrated in Figs. 2 and 3 it is desirable to use as many nozzles as possible and to have them as close together as possible. There is a critical distance, however, determined by experimentation for different sized systems, and the nozzles should not be closer together than this. If they are closer together, the repulsion effect exercised on each other by the fibers formed by various nozzles will become so pronounced that the fibers will not be distributed uniformly over the two counter-electrodes **25** and **26**, and part of the nozzles **22** will be supplying only one counter-electrode **25**, while another part of the nozzles is supplying only the other counter-electrode **26**.

Fig. 4 shows a further modification of the invention employing, in this instance, but a single wire rather than the two wires shown in Figs. 2 and 3. The fiber forming material enters the apparatus through a conduit **29** and is fed to a series of nozzles **30**. These nozzles, as in the systems shown in Figs. 2 and 3, constitute the jet electrodes and are preferably negatively charged. A thin wire or knife edge **31** appropriately supported by insulators **32** constitutes the counter-electrode which is preferably positively charged. The formation of fibers **33** is the same as in the systems previously described. An air jet **34** may be employed to facilitate the continuous movement of the fibers from the point of formation to the collecting device **35**.

The whole system, including jet electrodes, counter-electrodes, and air blast are preferably enclosed within a housing **36** in order to facilitate recovery of the solvent. Part of the solvent may be condensed and recovered at the bottom of the apparatus while some may be swept by the air current through the air outlet **37**, the solvent from this source being condensed in suitable apparatus and used again in the process.

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