Nov. 10, 1964 D. T. DUNLAP ETAL 3,156,016

TOW OPENING

Filed Nov. 13, 1961 2 Sheets-Sheet 1

Fig. 1.

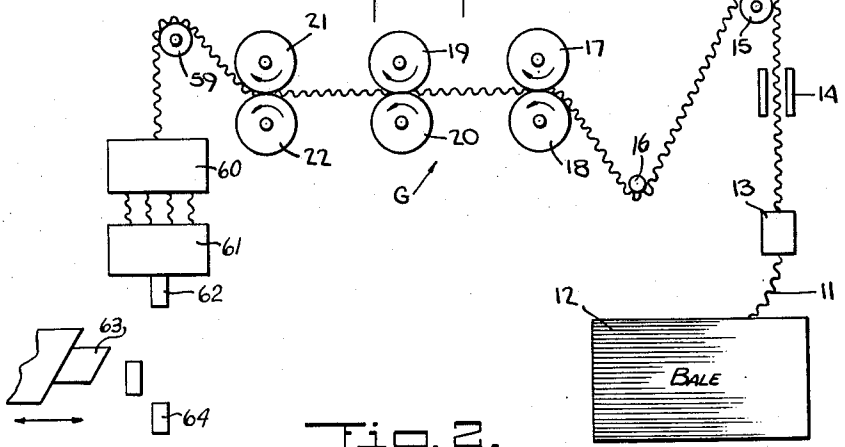


Fig. 2.

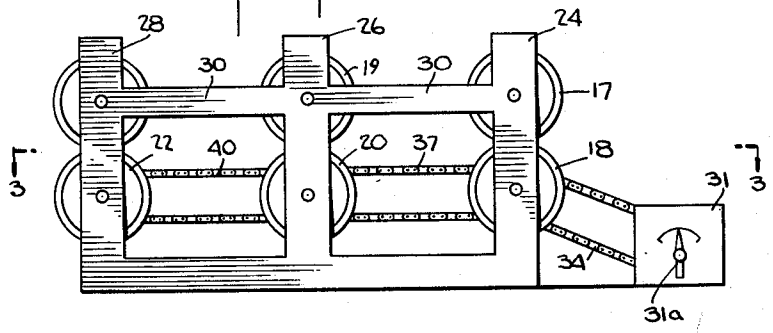
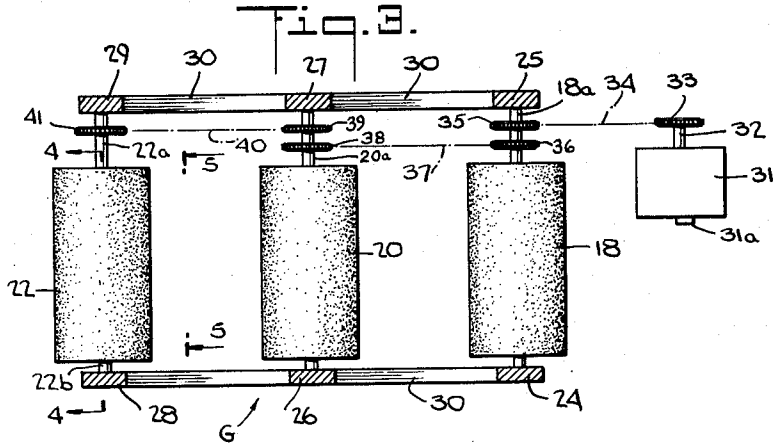


Fig. 3.



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TOW OPENING

Filed Nov. 13, 1961 2 Sheets-Sheet 2

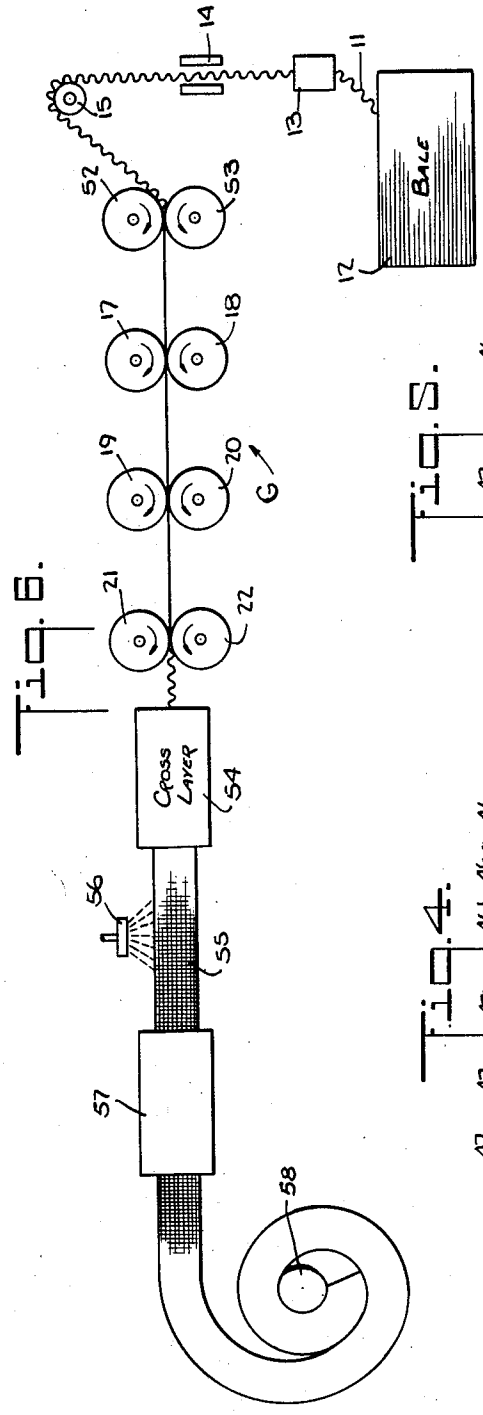


Fig. 6.

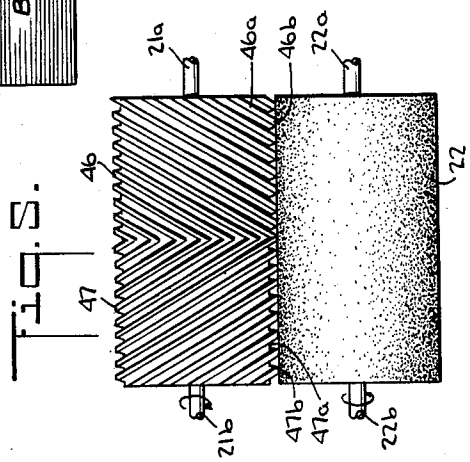


Fig. 5.

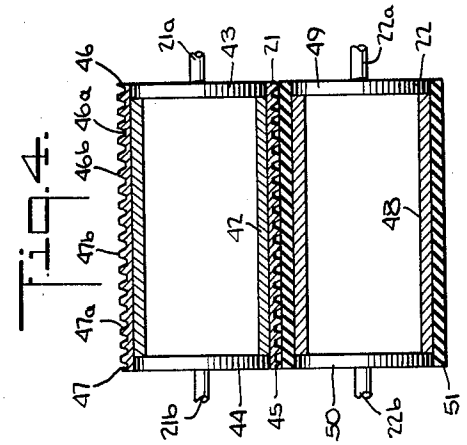


Fig. 4.

United States Patent Office 3,156,016 Patented Nov. 10, 1964

3,156,016

TOW OPENING

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Filed Nov. 13, 1961, Ser. No. 151,900
17 Claims. (Cl. 19—66)

This invention relates to novel processes of, and apparatus for, opening filamentary tows of the type generally employed in the manufacture of cigarette filters or filter plugs.

Cigarette filters by and large are formed from crimped continuous filaments combined into a tow or bundle consisting of several thousands of such filaments. Usually, the filaments are combined into the form of a tow first, and the tow is then crimped to the extent desired so that the filaments are more or less adhered to each other, with the crests and vales of the crimps in adjacent filaments being in registry. Upon being received by the filter or cigarette manufacturer, the tow is first opened either by being sinuously flexed or deformed to impart varying tensions thereto or by being passed through an air spreader to fluff up the bundle, is then fed by driven rolls through a chamber in which a plasticizer is applied to the tow, and is thereafter treated to reduce its cross-sectional area until it is approximately equal to the cross-sectional area of a cigarette. The condensed mass is formed into a coherent structure, e.g. by wrapping paper around it and/or by curing, and is ultimately cut into suitable plug lengths for incorporation into cigarettes.

In commercial operation it has been found that the filters so produced are not at all identical as far as filtering action is concerned. Specifically, it has been found that the filters occasionally differ in weight, in filtering efficiency and in the ease of draw of smoke therethrough, i.e., their resistance to gas flow. In addition, after smoking, many such filters show uneven darkening which indicates non-uniform passage of smoke therethrough, the more darkened areas identifying zones through which the smoke is preferentially drawn.

Repeated tests have disclosed that one of the major causes of the aforesaid irregularities in the smoking characteristics of cigarette filters is an improper opening of the initial continuous filament tow from which the filters are produced. As is well known, when the tow is being crimped, most of the filaments are acted upon simultaneously, as a result of which the crimps of adjacent filaments are in registry with one another. If such crimp registry is not eliminated as a part of the tow opening procedure, however, the tow will not be fully or evenly opened prior to application of the plasticizer thereto. Still further, the crimped tow may contain a number of filaments or groups of filaments which do not extend longitudinally of the tow but rather at an angle to the longitudinal dimension thereof. When it is attempted to open a tow so characterized, these transverse filaments or "cross-overs" tend to prevent those filaments adjacent which they lie from being spread apart laterally.

It will be understood that if the tow is, as a consequence, spread or opened incompletely and unevenly, an uneven application of plasticizer will result, which in turn leads to an uneven filter density. The same result is, of course, brought about if the tow is initially crimped unevenly, as nearly all tows are. In either case, the uneven density is accompanied by the formation of a great number of channels through which smoke can pass without contacting any interfering filament surface. This undesired channeling of smoke through the filter obviously destroys any value the smoke might have derived from the filter.

It is, therefore, an important object of the present invention to provide a novel and highly efficient process of, and apparatus for, treating crimped filamentary tows, by means of which process and apparatus the defects in cigarette filters produced from tows treated in accordance with known procedures are substantially eliminated.

A related object of the present invention is the provision of a novel process of, and apparatus for, treating tow in a manner which permits formation of uniform cigarette filters.

Another object of the present invention is the provision of a novel process of, and apparatus for, opening a continuous filament tow by differential gripping actions exerted on laterally adjacent sections of the tow.

A more specific object of the present invention is the provision of such an apparatus in which a combination of grooved and smooth-surfaced rolls is employed for opening the crimped continuous filament tow sufficiently to assure the subsequent formation of high efficacious and uniformly acting cigarette filters therefrom.

The foregoing and other objects, characteristics, and advantages of the present invention will be more fully comprehended from the following detailed description thereof when read in conjunction with the accompanying drawings, in which:

FIG. 1 is a schematic side elevational view of a tow opening apparatus emobdying the principles of the present invention.

FIG. 2 is a diagrammatic side elevational view of the tow opening roll system of the apparatus of FIG. 1.

FIG. 3 is a top plan view of the said roll system, the view being taken along the line 3—3 in FIG. 2.

FIG. 4 is a sectional view taken along the line 4—4 in FIG. 3.

FIG. 5 is a fragmentary elevational view of one set of rolls of the tow openings roll system, the view being taken along the line 5—5 in FIG. 3.

FIG. 6 is a schematic elevational view of a modified tow opening roll system with structure for bonding the opened tow.

Generally, in accordance with the present invention a crimped or coherent multifilament tow is opened by being subjected, while being fed along a predetermined path, to a differential gripping action between a plurality of points spaced from one another both longitudinally and transversely of the path, so that certain laterally spaced sections of the tow are positively gripped relative to other laterally spaced sections of the tow, alternating with the said gripped sections, which are not gripped at all or are gripped at different relative points. In this manner, there is produced, as a function of the differential positive gripping of the tow, a relative shifting of adjacent filaments longitudinally of the tow, whereby the crimps are moved out of registry with one another. Preferably, although not necessarily, the differential gripping action is such that a relative lateral displacement between adjacent filaments of the tow is also effected, so that the combination of two transverse filament movements brings about the complete opening of the tow.

By way of definition, the term "gripping" (or any variant thereof) is used herein to denote the confinement of the tow by two opposed members which tightly engage the tow at its opposite faces, and the term "differential gripping" is used to denote the confinement of the tow between two opposed members, as well as between sets of such opposed members, which have zones in which the tow is tightly engaged by the members alternating with zones in which the tow is only loosely or not engaged by the said members. The terms exclude a mere one-sided

frictional sliding engagement between the tow and a member past which the tow moves.

In accordance with the present invention, the aforesaid differential gripping action may be accomplished by the provision, before the usual plasticizing chamber, of a pair of rolls one of which is smooth-surfaced and the other of which is profiled, e.g. grooved, over its entire periphery. Broadly, the grooves and the ridges alternating therewith may be oriented in any desired manner relative to the direction of movement of the tow. Most preferably, however, a roll is employed which is obliquely or helically grooved in opposite senses from its center to its opposite ends, whereby when the tow passes between the two rolls some of the tow sections are gripped between the peaks of the ridges of the grooved roll and the outer peripheral surface of the opposed smooth roll, while other sections of the tow which are at that time located in the spaces between the ridges of the grooved roll are not gripped between the latter and the smooth-surfaced roll.

It is contemplated, in accordance with the present invention, that one of these two rolls, preferably the smooth one, is positively driven; the other roll, i.e. the groove-surfaced one, may also be positively driven or it may be biased toward and rotated through its peripheral contact with the smooth roll or the tow passing between the rolls.

The differential gripping rolls may be made of any suitable material, e.g. metal, plastic, rubber or fibrous materials, or any combination of the same. Where the roll exterior is not metallic the roll may have a metallic cylindrical core body coated with a layer of rubber or like elastic material. The desired arrangement of grooves and ridges is preferably produced by forming a pair of oppositely advancing helical threads in the covering layer of the roll. The depth, angle, pitch and shape of these threads can be determined as desired, depending on the tow material being processed. Advantageously one of the rolls is of rubber and the other of steel; preferably the rubber roll is smooth and below the grooved steel roll.

In accordance with another aspect of the invention, a plurality of sets of pairs of differential gripping rolls are arranged in tandem, the differential gripping roll pairs each consisting of one helically threaded or grooved roll and one smooth-surfaced roll, constructed as described hereinbefore. The sets of gripping rolls are preferably spaced about 10 to 50 inches from one another.

In accordance with a further aspect of the invention the peripheral speeds of the driven rolls of the several sets need not all be equal. In the event that the tow is placed under a small amount of tension in moving from the bale to the first set of rolls, the tension being sufficient to distend the crimp slightly without effecting opening or deregistry, successive sets of rolls can operate at slower peripheral speeds to effect opening while permitting relaxation of the tow. Alternatively, successive sets of rolls may operate at peripheral speeds as much as 50% or more greater than the preceding set so as to effect differential tensioning of individual filaments with resultant deregistry. If successive sets of rolls are driven at high-speed differentials this will be evidenced visually in the shape of the tow passing therebetween, i.e. the tow is taut and the crimps are tentatively straightened out. If an operator attempts to deflect the running tow between roll sets he will encounter a considerable resistance to such deflection as a result of the tension in the tow.

In a preferred embodiment of the invention successive sets of rolls are run faster than the preceding rolls but insufficiently fast to put the tow under tension. That the tow is not under significant tension is evidenced by its sinusoidal crimped configuration even between roll sets as well as by the ease with which it can be manually deflected out of its normal running path. In practice it has been found that if all the roll sets are operated at the same speed there is frequently a tendency to develop slack in the tow and if this is permitted to continue without correction the slack tow may lap around the rolls and necessitate interruption of the processing. While not wishing to be bound thereby, it is believed that as the cohesiveness of the filaments is overcome due to initiation of deregistry an individual filament no longer has its adjacent filaments to support it and lengthens (due to flattening of its crimp) as a result of its own weight plus the weight of unsupported filaments resting on it. This is manifested as slack in the tow line. To prevent this build-up of slack successive roll sets should be run sufficiently faster to compensate for this spontaneous lengthening. This can be effected without placing the tow under tension although the slack will also be avoided if the tow is put under tension. Tension can be introduced into the tow by use of braking rolls which are either idly mounted or driven slower than the sets of opening rolls, by use of tension bars, and the like, or preferably by operating successive sets of opening rolls at substantially higher peripheral speeds; two or more of these expedients may be employed simultaneously. The speed differentials necessary to eliminate slack will depend upon the spacing between roll sets and the degree of opening desired. The actual number of roll sets employed will depend on the type of tow being processed, and on such factors as its denier per filament, crimp level and uniformity, stretch recovery properties, and static characteristics, for example.

The tow is preferably composed of a plurality of crimped continuous filaments of an organic derivative of cellulose, e.g. esters or ethers of cellulose such as cellulose acetate, cellulose propionate and cellulose acetate propionate, highly esterified cellulose containing less than 0.29 free hydroxyl groups per anhydroglucose unit such as cellulose triacetate, and the like. Other filamentary materials such as rayon (regenerated cellulose), linear superpolyamides such as nylon-6 and nylon-66, linear polyesters, acrylonitrile polymers and copolymers, and the like, can also be employed. The number of filaments and the total denier can vary within wide limits, but in preparing filters for conventional cigarettes which are approximately 25 to 26 mm. in circumference, the number of filaments generally varies between about 5,000 and 33,000, and the total denier ranges from about 35,000 to 160,000, computed on uncrimped tow. The number of crimps per inch in the tow can range up to about 30–40, but preferably averages between about 4 and 25.

By virtue of the fact that a system of differential gripping rolls, consisting of one or more sets of such rolls, leads to a degree of openness of the tow heretofore not attainable, the plasticizer applied to the tow in the following stages of processing attacks all the filaments individually and uniformly, whereby the density of the tow and of any filters produced therefrom is uniform, and the filters are free of channels. The deregistration of the crimps of adjacent filaments also prevents channeling and permits production of a firm filter even with a tow of a smaller total denier than normally utilized. In addition, the filtering efficiency is increased so that a given efficiency can be achieved using less tow and thus with less resistance to draw, i.e. at a lower pressure drop.

The identity of the plasticizer will, of course, depend on the composition of the tow. With cellulose acetate, such compositions as triethyl citrate, dimethoxy ethyl phthalate and methyl phthalyl ethyl glycolate may be employed, but glycerol triacetate (triacetin) is preferred. The proportion of plasticizer applied generally varies from about 2% to 30% by weight of the tow to which it is applied, and preferably from about 4% to about 15%.

In accordance with a further aspect of the invention the novel process can be applied to opening tows intended for purposes other than cigarette filters, and is especially suited for the production of non-woven fibrous sheet-like structures such as may be used as sanitary napkin cover fabrics and the like. The opened tow leaving the rolls is superficially similar in appearance to a picker lap produced by a card and, similarly to such laps, may be

used as such or may be built up by lamination or cross-laying and/or bonded by agents such as solvents, plasticizers, adhesives, heat and/or pressure, etc. The products are superior to conventional non-wovens in their freedom from loose fiber ends, in their longitudinal uniformity, i.e. freedom from thick or thin spots, and especially in their strength in longitudinal direction. In addition, there are certain obvious economies of manufacture in the direct conversion of tow to non-woven in contrast with the conventional process wherein the tow is cut into staple fibers which must then be carded or otherwise formed into a fleece or web.

Referring now more particularly to FIG. 1 of the drawings, where a composite tow-treating system according to the present invention is schematically illustrated, it will be seen that a multifilament tow **11** is taken from a bale **12** thereof and fed through a straightening device **13** and an air spreader or banding jet **14**, both of conventional construction. The device **13** functions to remove folds from, and prevent twisting of the tow as it is drawn off the bale **12**, and the spreader of jet **14**, which is composed essentially of a pair of spaced parallel plates provided with a plurality of slots oriented in a pre-determined direction relative to the direction of movement of the tow and connected with a compressed air line, functions to provide a flat band of tow which can be fed uniformly into the tow opening mechanism of the system.

After leaving the air spreader or banding jet **14**, the tow is fed around a guide member **15** and then about a guide bar **16** to the differential gripping mechanism G which, in the illustrated embodiment of the invention, comprises three sets or pairs of gripping rolls **17–18**, **19–20** and **21–22**, the construction of which will be more fully described presently. The location of guide bar **16** relative to roll **18** may be changed thereby to change the amount of contact between the tow **11** and the surface of roll **18**. As clearly shown in FIGS. 2 and 3, the three sets of rolls are arranged in tandem within a rectangular framework consisting of a base **23** to the top and at the opposite sides of which are connected three pairs of vertical mounting members **24–25**, **26–27**, and **28–29** which in turn are interconnected by struts **30** for rigidifying the frame. The pair of rolls **17–18** is journaled in the members **24–25**, the pair of rolls **19–20** in the members **26–27**, and the pair of rolls **21–22** in the members **28–29**. If desired, the mounting members **24** to **29** may be displaceable relative to the base **23** and to one another to permit adjustment of the distances between the roll sets. The two rolls of each pair of gripping rolls are either mechanically, e.g. resiliently, or hydraulically loaded or biased toward one another.

As hereinbefore indicated, preferably only one roll of each of the three sets of gripping rolls is positively driven, while the other roll of each set is rotated by virtue of the contact pressure between it and its associated driven roll. To this end, there is provided in accordance with the present invention a drive mechanism **31** which may be provided with any suitable type of output speed selector or control **31***a*. The output shaft **32** of the mechanism **31** carries a sprocket wheel **33** about which passes one end of a sprocket chain **34**, the other end of which passes about a sprocket wheel **35** mounted on the axle **18***a* of the gripping roll **18**. The axle **18***a* carries a second sprocket wheel **36** about which passes one end of a chain **37**, the other end of which passes about a sprocket wheel **38** carried by the axle **20***a* of the roll **20**. Mounted on the axle **20***a* is another sprocket wheel **39** about which passes one end of a chain **40**, the other end of which passes about a sprocket wheel **41** carried by the axle **22***a* of the roll **22**. Thus, all of the rolls **18**, **20** and **22** are shown as being driven by a single drive mechanism, but individual drives may, of course, be employed. The characteristics of the transmission means composed of the various sprockets and chains are so selected as by variations in the numbers of teeth of the respective sprocket wheels or by employing rolls of approximately different diameters in the various sets of rolls that any desired relative speeds may be obtained. Other types of transmission means than chains and sprockets may also be employed. It will be understood as well that the drive means **31–33** need not be connected to the grooved roll of the first set of rolls as shown, but could be connected to the grooved roll of any of the other sets of gripping rolls. Both rolls of each set could also be positively driven, as hereinbefore mentioned.

The three sets of grippig rolls **17–18**, **19–20** and **21–22** are all identical in every respect, and thus only one of these sets of rolls will now be described in detail. Referring in particular to FIGS. 4 and 5, as well as to FIG. 3, it will be seen that according to the preferred aspect of the present invention the top roll **21** of the third set of gripping rolls comprises a cylindrical core body **42** to the opposite ends of which are affixed end plates **43** and **44**. The axles **21***a* and **21***b* by means of which the roll **21** is journaled in the support or mounting members **29** and **28**, respectively, are affixed to the outer faces of the end plates **43** and **44**. About the exterior surface of the core body **42** of the roll **21** there is provided a covering or layer **45** of steel or like material, which may, by way of example, be about 1 inch thick. The outer peripheral surface of the covering **45** is provided with a pair of helical threads **46** and **47** which start at the center of the roll and advance toward the opposite ends thereof, the thread **46** advancing in a counter-clockwise sense (as seen from the center of the roll) and the thread **47** in a clockwise sense (likewise as seen from the center of the roll). As clearly shown in FIG. 4, the threads **46** and **47** are composed, respectively, of helical grooves and ridges **46***a–46b* and **47***a–47b*, with the ridges **46***b* and **47***b* having flat faces or peaks to provide good gripping surfaces; the bottoms of the grooves **46***a* and **47***a* may be flat or V-shaped, as desired.

The associated roll **22** which is located below the roll **21** is likewise composed of a cylindrical core body **48** closed at its opposite ends by plates **49** and **50** which carry the axles **22***a* and **22***b* by means of which the roll **22** is journaled in the members **29** and **28**. The body **48** of the roll **22** is provided with an exterior covering **51** of rubber or like elastic material which has a smooth outer peripheral surface.

From the foregoing it will, therefore, be understood that at the nip between the two rolls of each of the three sets of gripping rolls **17–18**, **19–20** and **21–22** there are provided a plurality of grooves and a plurality of ridges alternating with one another. Accordingly, when the tow passes between the rolls **17** and **18** of the first set, it will be differentially gripped thereby, i.e., some sections of the tow will be gripped firmly between the smooth surface of the bottom roll **18** and the flat faces of the ridges **46***b* and **47***b* of the associated threaded top roll **17**, while other sections of the tow alternating with the gripped sections will be located within the confines of the grooves or spaces **46***a* and **47***a* between the ridges **46***b* and **47***b* and thus will be gripped not at all or at most only very slightly.

As a consequence of the helical threads the gripped sections of the tow will be displaced longitudinally relative to the ungripped sections of the tow so as to bring about a separation of these filaments and a deregistration of the crimps in the adjacent filaments. This will occur not only with respect to filaments lying in the same horizontal plane between the rolls, but also with respect to vertically coplanar filaments between the rolls, due to the fact that there will be some slippage between the filaments engaging the faces of the ridges of the driven top roll **17** and the filaments engaging the smooth surface of the bottom roll **18** which is not positively driven. At the same time, of course, the opposed helical arrangement of the grooves **46***a–47a* and ridges **46***b–47b* at opposite ends of the rolls **17–18** causes one half of the tow **11** to be shifted toward one end of the set of rolls **17–18**

and the other half of the tow to be shifted toward the other end of the set of rolls 17–18. Again, this occurs not only with respect to horizontally coplanar sections of the tow, but also with respect to vertically coplanar sections of the tow. Thus, the filaments are also separated laterally in every stratum of the tow, with the accompanying result of a further deregistration of the crimps of adjacent filaments.

Substantially similar actions occur when the tow 11 passes between the second set of rolls 19–20 and the third set of rolls 21–22.

FIG. 6 shows an apparatus for opening tow similar to that of FIG. 1 except for the addition of a pair of braking or tension rolls 52 and 53 which are journaled in any suitable supporting structure (not shown) and are preferably provided with smooth surfaces of an elastic material such as rubber. These rolls, thus, may be made entirely of rubber or of a metallic or other core body carrying a peripheral covering of rubber. The rolls 52 and 53, which may be positively driven or adapted to be rotated by the drag of the tow passing therebetween, are loaded or biased toward one another by any suitable hydraulic or mechanical means (not shown) and function as retarding or braking means for the tow being fed through the apparatus. The magnitude of the loading or biasing force is so selected that the rolls 52 and 53 also function to iron out possible crimp variations while at the same time aiding in the maintenance of a predetermined tension on the tow being processed, as will be more fully described hereinafter.

From the braking or tension rolls 52 and 53, the tow 11 passes to the three sets or pairs of gripping rolls 17–18, 19–20 and 21–22. In this embodiment roll 22 is driven 20% faster than roll 20 which, in turn, is driven 20% faster than roll 18. As a consequence the tow 11 is tensioned immediately upon leaving the nip of rolls 52 and 53, and this tension is maintained until the tow exits from between rolls 21–22, as evidenced by the taut appearance of the tow. The tow which is now open relaxes beyond rolls 21–22, as can be seen from the reappearance of the crimp, and advances to a cross-laying apparatus 54 where it is built up in weight per square yard and in height to several times its original value. The resulting web 55 next passes below a spray nozzle 56 where it is sprayed with a solution of a bonding agent and then passes through an oven 57 in which it is dried to yield a bonded, coherent non-woven fabric which is taken up on a driven core 58.

In addition to the lateral opening action achieved by the grooves, the use of tension effects deregistry due to differential longitudinal action as well. Thus, some sections of the tow will be gripped at their leading ends by the faster moving rolls 19 and 20 while other sections adjacent thereto will be ungripped, and at the same time the trailing ends of these same sections of the tow may or may not be gripped by the rolls 17 and 18. Similarly, some of the sections of the tow will be gripped at their leading ends by the fastest moving rolls 21 and 22 while adjacent sections are not so gripped by these rolls, and at the same time the trailing ends of these sections may or may not be gripped by the rolls 19 and 20. A further consequence of these operational conditions is that a variety of combinations of gripping actions may arise. For example, some of the sections of the tow, all of which are gripped by the braking rolls 52 and 53, may be gripped by the first set of rolls 17–18, while other sections may be gripped by the second set of rolls 19–20 without being gripped by the rolls 17–18, and still other sections of the tow may be gripped or ungripped by the third set of rolls 21–22 without being gripped by either of the first two sets of rolls or while being gripped by both or by only one or the other of the first two sets of rolls.

All of this, of course, is what takes place at any given point of time during the movement of the tow through the apparatus. Inasmuch as the tow is continuously moving and the rolls 17, 19 and 21 are continuously rotating, however, the various combinations of gripping actions are continuously changing from one instant to the next, whereby there is produced a rapid sequence of gripping and releasing, i.e. tension application and relaxation, for each section of the tow. It is, therefore, evident that the differential gripping actions of the sets of rolls 17–18, 19–20 and 21–22 in the course of their operation are such that by the time the tow leaves the last set of these rolls it is completely opened, for all practical purposes without adjacent filaments still adhering to one another and with all crimps effectively deregistered. In accordance with this invention the maximum speed of the last set of gripping rolls is so predetermined, with reference to the loading of the braking rolls 52 and 53, that the tow can never be stretched excessively to bring about a permanent deformation of the filaments, i.e. a permanent straightening out of the crimps. The actual degree of stretch permissible is, of course, determined by the elongation and recovery characteristics of the tow being opened.

Although the tow opening system of the present invention has been described herein as employing three sets of differential gripping rolls, it is not to be considered as limited to this or any specific number of such roll sets. As will be clear to those skilled in this art, large variations from normal or average values of total tow denier and number of filaments may necessitate the use of a greater number of sets of gripping rolls or may permit the use of less than three such sets. Merely by way of example, acetate tow with a denier per filament of 17 can be opened by a single set of differential gripping rolls acting in conjunction with the braking rolls, while for acetate tow with a denier per filament of about 2 or 3, two or more sets of differential gripping rolls without braking rolls will achieve the same degree of opening.

Reverting again to FIG. 1, it is seen that the tow 11 which leaves the gripping rolls 21–22 in a completely opened state, passes about a guide member 59 and thence into a chamber 60 in which a suitable plasticizer selected from the types mentioned hereinbefore is applied to the individual filaments, preferably by means of an atomizing device (not shown) of conventional construction which creates a mist of plasticizer particles or droplets in the chamber. If desired, the tow 11 may, prior to entering the plasticizing chamber 60, be passed through another air spreader or banding jet (not shown). The plasticized tow upon emerging from the chamber 60 is now in condition for passage to the usual rod-forming equipment 61 in order to be formed continuously into a cigarette filter 62 which is cut by a reciprocating blade 63 into plugs 64. Even if the tow had been opened with tension as in FIG. 6, at this point the tow would again be relaxed and relatively free of tension, but the distances between the crests of adjacent crimps in each filament might be somewhat greater than they were in the initially crimped tow taken from the bale 12.

Filter rods and plugs formed from the tow 11 processed as described herein are characterized by uniformity in weight, density and filtering properties. Smoke passing through such a filter is not channeled, as can be seen from the absence of unevenly discolored areas at the end of the filter. The plugs are firm and the paper wrapping does not wrinkle, indicating a tight and uniform packing. These advantages are noted even when the original tow was irregularly crimped and contained many cross-overs.

As contrasted with conventional braked roll tow opening systems, the novel system effects opening without excessive pulling out of crimp. Because opening is associated with pulling out crimp in the conventional system there is relatively little latitude possible in the weight per unit length of opened tow, i.e. about a 4% range of weights. By the instant system a particular tow can be processed to give a product whose weight, at will, can be varied over a range of 12%. Moreover, once a particu-

lar target weight has been set the novel system will produce opened tow of marked uniformity so that filter tips produced therefrom will all be of substantially the same weight whereas a tow opened in conventional manner will yield filter tips varying considerably from one another in weight.

The superior opening of the novel system evidences itself in more firm plugs or plugs of conventional firmness at lower weight which in turn reduces the amount of plasticizer needed. Less fiber is required to meet particular smoke removal and pressure drop specifications than with conventional opening systems and, in addition, a particular smoke removal efficiency can be achieved at a lower pressure drop, i.e. with greater ease of draw.

The following examples are given to illustrate the present invention further, all parts being by weight.

Example I

A crimped tow composed of 16,675 secondary cellulose acetate filaments of 3.2 denier is processed through the apparatus shown in FIG. 1 with the rolls **19**, **20** separated so as not to operate on the tow and the nip of rolls **17**, **18** spaced **18** inches from the nip of rolls **21**, **22**. Rolls **18** and **22** are rubber covered and driven at peripheral speeds of 145 and 170 feet per minute; since the crimp in the tow is of such magnitude that it could be pulled by roll **22** up to 200 feet per minute without removing the crimp, the tow is not under any significant tension between rolls **18** and **22**. Rolls **17** and **21** are made of steel and helically threaded from their center lines to their ends in opposite directions. They are idly mounted and rotate through contact with the driven rubber rolls therebelow. The opened tow picks up 7.2% of its weight of dimethyoxyethyl phthalate as plasticizer, is wrapped in paper in conventional manner, cut into filter plugs of 17 mm. length and cured for 2 hours at 76° F. The plugs exhibit a pressure drop of 54 mm. H_2O, the pressure drop being the suction necessary to maintain a flow rate of 17.5 cc. of air per second through the plug, not incorporated into a cigarette. The plugs exhibit a smoke removal efficiency of 39%, determined as follows: 12 puffs of 35 cc., i.e. 2 seconds of puffing, are drawn from a lit cigarette through the filter and through a trap having on its bottom a sintered glass disk. Two grams of sifted alpha cellulose are placed on the disk, producing a pressure drop of about 5 centimeters of water. The trap is immersed half way in a Dry Ice-acetone bath. The formula for the smoke removal efficiency is as follows:

$$\text{Percent efficiency} = \frac{\text{Weight of filters}}{\text{Wt. of filters} + \text{Wt. of trap}} \times 100$$

To obtain a comparable pressure drop and smoke removal efficiency employing conventional tension opening, it is necessary to employ a tow of 60,000 total denier; such tow at equal plug weight has a pressure drop of 52 mm. H_2O and a smoke removal efficiency of 36%; its compressibility is 29% whereas that of the 54,000 denier tow processed with the threaded roll is only 22%. Compressibility is measured by permitting a 4-ounce load knife edge to rest transversely of the paper-wrapped plug for 10 seconds. The percent compressibility is 100 times the difference between the original diameter and the height of the plug at the base of the depression divided by the original diameter. A low compressibility indicates a firm plug. If threaded rolls are used to process the 60,000 total denier tow the plug weight will be 0.168 gram, the compressibility 21%, the pressure drop 68 mm. H_2O and the filtration efficiency 45%.

If in the foregoing example rolls **17** and **21** are replaced by smooth-surfaced rolls the tow is not opened sufficiently to produce a commercially useful product.

Example II

The apparatus of FIG. 1 except for inclusion of braking rolls **52–53** of FIG. 6 is used to process a tow composed of 35,000 continuous filaments of cellulose acetate, having a total denier of 70,000 and an average of 12 crimps per inch. The gripping rolls **17** to **22** are 5 inches in diameter, which includes a 1-inch layer of rubber having a hardness value of about 60 durometer, and approximately 14 inches long. The sets of rolls are spaced about 15 inches apart, and each of the rolls **17**, **19** and **21** has two opposite helical threads of 14 turns per inch cut about 1/16-inch deep into its outer surface. The threaded or grooved roll **17** is driven by any suitable mechanism to have a surface speed of 36.0 yards per minute, the roll **19** to have a 5% greater speed of 37.8 yards per minute, and the roll **21** to have still another 5% greater speed of 39.7 yards per minute. The braking rolls **52–53** are idly mounted for rotation and are biased toward each other so strongly as to require a pull, i.e. tension, of 10 pounds to advance the tow therebetween. The tow is passed through the banding jet **14**, then is drawn through the pair of braking rolls **52–53** and the sets of differential gripping rolls **17–18**, **19–20** and **21–22**, and thereafter passes through the plasticizing chamber **60** in which it picks up about 5.6% of its weight of triacetin. The tow leaving the chamber **60** shows no signs of being overstretched, and is characterized by uniformity of openness throughout, by thorough deregistration of crimps, and by a minimum percentage of broken filaments.

Example III

A 50,000 denier tow of 3.3 denier secondary cellulose acetate filaments crimped to the extent of 10 crimps per inch is opened by the apparatus of FIG. 6 to give a web weighing 0.45 ounce per square yard. Except for omission of the cross-layer the web is further processed web is further processed as in FIG. 6, being sprayed to a pick-up of 50% solids, i.e. total solids of fiber plus binder of about 0.7 ounce per square yard, with an aqueous latex comprising 77% water, 0.13% of oxyethylated iso-octyl phenol, 0.63% of ammonium chloride, 18.5% of a methyl methacrylate-ethyl acrylate copolymer containing cross-linking groups, and 3.8% of methyl methacrylate polymer. The wet web is subjected to a temperature of 325° F. in an infrared oven for 15 seconds to effect drying and curing, and is collected.

Example IV

The process of Example III is repeated except that the bonding agent is a 23% emulsion of a methyl methacrylate-ethyl acrylate copolymer containing cross-linking groups, and is applied to a solids pick-up of 100% based on the weight of the fiber. The bonding agent is cured by passage of the opened tow through an oven with a residence time of 160 seconds, the first half of the oven being heated to 375° F. and the second half to 425° F. Because of the greater amount of bonding agent emulsion applied to the tow the fabric is somewhat thinner but stronger than that of Example III.

Example V

The starting tow of Example III is opened as in Example III and is sprayed with 10% its weight of dimethoxyethyl phthalate. The tow, together with a paper support, is then passed between a pair of calender rolls at 275° F. under 4 tons of pressure. The resultant product is a thin, strong, porous sheet glazed on the face which directly contacted the calender roll, and unglazed and having a fibrous feel on the face which contacted the paper support.

Although the tow opening process has so far been described as preparatory to the manufacture of cigarette filters and non-woven, it is to be understood that the present invention is not so limited, and that its basic principles are adapted for application to a number of other textile operations where continuous filament tow is employed and where the opening of such tow is essential.

By way of résumé, thereof, in processing tow according to the broadest aspect of the present invention, the tow is advanced longitudinally and concurrently therewith is subjected to a differential gripping action at a plurality of points spaced from one another transversely of the tow and defined at the nip between a smooth-surfaced roll and an opposed, circumferentially grooved, and preferably doubly helically threaded roll. In another form, the tow is differentially gripped at a plurality of sets of points so defined, these sets being spaced from one another longitudinally of the tow with the points in each set being spaced from one another transversely of the tow. Most preferably, the tow is subjected to the differential gripping action between a line extending transversely of the tow and defined at the nip between a pair of smooth-surfaced opposed rolls, and one or more of the aforesaid sets of points, which set or sets are spaced from the said line longitudinally of the tow in the direction of movement of the latter.

This application is a continuation-in-part of U.S. application Ser. No. 90,864, filed February 21, 1961, now abandoned.

It is to be understood that the foregoing detailed description is given merely by way of illustration and that many variations may be made therein without departing from the spirit of our invention.

Having described our invention, what we desire to secure by Letters Patent is:

1. The process of opening a coherent multifilament tow, comprising the steps of longitudinally advancing said tow, and subjecting said tow while the same is in motion to a differential gripping action at a plurality of points spaced from one another transversely of said tow and defined by a pair of opposed surfaces one of which is profiled and the other of which is smooth, to effect a separation of the filaments constituting said tow.

2. The process of opening a coherent multifilament tow, comprising the steps of longitudinally advancing said tow, and subjecting said tow while the same is in motion to a differential gripping action at a plurality of sets of points, each of said sets of points being defined by a pair of opposed surfaces one of which is grooved and the other of which is smooth, said sets being spaced from one another longitudinally of said tow, and said points in each set being spaced from one another transversly of said tow, to effect a longitudinal separation of the filaments constituting said tow.

3. The process of opening a coherent multifilament tow, comprising the steps of longitudinally advancing said tow, and subjecting said tow while the same is in motion to a differential gripping action between a line defined by a pair of opposed smooth surfaces and extending transversely of said tow, and a plurality of points spaced from said line longitudinally of said tow in the direction of movement thereof and from one another transversely of said tow and defined by a pair of opposed surfaces one of which is grooved and the other of which is smooth, to effect a separation of the filaments constituting said tow.

4. The process of opening a coherent multifilament tow, comprising the steps of longitudinally advancing said tow, and subjecting said tow while the same is in motion to a differential gripping action between a line defined by a pair of opposed smooth surfaces and extending transversely of said tow, and a plurality of sets of points, each of said sets of points being defined by a pair of opposed surfaces one of which is grooved and the other of which is smooth, said sets being spaced from one another and said line longitudinally of said tow in the direction of movement thereof, and said points in each set being spaced from one another transversely of said tow, to effect a longitudinal separation of the filaments constituting said tow.

5. The process of opening a crimped multifilament tow, comprising the steps of longitudinally advancing said tow between and in contact with at least one pair of opposed cylindrical surfaces one of which is circumferentially ridged and the other of which is smooth, and positively rotating at least one of said surfaces as said tow passes therebetween to thereby effect relative displacements between adjacent filaments for separating the same and deregistering the crimps thereof.

6. The process of opening a crimped multifilament tow, comprising the steps of longitudinally advancing said tow between and in contact with each of a tandem series of pairs of opposed cylindrical surfaces wherein one surface of each pair is circumferentially ridged and the other surface of each pair is smooth, and positively rotating at least one surface of each of said pairs of surfaces as said tow passes therebetween so that the positively rotated surface of each pair has a higher surface speed than the positively rotated surface of the preceding pair, to thereby effect relative displacements between adjacent filaments for separating the same and deregistering the crimps thereof.

7. The process of claim 6, wherein said tow is composed of cellulose acetate continuous filaments.

8. The process of claim 5 including the preliminary step of passing said tow over a tension device prior to the series of pairs of surfaces so that the tow is under tension when acted upon by said ridges.

9. The process of claim 6 including the further steps of applying a plasticizer to said opened tow, enclosing said plasticized tow in a wrapper, and severing said wrapped tow into cigarette filter plugs.

10. The process of treating a crimped multifilament tow comprising the steps of spreading said tow into the form of a flat band, longitudinally advancing the band-shaped tow between and in contact with a first pair of idly rotatable opposed cylindrical surfaces both of which are smooth and are rotated in response to movement of said tow therebetween so as to exert a drag on said tow, further advancing said tow between and in contact with each of a tandem series of additional pairs of opposed cylindrical surfaces wherein one surface of each of said additional pairs is circumferentially ridged and the other surface of each additional pair is smooth, positively rotating at least one surface of each pair of said additional pairs of surfaces at respective progressively higher surface speeds so as to differentially grip said tow as it moves from said first pair of surfaces to the last of said additional pairs of surfaces, whereby the filaments of said tow are separated longitudinally and the crimps in adjacent filaments are deregistered so as to result in an open tow.

11. The process which comprises longitudinally advancing a coherent multifilament tow, subjecting said tow while the same is in motion to a differential gripping action at a plurality of points spaced from one another transversely of said tow and defined by a pair of opposed surfaces one of which is grooved and the other of which is smooth, to effect a separation of the filaments constituting said tow, and then continuously bonding the filaments of said tow while in laterally extended form to yield a bonded continuous filament non-woven sheet-like structure.

12. The process which comprises longitudinally advancing a coherent crimped multifilament tow between and in contact with at least one pair of opposed cylindrical surfaces at least one of which is circumferentially ridged to thereby effect relative longitudinal displacements between adjacent filaments for longitudinally separating the same and deregistering the crimps thereof, continuously applying a bonding agent to said deregistered tow and heating said deregistered tow while in laterally extended form to yield a bonded continuous filament non-woven sheet-like structure.

13. Apparatus for forming a crimped multifilament tow into cigarette filter plugs, comprising at least one pair of opposed differential gripping rolls one of which

is circumferentially ridged and the other of which is smooth-surfaced, means for driving only one of said rolls, said rolls being biased toward one another so that the roll which is not driven is also caused to rotate, whereby as said tow passes between and in contact with both said rolls the filaments of said tow are separated from one another longitudinally and the crimps of adjacent filaments are deregistered, means for enclosing the deregistered tow in a wrapper, and means for severing said wrapped tow into cigarette filter plugs.

14. Apparatus according to claim 13, further comprising a pair of opposed smooth-surfaced braking rolls positioned upstream of said differential gripping rolls.

15. Apparatus for treating a crimped multifilament tow, comprising banding jet means for shaping said tow into a flat band, at least one pair of opposed differential gripping rolls between and in contact with which said tow is adapted to pass, in each pair one of said differential gripping rolls being provided with a profiled surface and the other being smooth-surfaced, drive means operatively connected to at least one roll of each pair so as to rotate the same positively at a predetermined surface speed, the rolls of each pair being biased toward one another and being rotatable together, whereby said tow upon moving through said differential gripping rolls while the latter are being rotated by said drive means is differentially gripped to effect a longitudinal separation of the filaments of said tow and deregistration of the crimps of adjacent filaments so as to result in a completely opened tow.

16. Apparatus according to claim 15, including a plurality of pairs of differential gripping rolls, the connection between said drive means and said pairs of differential gripping rolls being such that the driven rolls of successive pairs are driven at successively higher surface speeds.

17. Apparatus for producing a non-woven sheet-like structure from a coherent multifilament tow comprising at least one pair of opposed differential gripping rolls at least one of which is circumferentially ridged, means for advancing said tow between said rolls whereby as said tow passes between and in contact with said rolls the filaments of said tow are longitudinally separated from one another, means for applying a bonding agent to said tow, and means for heating said tow while in laterally extended form to complete bonding thereof into a non-woven sheet-like structure.

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