

Oct. 4, 1960

C. BOYER

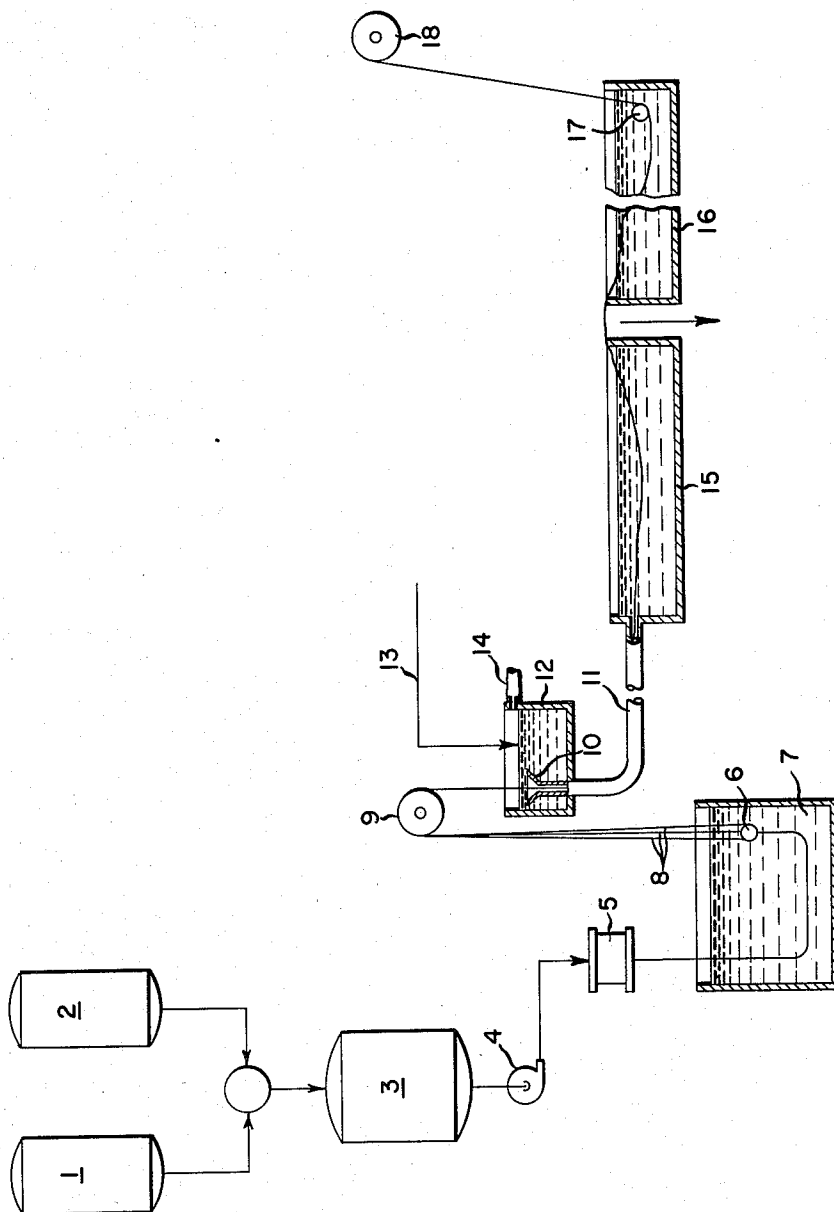
2,955,017

PROCESS OF FLOWING FILAMENTS IN LAMINAR FLOW SURROUNDED BY
AN OUTER AREA OF TURBULENT FLOW

Filed Aug. 4, 1958

2 Sheets-Sheet 1

Fig. 1



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2 Sheets-Sheet 2

Fig. 2

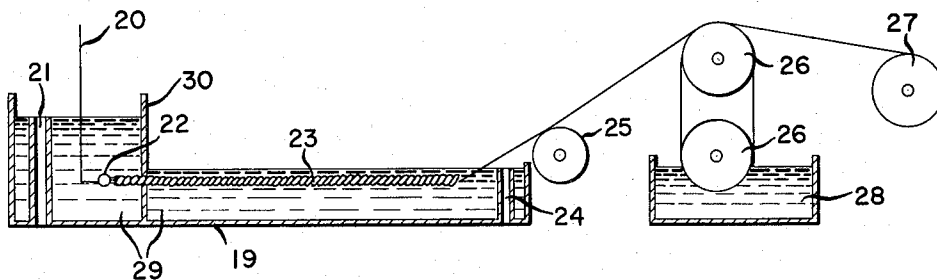
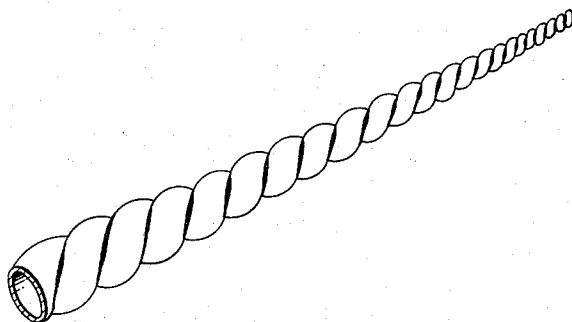


Fig. 3



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PROCESS OF FLOWING FILAMENTS IN LAMINAR FLOW SURROUNDED BY AN OUTER AREA OF TURBULENT FLOW

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3 Claims. (Cl. 18—54)

The present invention relates to a novel and useful process for forming a filamentary structure. More particularly, it relates to an improved process for preparing fibers, filaments, ribbons, and the like at relatively high speeds.

One of the major problems in preparing filamentary structures by the various prior art processes is the fragility of the freshly formed thread line. Since the filament is fragile in the initial spinning stage, the filament may be easily damaged and various precautions are necessary if good quality filaments are to be obtained. This has been a serious problem in the various wet-spinning procedures in which a polymer solution is extruded into a coagulating liquid to form filaments. Typical examples of such conventional processes are the preparation of rayon filaments by extruding viscose into a coagulating bath, the preparation of rubber filaments by extruding rubber latex into a coagulant, and the preparation of filaments of condensation elastomers by extruding solutions of the elastomers into aqueous coagulating baths. It also represents a serious problem in the so-called "matrix" or "dispersion" type of spinning process. In this process a small amount of a relatively cheap matrix-forming material, such as sodium alginate, is added to a polymer in dispersion form. The modified dispersion is then extruded into a setting medium for the matrix-forming material so as to form a fragile shaped article comprising a gel matrix containing immobilized discrete polymer particles. The polymer particles in the gel structure are then coalesced or fused with a coalescing solution, into filaments, fibers, etc., composed predominantly of the polymeric material but usually containing a small amount of the matrix-forming material.

In each of these processes the spinning speed is generally reduced somewhat in order to avoid breaks and damage which occur to the fragile thread line when standard speeds are used. For example, in "matrix" or "dispersion" spinning the maximum speed heretofore obtainable has been about 20 yards per minute. When this is compared to the spinning speeds used in the conventional viscose process, i.e., about 100 yards per minute, it is clear that this procedure is not as attractive as it could be from a commercial standpoint. Even in those processes in which commercial speeds are obtainable, such as in the viscose process, variations or fluctuations in the bath flow direction or velocity cause filaments of poor quality to be formed.

The seriousness of this problem is reflected in the large number of patents which have issued describing techniques and devices for minimizing this problem. Many patents have suggested the use of spinning tubes to confine the bath liquid and to minimize turbulence in the bath flow. In many instances it has been recommended that the bath flow at the same rate that the thread line is moving so that no appreciable tension will be exerted on the filament during the initial stages of formation. The use of counter-current flow or bath flowing more rapidly than

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the thread line has also been suggested to provide some stretching action in the bath. In such cases, however, a smooth bore tube of uniform cross section is always used.

It is an object of the present invention, therefore, to provide an improved spinning process which permits a substantial increase in spinning speeds with no damage to the filament. Another object is to provide a process which improves liquid contact with the filament, reduces the load on the filament, allows easier stringing up and permits increasing the speed of the process. A still further object is to provide a process in which a freshly formed thread line is intimately contacted with a filament-forming liquid while being partially supported by this liquid. Other objects will become apparent from the descriptions, drawings and the claims.

These objects are accomplished by the present invention which provides an improvement in the process of forming a filamentary structure by contacting a freshly extruded polymer with a filament-forming liquid to form a filamentary structure; the improvement which comprises flowing the filament-forming liquid concurrently with the polymer as a single stream, the cross section of the concurrent stream of the filament-forming liquid having an inner area and a surrounding outer area, the said inner area surrounding the extruded polymer and being in laminar flow and the said outer area being in a state of turbulent flow which proceeds concurrently with the polymer in the form of a helix around the inner area of laminar flow.

The terminology "process . . . to form a filamentary structure" is used to describe the conventional processes, such as the ones hereinbefore mentioned. It thus includes the conventional wet-spinning and the matrix type of spinning procedures. The term "a filamentary structure" is used to designate a structure which is long as compared to its width or cross section, such as a filament, fiber, ribbon or the like. The term "freshly extruded" is used to signify that the polymer has recently come from the extrusion orifice and that it has not as yet been completely changed to a structure in which the final polymer runs continuously throughout the structure. The term "filament-forming" is used to describe a liquid which causes the polymer to solidify or coalesce so that it is distributed continuously throughout the filamentary structure. The filament-forming liquid may thus be either a coagulating or a coalescing liquid for in each case it causes the polymer to be continuous through the structure. The terms "laminar flow" and "turbulent flow" are given their conventional meaning as in hydraulics. The term "laminar flow" thus means "streamline" or "viscous" flow whereas the term "turbulent" means that the flow is non-laminar or in a state of turbulence.

The desired flow of the present invention is obtained by the use of a novel enclosure which imparts this flow pattern to the filament-forming liquid. One type of enclosure for achieving this flow is a non-round or elliptical tube twisted lengthwise about its axis, the turns being in the same or in alternately opposed directions. Such a non-circular cross section can be given to a tube by indenting the tube, by creasing the tube, by partially flattening the tube to an oval shape, by the proper molding or extruding of the tube, etc., or by a combination of these or other operations. Each of these tubes has an inner periphery which is non-uniform. A liquid which would normally pass through the tube in laminar flow is thus given an outer area of turbulence. The preferred tubes employed in this invention are those which have an oval or elliptical cross section with a maximum internal free passageway of about 1 inch, a length of from about 1 to about 16 feet and a twist of from about 1 to about 10 turns per foot.

In the accompanying drawings which illustrate preferred embodiments of the invention,

Figure 1 is a diagrammatical flow sheet of this invention as applied to the "matrix" or "dispersion" type of spinning process;

Figure 2 is a diagrammatical flow sheet of this invention as applied to the "coagulation" type of spinning process; and

Figure 3 is a plain view of one enclosure which may be used in the practice of this invention.

In Figure 1, a dispersion of the synthetic polymer particles is prepared by polymerizing the monomer in an aqueous medium containing an emulsifying agent. This dispersion is stored in tank 1. A quantity of an aqueous solution containing the matrix-forming material, such as a one percent by weight solution of sodium alginate is prepared and stored in tank 2. The contents of both tanks are then mixed in a mixer 3 to form a modified dispersion. The mixture is pumped by pump 4 through a filter 5, then through the orifices of spinneret 6 into the coagulating or setting medium 7, to form the filaments 8. The filaments comprising the gel matrix containing immobilized discrete particles of polymer are converged over roll 9 and led through funnel 10 into the coalescing tube (twists not shown) 11. The coalescing liquid is fed into trough 12 through tube 13. An overflow tube 14 allows a constant head to be maintained in trough 12. After several feet of concurrent travel through tube 11, the coalescing liquid and filament are led into trough 15 containing additional coalescing liquid. The filament then passes over the edge of trough 15 into trough 16 which contains wash water. After being washed, the filament is led under roll 17 to the windup 18.

In Figure 2, a solution of the polymer from supply pipe 20 is extruded through spinneret 22 into a coagulating bath 29 maintained at a constant head in tank 30 by means of an adjustable overflow 21. The extruded polymer proceeds through twisted tube 23 along with the coagulating liquid 29 into trough 19, which contains additional coagulating liquid 29. The trough 19 is equipped with an adjustable overflow pipe 24 to control the liquid level in the trough. The filament upon emerging from the coagulating liquid 29 in trough 19 is carried over a guide roll 25 around wash rolls 26 into wash water 28 to windup 27.

Figure 3 is a detailed illustration of a section of one of the tubes used in the process of the present invention. The tube is noncircular in cross section and is twisted about its axis to provide a spiral pattern.

The invention is illustrated by the following examples which are cited to illustrate the invention but are not intended to limit it in any manner. Unless otherwise stated, all percentages mentioned in the specification are by weight. When tubes are employed in the following examples, the differential (hydrostatic) head between the two baths connected by the tube is maintained at about 4 inches.

Example I

An aqueous dispersion of polyacrylonitrile is prepared from 0.11 part of potassium persulfate, 2.2 parts of sodium lauryl sulfate, 120 parts of water, and 88 parts of acrylonitrile. A stainless steel kettle is used, and the free space of the kettle is flushed with nitrogen gas and then sealed. After mixing the contents by relatively mild agitation for 16 to 17 hours at 40° C., the resulting polymer dispersion contains approximately 40% solid material as determined by evaporation of a portion. The aqueous polymer dispersion is diluted with an equal volume of water containing 1% by weight of sodium alginate.

The modified dispersion is extruded (using the apparatus of Figure 1) through a 100 hole 3 mil spinneret into an aqueous coagulating bath containing 5% by weight of calcium chloride. The coagulated gel filament

is then passed over a wheel into a coalescing bath containing 60% calcium thiocyanate at 103° C. In this bath the filament is passed through a 4.5 foot straight bore smooth-walled 1½ inch internal diameter glass tube at a rate of 30 y.p.m. The filaments are washed and wound up at 33-40 y.p.m. These filaments cannot be drawn more than about 8×. Portions of these filaments drawn 7× in water heated at 100° C. have the following properties: tenacity=4.8 g.p.d., elongation=24%, and initial modulus=35 g.p.d.

No improvement is noted if a flexible tube is used in place of the glass tube and the filament passed through this tube arranged in a spiral pattern. For example, the dispersion described in the first paragraph is extruded through a 40 hole 3 mil spinneret into a 5% calcium chloride bath, and then passed over a wheel into a coalescing bath containing 65-70% of calcium thiocyanate heated to 102° C. In this bath the filament is passed at approximately 29 y.p.m. through 6 feet of 0.75 inch internal diameter flexible plastic tubing arranged in the form of a coil and then washed. Portions of these filaments drawn 7× in water heated at 100° C. have the following properties: tenacity=3.7 g.p.d., elongation=31%, and initial modulus=39 g.p.d.

The following data show the advantage of the tube design of this invention. A 4.5 foot, 0.75 inch internal diameter stainless steel tube is flattened to an oval shape and twisted approximately 3 turns/ft. A 40% dispersion (550 grams) of polyacrylonitrile is mixed with 515 grams of a 1% sodium alginate solution containing 0.5% of sodium lauryl sulfate. Filaments are prepared by extruding (using the apparatus of Figure 1) at approximately 50 y.p.m. and coagulating as described in the preceding two paragraphs. The coagulated gel filament is then passed over a wheel into a 65% calcium thiocyanate solution heated at 110° C. The coagulated gel filament is passed along with this solution through the twisted stainless steel tube where coalescence occurs. The filaments are then washed and wound. The coalesced filaments can be drawn as much as 22×. The following table shows the properties obtained at various draw ratios:

Draw Ratio	Tenacity (g.p.d.)	Elongation (percent)	Initial Modulus (g.p.d.)	Denier
10X	5.5	23	80	2.5
18X	6.7	12	84	1.1
22X	10.0	8.7	153	0.94

Example II

Poly(tetramethylene oxide) glycol (124.5 grams=0.12 mol) having a molecular weight of 1035 is reacted with 10.50 grams (0.06 mol) of 4-methyl-m-phenylene diisocyanate by stirring in an anhydrous atmosphere for 3 hours at steam bath temperatures. To this "dimer" with hydroxyl ends is added without cooling 30.0 grams (0.12 mol) of methylene bis(4-phenylisocyanate) dissolved in dry methylene chloride and the mixture allowed to react for 1 hour at steam bath temperatures. The "dimer" with isocyanate ends is allowed to cool and 400 grams of N,N-dimethylformamide added. To this solution is added 3.0 grams (0.06 mol) of hydrazine hydrate dissolved in 26 grams of N,N-dimethylformamide. The resulting polymer solution, which contains approximately 28% solids, is diluted with N,N-dimethylformamide to produce a spinning solution containing about 20% solids.

The solution is extruded through a 20 mil single hole spinneret into varying aqueous baths heated at 80° C. A filament formed at a rate of approximately 50 y.p.m. by extruding into water is found to have a tenacity of 0.32 g.p.d. and an elongation of 418%. By changing the coagulation bath to one containing 50% by weight of N,N-dimethylformamide, filaments can be obtained

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from this solution which have a tenacity of 0.56 g.p.d. and an elongation of 570%. This represents greatly improved physical properties, because the tenacity has been markedly increased with an accompanying increase in elongation. The improvement in properties is attributed to the presence of the N,N-dimethylformamide in the spinning baths, which causes slower coagulation and the formation of a more desirable structure.

However, despite the fact that the ultimate properties are better, the filament initially formed when this bath is used is actually much weaker. Consequently, in order to maintain spinning continuity, it is necessary to reduce the spinning speed materially. Spinning continuity can be maintained at a satisfactory level using spinning speeds of 50 y.p.m. with this bath while still retaining the desirable level of properties (e.g., filaments with a tenacity of approximately 0.5 g.p.d. and an elongation of approximately 600%) only by using the twisted tube of the preceding example in the spinning bath as shown in Figure 2. The use of a twisted tube made of a transparent material shows that the running filament stays in the center of the twisted tube and does not come in contact with the walls. Further tests show that flow contains a central area of laminar flow (through which the filaments pass) and an outer area of turbulence adjacent the wall of the twisted tube.

Example III

A polymer with an inherent viscosity of approximately 1.62 in sulfuric acid is prepared from m-phenylene diamine and isophthaloyl chloride. A portion of this polymer is dissolved in N,N-dimethylacetamide to produce a solution containing approximately 19.5% of the polymer and 4.5% by weight of calcium chloride (based on polymer weight). This solution is heated to 60° C. and extruded through a 100 hole 3 mil spinneret into a bath maintained at 60° C. which contains a mixture of 35% by weight of N,N-dimethylacetamide, 20% of calcium chloride, and 45% by weight of water. After passing through approximately 5 yards of this bath at a rate of 18 yards per minute, the filament is transferred to a bath of water at room temperature. After passing through approximately 18 yards of this bath at the same speed, the filaments are collected on a bobbin. The filaments are drawn approximately 1.5× while passing through these baths. They are subsequently after-drawn by passing through steam and over a hot-plate to produce a filament which has had a total draw of approximately 3.6×.

The above spin is repeated with a 6 foot section of a 0.75 inch stainless steel tube flattened to an oval cross section and twisted to three turns per foot inserted (as shown in Figure 2) in the first bath. In this instance the filament is first passed through the tube and then through an additional 5 yards of the first bath and then through approximately 30 yards of the second bath. In both baths the filament travels at a rate of about 30 yards per minute. The remainder of the processing is the same as before.

Following is a comparison of the properties of the filaments obtained by these two different processes:

	Denier	Tenacity (g.p.d.)	Elongation (percent)	Initial Modulus (g.p.d.)
Control.....	2.4	2.8	42	56
Tube-Spun.....	2.5	4.5	40	67

This example demonstrates that the use of the twisted tube results in the formation of filaments with substantially superior properties even when higher spinning speeds are used. The following example shows that the properties are more divergent when equal spinning speeds are used.

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Example IV

The polymer used in the preceding example is dissolved to form a solution of the same composition. The spinning conditions are identical with those described in the preceding experiment. However, in this experiment, the spinning without the tube is done at 30 yards per minute and the length of travel in the bath is 30 yards rather than 18. The properties of the two filaments are compared in the following table:

	Denier	Tenacity (g.p.d.)	Elongation (percent)	Initial Modulus (g.p.d.)
15 Control.....	4.1	1.7	24	42
Tube.....	2.2	4.4	31	76

The use of the special enclosure permits one to at least double, and in some cases more than quadruple, the rate of spinning without increasing the number of breaks in the thread line. While a tube of one particular design has been demonstrated in the examples, any enclosure which imparts the desired flow to the coalescing bath as it flows concurrently with the filaments can be used.

Another advantage of the special enclosure of the present invention is the fact that string-up trouble is practically eliminated when spinning is initiated. In the prior art, when tubes were used, the freshly spun filament was led into the tube where it often became tangled to such an extent that the tube became partially or totally obstructed and spinning had to be restarted. When employing the process of the present invention, however, the freshly spun filament is carried through the tube with substantially no tangling of the filament or plugging of the tube passageway.

Many types of materials may be used for preparing the tubes employed in the present invention. For example, ordinary glass and plastic tubing may be used. The flow characteristics in tubes of metal or plastic or glass can be modified by pressing dimples or rings into the outside surface to form irregularities on the inner surface. The tube may also be made uneven by corrugating or sand blasting. The tubing can also be made from elastomeric materials, which can, if desired, be distorted or made uneven by applying an irregular outer cover prior to vulcanization, or by using an irregular curing mold.

As mentioned earlier, the process of this invention is useful when utilized in the preparation of rubber threads from latices. The usual processes for preparing rubber threads in this manner are well known in the art. Latices from natural rubber or synthetic polymer latices prepared by emulsion polymerization may be used. The stabilized emulsions are extruded through suitable orifices into a coagulating bath. Acetic acid has been suggested as a suitable coagulant. The freshly formed thread line is very weak and very gentle handling is required. The process of this invention is well suited to the handling of this thread line during its formative stages.

The apparatus is also well suited to the processing of highly elastic filaments from condensation elastomers. This is a conventional wet-spinning process in which solutions of the elastomers are extruded into a coagulating bath. Typical condensation elastomers are those in which a low molecular weight polymer with active hydrogen ends, such as a polyester of a polyether glycol, is reacted with a diisocyanate and this isocyanate-terminated low molecular weight polymer is chain-extended with a difunctional active hydrogen compound. As is true in the case of the addition elastomers, the freshly formed filaments tend to be quite weak. These filaments increase in strength upon further treatment in the bath, but very low spinning speeds must be used until coalescence is sufficiently complete to permit more rapid

processing. The use of the flow of the present invention eliminates contact with the walls of the tube. This factor, in conjunction with the concurrent bath-flow made possible by the use of this tube, reduces the tension on the filaments and permits spinning speeds to be increased from approximately 30 y.p.m. to approximately 100 y.p.m.

The process of this invention is particularly well adapted to the processing of the relatively weak freshly formed filaments obtained by extruding dispersions of water-insoluble synthetic linear polymers in a solution of a matrix-forming material. This process has been referred to earlier and will be described in detail in the following sections. The following advantages have been observed when the process of this invention is applied to the preparation of filaments by this method:

(1) No dragging or snagging of the filaments on the walls of the tube.

(2) Better coalescence of the polymer particles embedded in the matrix.

(3) Filaments are obtained which are more readily drawable and can be drawn to a final length which is a much higher percentage of the original length than is possible without the use of this tube.

(4) Yarn obtained is free of loops.

(5) Much higher spinning speeds are possible.

(6) Fewer interruptions in the spinning process due to filament breakage.

(7) Permits use of baths which would otherwise be impractical because of the weak thread line developed.

As illustrated by the examples, attempts to use an unmodified cylindrical tube, or even a cylindrical tube arranged to form a spiral passage, does not provide comparable results. The filaments tend to "hang up" on the walls of the tube and breakage of the thread line results when speeds substantially above about 30 yards per minute are tried when preparing filaments from polymer dispersions. Despite the fact that the turbulence, along with the laminar flow, within the tube would appear to represent a harsher treatment for the filaments, the results demonstrate that the reverse is actually true.

The preparation of filaments from polymer particles dispersed in a solution of a matrix-forming material is a recently developed process which has not been described extensively in the literature. Accordingly, it will be described in more detail than the other spinning processes well-known in the art which may be improved by the use of this invention. In general, the dispersion spinning process may be used to prepare films and fibers of water-insoluble synthetic linear polymers having a molecular weight of 10,000 or higher. Some of the many polymers that can be used include: acrylonitrile polymers and copolymers; polyacrylic and polymethacrylic esters, such as poly(methyl methacrylate); poly(vinyl chloride) and copolymers of vinyl chloride with vinyl esters, acrylonitrile, vinylidene chloride, and the like; copolymers of vinyl compounds with conjugated dienes such as butadiene; vinylidene chloride polymers; polyethylene; polytetrafluoroethylene; polychlorotrifluoroethylene; poly(vinyl acetate); partially hydrolyzed poly(vinyl esters); poly(methyl vinyl ketone); polyvinyl ethers; chlorosulfonated polyethylene; poly(vinyl carbazole); poly(vinyl acetals); polyamides, such as poly(hexamethylene adipamide), poly(N-methoxymethylhexamethylene adipamide), poly(ethylene sebacamide), poly(methylene bis-[p-cyclohexylene] adipamide); polysulfonamides; polyureas, such as poly(tetramethylene urea); polyurethanes, such as those prepared from piperazine; polyesters, such as poly(ethylene terephthalate), and elastic copolyesters, such as those prepared from a mixture of aromatic and aliphatic dibasic acids and a suitable glycol; polyesteramides; polythioesters; polysulfones; polyethers; cellulose derivatives, such as cellulose acetate, and many others. Copolymers of all types can be used as well as the homopolymers listed,

The term copolymer is intended to include all types, such as random, alternating, segmented or block, and graft copolymers. The polymer particles may even be cross-linked, providing the degree or tightness of cross-linking is not sufficient to prevent the coalescence required to produce the desired structure.

The matrix-forming materials useful in the invention comprise cationic or anionic polymeric electrolytes or neutral or non-ionic polymeric materials which are soluble in the dispersion of the fiber-forming polymer and which can be shaped in aqueous or non-aqueous media. Suitable anionic polymer materials contain a plurality of acidic groups, such as carboxyl, sulfonic and/or phosphoric or other acid groups. Specific polymers and classes of polymers which are applicable as anionic matrix-forming materials in this process include the following: alginates, carboxyalkylcelluloses, carboxymethylhydroxyethylcelluloses, viscose, polyacrylates, polymethacrylates, and the like. In most cases the monovalent alkali metal salts of the anionic polymeric electrolytes are more soluble in water and are preferred.

Cationic polymeric electrolytes suitable as matrix-forming materials contain a plurality of basic groups. These are usually amino and/or quaternary ammonium groups. Examples of useful cationic polymeric electrolytes are polyvinylpyridine, diethylaminomethyl methacrylate polymer, hydrolyzed copolymers of vinyl acetate and vinyl pyridine, N-vinylphthalimide, N-vinylsuccinimide, and other vinyl-substituted amino and masked amino polymers.

Neutral polymers which may be used as matrix-forming materials include methylcellulose, hydroxyethylcellulose, cellulose acetate, urea-formaldehyde and melamine-formaldehyde resins, cyanoethylcellulose, poly(vinyl alcohol) and polyacrylamide.

Only small amounts of matrix-forming material are required to provide a definite advantage over none at all. The quantity used ranges from 0.10% to 10% by weight of the dispersion, with 0.25 to 5% being preferred. The specific quantity preferred varies with the matrix material.

The setting or immobilizing medium may be any liquid or vapor capable of precipitating or gelling the matrix-forming material. This includes air and vapors such as volatile strong acids, e.g., hydrogen chloride. Also useful are various other compounds and/or mixtures in liquid or vapor form, such as water-miscible organic compounds and aqueous solutions of solid, liquid, or gaseous inorganic and/or organic compounds. Preferably, aqueous solutions are used which contain a low concentration (e.g., 0.5-40% by weight of the aqueous solution) of an electrolyte or a non-electrolyte. Typical useful non-electrolytes are water-miscible organic liquids, such as alcohols, ketones, or glycols. High or low temperatures may be used in coagulating baths to develop the desired precipitating qualities of the particular setting agent being used.

When aqueous baths are used, the anionic and cationic matrix-forming materials will generally be formed into shaped articles through gelation as a result of chemical action on the materials by the coagulating bath. Aqueous solutions of polyvalent metal salts are particularly useful as precipitants when an anionic matrix-forming material is used. When a neutral, water-soluble polymeric material is used, physical gelling action of the coagulating bath will most likely be involved.

The choice of matrix-forming material depends to some extent on the water-insoluble dispersed polymer. It is obvious that one will use a matrix-forming material which will not coagulate the polymer in the dispersion prior to shaping. Appropriate mixtures, such as a neutral with a cationic matrix-forming material, may also be used. In all cases, precipitation is practically instantaneous, the time required being in the order of 0.04 second. It is, of course, obvious from the earlier discussions that liquid baths may be replaced by other fluid setting media, such as air.

Water-soluble salts are preferred as coalescing solutions and include preferably metal salts of inorganic acids. These salts should be sufficiently soluble in water to yield 10% solutions and, preferably 30% solutions. Furthermore, concentrated aqueous solutions of the salt being used should be capable of dissolving the polymer being processed at some temperature up to the boiling point of the salt solution, for example, from 0° C. to 175° C., and generally from 20° C. to 120° C. Coalescence can also be achieved by the use of organic coalescing agents. Organic compounds which are to be used should, preferably, be capable of dissolving the polymers at a temperature below their boiling points. However, temperatures higher than the boiling point of the liquid may be used for conducting the process in the vapor phase or under pressure. In practice, any coalescing agent need only exert a solvent action on the polymer that can be regulated to achieve the desired fusing of the discrete polymer particles.

It is possible to extrude the polymer dispersion into a liquid medium which will precipitate the matrix-forming material and will also exert solvent action on the polymer particles in the precipitated matrix. In this case, the special enclosure would be used in the single bath system to protect the filaments during the combined coagulation and coalescence.

In coalescing the polymer particles room temperatures or lower can be used, but it is generally preferred that the coalescing bath be heated, since less time is needed. For example, temperatures of the order of 30–175° C. may be employed momentarily in transforming the semi-rigid shaped article to a transparent, coherent film or fiber. Low time consumption is preferred in continuous processes and it is advantageous that the coalescence step consume only a few seconds or less. The use of the flow pattern of this invention is particularly useful in this step of the dispersion spinning process.

Removal of the coalescing agent from the shaped polymer is readily accomplished by washing. In washing multifilaments it is generally preferred that cold water be used. The resulting structure may then be after-treated with boiling water, and, if desired, stretched to orient the molecules to effect improvement in physical properties. On the other hand, the coalesced structure may be at least partially oriented by drawing prior to the washing step.

In addition to water, matrix-forming material, and polymer, the dispersion used for producing this shaped article can contain dispersing agents, plasticizers, pigments, "non-solvent" salts, dyes, clay, silica, alcohol, acetone, and similar materials. Alternatively, these materials may be incorporated in the coagulating bath, in the coalescing bath, or in separate baths or combinations thereof. These substances may or may not appear in the shaped article. If desired, the coagulated articles may be passed through a bath between the coagulating and coalescing media for washing, filling, plasticization, and the like, prior to coalescing. After coalescing, the shaped article may be treated with a suitable finishing

agent to enhance its usefulness or to facilitate subsequent processing.

The filaments which are produced in accordance with the present invention are useful in filter cloths, conventional textile fabrics, industrial fabrics, elastomeric fabrics and the like.

Many modifications will be apparent to those skilled in the art from the reading of the above without a departure from the inventive concept.

What is claimed is:

1. In a process of forming a filamentary structure by contacting a freshly extruded polymer with a filament-forming liquid to form a filamentary structure; the improvement which comprises flowing the filament-forming liquid concurrently with the polymer as a single stream, the cross section of the concurrent stream of the filament-forming liquid having an inner area and a surrounding outer area, the said inner area surrounding the extruded polymer and being in laminar flow and the said outer area being in a state of turbulent flow which proceeds concurrently with the polymer in the form of a helix around the inner area of laminar flow.

2. In a process of forming a filamentary structure by contacting a freshly extruded polymer, the said polymer being present as particles which are immobilized in a gel matrix, with a coalescing liquid to coalesce the polymer particles into a filamentary structure; the improvement which comprises flowing the coalescing liquid concurrently with the polymer as a single stream, the cross section of the concurrent stream of the coalescing liquid having an inner area and a surrounding outer area, the said inner area surrounding the extruded polymer and being in laminar flow and the said outer area being in a state of turbulent flow which proceeds concurrently with the polymer in the form of a helix around the inner area of laminar flow.

3. In a process of forming a filamentary structure by contacting a freshly extruded polymer solution with a coagulating liquid to coagulate the polymer into a filamentary structure; the improvement which comprises flowing the coagulating liquid concurrently with the polymer as a single stream, the cross section of the concurrent stream of the coagulating liquid having an inner area and a surrounding outer area, the said inner area surrounding the extruded polymer and being in laminar flow and the said outer area being in a state of turbulent flow which proceeds concurrently with the polymer in the form of a helix around the inner area of laminar flow.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 2,955,017

October 4, 1960

Clarence Boyer

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 4, lines 64 and 65, for "N,N-dimethyl-formamide"
read -- N,N-dimethylformamide --; column 6, line 67, for
"of" read -- or --.

Signed and sealed this 11th day of April 1961.

(SEAL)

Attest:

ERNEST W. SWIDER

Attesting Officer

ARTHUR W. CROCKER
Acting Commissioner of Patents