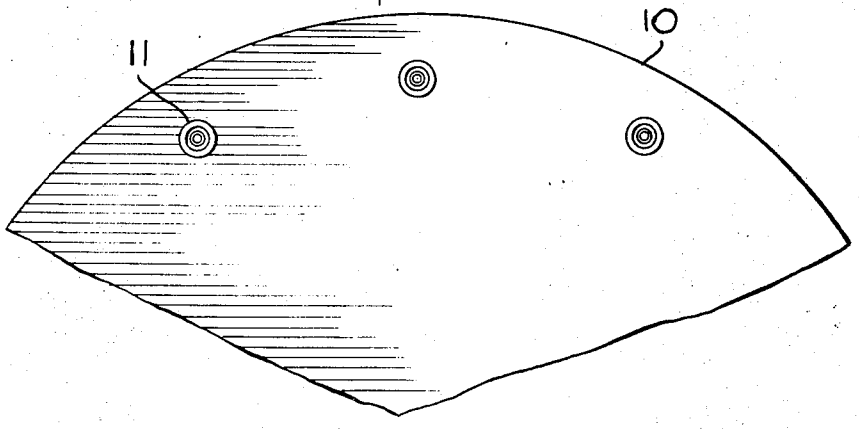
Nov. 3, 1970 J. G. SANTANGELO 3,537,135

SPINNING APPARATUS

Filed Aug. 7, 1968

Fig. 1.



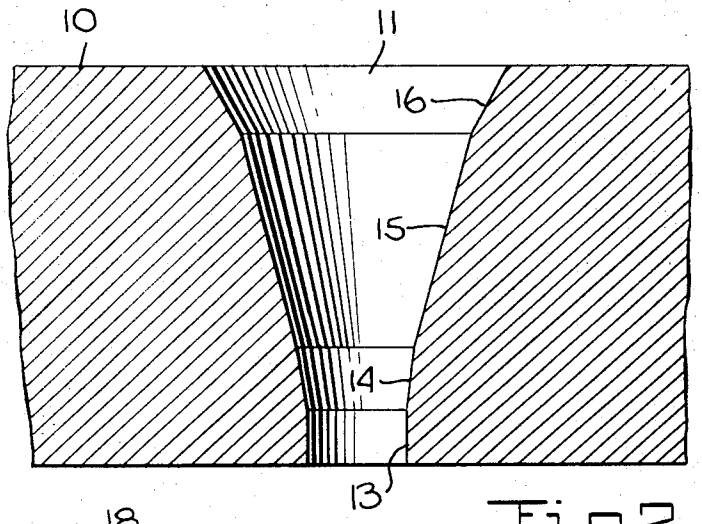


Fig. 2.

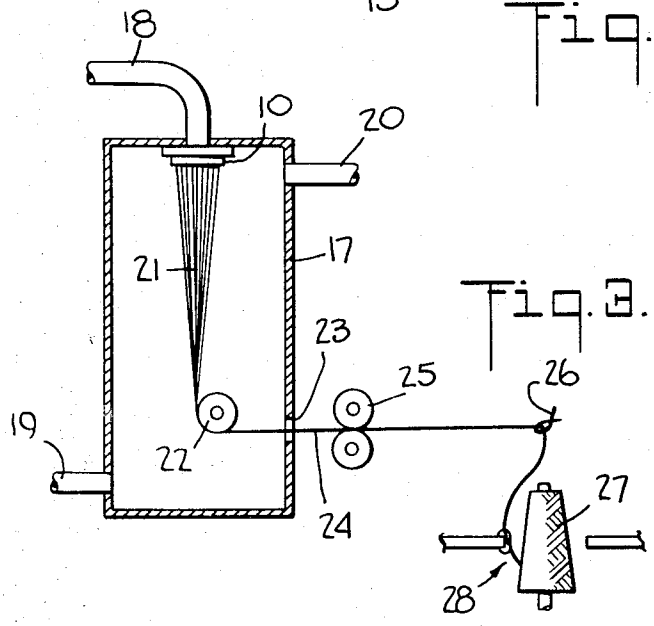


Fig. 3.

United States Patent Office 3,537,135 Patented Nov. 3, 1970

3,537,135

SPINNING APPARATUS

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Continuation-in-part of application Ser. No. 336,683, Jan. 9, 1964. This application Aug. 7, 1968, Ser. No. 750,839

Int. Cl. D01d 3/00; D01f 3/02

U.S. Cl. 18—8 5 Claims

ABSTRACT OF THE DISCLOSURE

A spinneret and method of spinning therewith, the spinneret comprising three frusto-conical sections, each having an apex angle larger than the foregoing section, and arranged successively in concentric relationship to communicate with a cylindrical portion forming the downstream portion of the spinneret, the frusto-conical sections being divergent to the upstream end thereof, said spinneret permitting the production of lower denier material at a lower drawndown with superior mechanical properties and being characterized by ease of mechanical production and special utility in spinning processes to minimize jet deposits and prolong jet life.

This application is a continuation-in-part of United States application Ser. No. 336,683, filed Jan. 9, 1964 and now abandoned.

BACKGROUND OF THE INVENTION

The present invention relates to a novel spinning process and a novel jet or spinneret used in such process.

In spinning a man-made fiber-forming material such as cellulose triacetate into filaments, a liquid comprising the polymer, i.e., a solution of the polymer in an appropriate solvent or a molten composition containing the material, is extruded through fine capillary orifices. While satisfactory products have been obtained with orifices having profiles heretofore used, the formation of these orifices is often difficult and costly and/or their use in the spinning process results in various process disadvantages, e.g., the formation of excessive amounts of deposits in the orifices resulting in high pressure drops across the spinneret and necessitating the use of larger than desirable orifices which have a diverse effect on fiber properties, in starting up the process.

In dry spinning, since the filaments are not normally given an after-stretch, the major orientation imparted to the fiber takes place in the vicinity of the jet. Since fiber properties are related to the degree of orientation, it is desirable to have a detailed understanding of this mechanism.

The flow profile or velocity distribution of the fluid leaving the jet is a function of the orifice design. The pressure distribution throughout the orifice is also related to orifice design. If we assume that the major flow pattern, e.g., smooth flow lines vs. turbulence, is translated down to the smaller element, the molecule, then a smooth flow pattern through the orifice will orient the molecules along their major axis whereas turbulence would produce random non-oriented molecules.

An analysis of orifice design, as related to velocity and pressure distributions, shows that the flow lines are smooth and undisturbed over the continuous portion of the orifice. It was found that when the polymer flow meets an angle or other discontinuous surface, eddy currents and turbulence set in. This condition becomes worse as the velocity of the polymer through the orifice is increased. These conditions are not conducive to molecular orientation and disrupt molecular alignment. The correct rate of change of curvature eliminates this disruption and improves yarn properties and this same mechanism also contributes to a reduction in jet corrosion.

The ideal solution to the problem of turbulence is a jet with a smooth hyperbolic approach to the orifice. This design minimizes flow turbulence and produces greater orientation in the yarn. To produce pure hyperbolic holes in a spinneret would be extremely difficult and impractical, but the novel technique developed by applicant is an excellent inexpensive approximation. Yarn tenacity, elongation and jet deposits are unexpectedly improved with a decrease in turbulence caused by a decrease in the orifice incidence angle. Therefore, the preferred jet design for both quality and productivity, especially with regard to jet deposits, combined a smooth hyperbolic approach and an incidence angle which approaches zero.

It is an object of this invention to provide a process for the formation of man-made fiber-forming materials such as cellulose triacetate into filaments using an improved spinning process.

It is a further object of this invention to provide a spinning process using a novel jet or spinneret whereby the problem of turbulence in spinning filaments is eliminated, as evidenced by a reduction in jet deposits, a reduction in pressure drop across the spinneret and the production of yarn having extremely high tensile properties.

It is a still further object of this invention to provide novel jets or spinnerets having a specified profile which may be produced using a relatively simple manufacturing operation.

Other objects will be apparent from the following detailed description and claims wherein all parts are by weight unless otherwise indicated.

DISCUSSION OF THE PRIOR ART

The spinneret of this invention represents an improvement over the prior art spinneret disclosed in United States Pat. 3,210,451, to Manning, isued on Oct. 5, 1965, on an application filed on Dec. 1, 1960. This patent is assigned to the assignee of the present application. In addition to the advantages of Manning's spinneret, applicant's apparatus and process significantly reduce jet deposits which cause great pressure drops across the spinneret and allow the production of high tenacity and high elongation fibers by utilizing a smooth approach to the capillary. Jet deposits tend to form when there is a sharper line of demarcation between the smallest or first frusto-conical section and the bottom cylinder or capillary.

SUMMARY OF THE INVENTION

In accordance with one aspect of the invention, a fiber-forming material, such as cellulose triacetate or cellulose secondary acetate, is formed into filaments by extruding a liquid comprising such material, e.g., a solution of such material in an appropriate solvent or a molten composition containing such material, through an orifice having a cylindrical portion communicating with the outlet face of the spinneret and three frusto-conical portions which are divergent toward the inlet side of the spinneret, with the apex angle of each frusto-conical portion being larger, the farther away it is from the cylindrical portion. Thus, if the frusto-conical portion adjacent to the cylindrical portion is termed the first frusto-conical portion, then the second frusto-conical portion adjacent to the first has an apex angle larger than that of the first and the third frusto-conical portion adjacent to the second on the inlet side has an apex angle greater than that of the second.

The first frusto-conical portion, i.e., that communicating with the cylindrical portion preferably has an apex angle of less than about 17 degrees, e.g., 12 to 17 degrees, and most suitably in the range of 16 to 17 degrees; the second frusto-conical portion communicating with the first frusto-

conical portion preferably has an apex angle of at least 13 degrees greater than the apex angle of the first frusto-conical portion and most suitably in the range of 25 to 35 degrees; and the third frusto-conical portion communicating with the second frusto-conical portion preferably has an apex angle of at least 30 degrees greater than that of the second frusto-conical portion and most suitably in the range of 60 to 65 degrees.

The use of an orifice having the above-described profile allows for an orifice size, e.g., expressed as diameter, of the cylindrical portion, which is smaller than usual. The use of smaller holes, e.g., as low as 0.025 mm., allows for the production of lower denier material, e.g., as low as 1 denier per filament, produced at a lower drawdown or "spin draw" ratio, defined as the ratio of the denier of the fiber-forming material being extruded to the denier of the taken-up material. This type of material is very desirable for certain uses, e.g., cigarette filters. Moreover, smaller holes with the concomitant employment of smaller drawdown ratios also result in superior mechanical properties, e.g., tenacity and elongation.

The term "cylindrical" is employed herein for the jet face section of the orifice design since it connotes a generally regular cross-section, as distinguished from the diameters of the remaining sections, but it is understood that such cross-section may be circular or any non-circular configuration conventional in this art such as triangular cross-sections, square cross-sections, Y cross-sections, I-beam cross-sections, X cross-section, trilobal cross-sections and the like.

Suitably, the length of the cylindrical portion along the axis of the spinneret is about ½ to 10, preferably ½ to 1½ times the diameter of the cylindrical portion, the length of the first frusto-conical portion is about ½ to 1 times the diameter of the cylindrical portion; the length of the second frusto-conical portion is about 3 to 8 times the diameter of the cylindrical portion, and the length of the third frusto-conical portion is about 20 to 30 times the diameter of the cylindrical portion.

Preferable ranges of linear values for the dimensions of each portion of the orifice are as follows: about 0.025 to 0.50 mm., preferably about 0.025 to 0.060 mm. for the diameter of the cylindrical portion; about 0.0125 to 0.50 mm., preferably about 0.0125 to 0.060 mm. for the length of the cylindrical portion; about 0.030 to 0.040 mm. for the length of the first frusto-conical portion; about 0.1 to 0.23 mm. for the length of the second frusto-conical portion; and about 0.76 to 0.89 mm. (i.e., about 30 to 40 mils) for the third frusto-conical portion.

A particularly desirable spinneret of the type described above is one having orifices each with a cylindrical portion having a circular cross-sectional diameter no greater than about 0.034 mm. and a length of about ½ times the diameter of the cross-section, a first frusto-conical portion having an apex angle of about 17 degrees and a length of about 1 times the diameter of the cylindrical portion, a second frusto-conical portion having an apex angle of about 30 degrees and a length of about 6 times the diameter of the cylindrical portion, and a third frusto-conical portion having an apex angle of about 60 degrees and a length of about 22.5 times the diameter of the cylindrical portion, all the lengths being measured along the axis of the orifice.

The process is of particular value in the dry, spinning of cellulose triacetate from solution in a solvent comprising a major amount of a halogenated hydrocarbon.

Novel spinnerets of this invention may be made without frequent breakdown of drilling tools by first countersinking a hole with a tool having an angle equal to that of the third frusto-conical portion, the depth of such hole corresponding to the length desired for such third frusto-conical portion. A drilling or countersinking tool having an angle corresponding to the second frusto-conical portion, i.e., less than that of the first tool used, is then inserted into the hole and used to further drill a hole to an increased depth corresponding to the desired length of the second frusto-conical portion. A cylindrical tool is inserted into the hole and used to drill the cylindrical portion of the orifice which extends entirely to the outlet face of the spinneret. Finally, a punch is used to form the first frusto-conical portion by pressing down the circle of intersection between the second frusto-conical portion and the cylindrical portion, using a punching tool with an angle corresponding to the desired first frusto-conical portion. After the first operation resulting in the formation of a cone-shaped hole including a part corresponding to the third frusto-conical portion, the placing of each drilling tool is simplified by the fact that it need only be inserted into an already formed hole.

It can be seen that when using the above-described method, the relatively weak drilling tools, i.e., the tool used to drill the cylindrical portion and the frusto-conical portions of smaller apex angles, are only employed to drill relatively small proportions of the total thickness of the spinneret plate. This has the effect of drastically reducing breakage of the drilling tools.

The cylindrical portion of the orifice may be punched rather than drilled, in which case such section may have, in addition to a circular cross-section, cross-sections of other shapes, such as a triangular cross-section, a square cross-section, etc., depending upon the shape of the punching tool.

Contemplated under this invention are spinnerets having plates with thicknesses up to about 7.62 mm., i.e., about 300 mils. However, to avoid an unduly large amount of breakage of drilling and/or punching tools, particularly when the spinneret is to be used in a dry spinning process, a plate having a relatively small thickness is suitably used, e.g., no greater than about 1.016 mm., i.e., about 40 mils, and most suitably in the range of about 0.635 to 1.016 mm., i.e. about 25 to 40 mils. Moreover, the use of a spinneret plate of small thickness has the further advantages that it results in lower pressure drop across the spinneret plate making spinning easier and reduces the chance of blockage of the orifice.

As mentioned previously, the process of this invention is particularly useful in the dry spinning of cellulose esters, such as the spinning of cellulose triacetate from solution in a solvent comprising a major proportion of a halogenated hydrocarbon. The process may be suitably carried out using fairly high spinning speeds using 100 to 1000 meters per minute to produce filaments having a denier in the range, for example, of 1 to 10 denier per filament. However, deniers outside of this range may also be obtained.

As employed herein, cellulose triacetate has reference to cellulose acetate having fewer than about 0.29 and preferably fewer than about 0.12 free hydroxyl group per anhydroglucose unit of the cellulose molecule, i.e., an acetyl value calculated as combined acetic acid by weight of at least about 59 percent and preferably at least about 61 percent.

Advantageously, its intrinsic viscosity ranges from about 1.5 to 2.5 and is preferably about 2, and it is present in the dope to a concentration ranging from about 20 to 25 percent. In place of methylene chloride, the dope solvent may comprise other halogenated lower alkanes such as ethylene dichloride or propylene chloride. Advantageously, up to about 15 percent by weight of the dope solvent comprises a lower alkanol such as methanol, ethanol, isopropanol, etc. The preferred dope solvent is methylene chloride-methanol in the proportions of about 90–10 by weight.

The process of this invention is also especially useful in the dry spinning of cellulose secondary acetate from solution in a solvent such as acetone. Cellulose secondary acetate, as employed herein, has reference to cellulose acetate having an acetyl value in the range from 54 to 56 percent, preferably between 54 and 55 percent, calculated as combined acetic acid.

For convenience, the invention has been described and illustrated with reference to the dry spinning of cellulose triacetate, but it should be understood that both the process and apparatus are applicable to the spinning of other fiber-forming materials by wet, dry or melt spinning such as polyamides, polyesters, acrylics, vinyl chloride and vinylidene cyanide polymers and the like. Since the essential operative principle stems from rheological rather than chemical or mechanical characteristics, and suitable dimensional adaptations may easily be achieved within the context of such systems.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention may be further illustrated with reference to the accompanying drawing wherein:

FIG. 1 is a plane view of a section of a spinneret used in accordance with this invention with the orifices arranged in a circle around the periphery of the spinneret plate and their size exaggerated to indicate their appearance;

FIG. 2 is a sectional view showing the profile of the contemplated orifices; and

FIG. 3 is a schematic illustration of a dry spinning operation.

Referring now more particularly to the drawing, FIG. 1 shows a spinneret or jet plate **10** as viewed from the inlet side with orifices **11** each of which has the appearance of four concentric circles corresponding to the largest diameter of the orifice at the inlet face of the plate and the circles of intersection of the various frusto-conical portions and the cylindrical portion, at the outlet side of the spinneret plate.

As shown in FIG. 2 illustrating the profile of the contemplated orifice of spinneret **10**, the wall of the cylindrical portion is indicated at **13** with numerals **14, 15** and **16** identifying the walls of the first, second, and third frusto-conical portions of the orifices respectively.

In FIG. 3 there is shown a dry spinning cabinet **17** to which dope is supplied through a pipe **18**, being extruded through the spinneret **10** of FIGS. 1 and 2. Hot air is admitted to the cabinet **17** at **19** and is exhausted at **20** along with vapors of the dope solvent. The filaments **21** leaving spinneret **10** pass about a guide **22** and leave the cabinet at **23** being pulled as a yarn **24** by draw rolls **25**. The yarn **24** passes through a guide **26** and is twisted and taken up on a bobbin **27** by a conventional collector such as ring spinner **28**.

In addition to the fact that smaller orifices may be used in carrying out the process with the advantages described above, the process of this invention results in the formation of substantially less jet deposits than when various other orifice shapes are used, particularly in the case of the dry spinning of cellulose triacetate from solution in a solvent comprising a major proportion of a halogenated hydrocarbon. Moreover, the employment of the orifice profile of this invention results in considerably longer jet life, a more uniform filamentary product (e.g., in terms of cross-section) with better properties, e.g., of tenacity and elongation that is the case when spinnerets are employed with more conventional orifice designs. Improved dyeing properties may also be obtained.

Finally, the process of the invention using the distinct orifice shape as described above may be started up much more easily than other spinning processes, and makes possible the employment of higher spinning speeds without deterioration of filament properties.

The following example further illustrates the invention:

Example I

A 22 weight percent solution of fiber-forming cellulose triacetate having an acetyl value of 61.5 percent by weight calculated as combined acetic acid in a solvent mixture consisting of 91 percent of methylene chloride and 9 percent of methanol was extruded through a chromium plated stainless steel spinneret with a plate having a thickness of 1.016 mm. and with 5 orifices arranged in a circle each with a profile as indicated in FIG. 2. Cylindrical portion **13** of each orifice had a circular cross-section with a diameter of 0.034 mm. and a length of 0.018 mm. First frusto-conical portion **15** had an apex angle 17 degrees and a length of 0.035 mm.; second frusto-conical portion **16** had an apex angle of 30 degrees and a length of 0.20 mm.; and third frusto-conical portion **17** had an apex angle of 60 degrees and a length of 0.762 mm., each of the lengths being measured along the axis of the orifice. The resulting filaments passed through air in a spinning cabinet at 35 degrees centigrade and were taken up on a bobbin at a linear speed of 500 meters per minute after being withdrawn from the spinning cabinet. The yarn had a denier of 3.75 d.p.f., a tenacity of 1.35 grams per denier and an elongation of 35 percent.

After 24 hours of continuous operation from the time that the spinneret was installed, the jet deposits resulted in a reduction in orifice area equal to only 1.7 percent of the total due to deposited material when observed at 400 magnification. This represents a substantially smaller formation of jet deposits than is obtained when orifices of more conventional profile are used.

Example II

A 22 weight percent solution of fiber-forming cellulose triacetate having an acetyl value of 61.5 weight percent was extruded through the chromium plated stainless steel spinneret of Example I utilizing the procedure of Example I. The resulting filaments pass through air in a spinning cabinet at 40 degrees centigrade and were taken up on a bobbin at a linear speed of 350 meters per minute after being withdrawn from the spinning cabinet.

A 22 weight percent solution of fiber-forming cellulose triacetate having an acetyl value of 61.5 percent was extruded according to the procedure of the example of U.S. Pat. 3,210,451, Manning, utilizing the spinneret disclosed therein. The resulting filaments were passed through air in a spinning cabinet at 40 degrees centigrade and were taken up on a bobbin at a linear speed of 350 meters per minute after being withdrawn from the spinning cabinet.

Table I below shows the comparative jet deposit ratings of spinnerets utilized for long periods of time in the process of this invention and the prior art process and jet of U.S. Pat. 3,210,451:

TABLE I

Prior art jet—plated			Jet of this invention—plated		
Jet No.	Spinning time hrs.	Percent deposits (400X)	Jet No.	Spinning time, hrs.	Percent deposits (400X)
1	102	5.50	1	102	1.90
2	102	3.70	2	102	1.60
3	300	4.20	3	282	1.70
4	300	3.40	4	300	1.40
5	300	3.10	5	300	4.20
6	300	5.10	6	300	3.60
7	300	3.50	7	300	4.00
8	300	5.00	8	300	2.80
	300	10.10	9	200	2.50
10	300	4.10	10	300	3.32
As received, average		4.80	As received, average		3.10
Average [1]		2.60	Average [1]		1.40

[1] Boiled 3 hrs. in methylene chloride.

Cellulose triacetate filaments extruded according to the foregoing procedures was put on cones and beams and data collected for a period of six months. Data comparing efficiency and tensile properties of filaments extruded utilizing the Manning spinneret with filaments utilizing the spinneret and process of this invention are shown in Table II below:

TABLE II

	Prior art—plated	Jet of this invention—plated
Bleb rate/M lbs.	4.5	3.4
Part-runs, percent	5.0	3.9
Tenacity, g.p.d.	1.23	1.25
Elongation, percent	31	31
Major Lindly/BTY	230	150
Beam rejection, percent	3.1	3.8
Cone rejection, percent	5.5	4.5

EXAMPLE III

Fiber-forming cellulose triacetate was extruded according to the procedure of Example I utilizing unplated stainless steel spinnerets having the dimensions of the spinneret of Example I. The resulting filaments were passed through air in a spinning cabinet at 25 degrees centigrade and were taken up on a bobbin at a linear speed of 500 meters per minute after being withdrawn from the spinning cabinet.

Cellulose triacetate was extruded according to the procedure of the example of U.S. Pat. 3,210,451, Manning, utilizing an unplated spinneret having the dimensions of the spinneret of the said example. The resulting filaments were passed through air in a spinning cabinet at 25 degrees centigrade and were taken up on a bobbin at a linear speed of 500 meters per minute after being withdrawn from the spinning cabinet.

A comparison of the jet deposit data for jets run for 24 hours utilizing the process of this invention and the prior art process and jet of U.S. Pat. 3,210,451 is shown in Table III below:

TABLE III

		Percent deposits		
Run	Jet (1-inch×5-hole×0.032 mm.)	Jet A	Jet B	Average
1	Prior art—unplated	9.0	14.0	11.5
2	Prior art—unplated	9.4	8.8	9.1
3	Prior art—unplated	11.8	8.0	9.9
Grand average				10.2
4	Jet of this invention—unplated	1.4	6.0	3.7

EXAMPLE IV

A 22 weight percent solution of fiber-forming cellulose triacetate having an acetyl value of 61.5 percent by weight calculated as combined acetic acid in a solvent mixture consisting of 91 percent of methylene chloride and 9 percent of methanol was extruded through an unplated stainless steel spinneret at a jet face temperature of 80 degrees centigrade. The spinneret having a plate with a thickness of 1.016 mm. and with 20 orifices arranged in a circle each with a profile as indicated in FIG. 2. Cylindrical portion 13 of each orifice had a circular cross-section with a diameter of 0.028 mm. and a length of 0.018 mm. First frusto-conical portion **15** had an apex angle 17 degrees and a length of 0.035 mm.; second frusto-conical portion **16** had an apex angle of 30 degrees and a length of 0.20 mm.; and third frusto-conical portion 17 had an apex angle of 60 degrees and a length of 0.762 mm., each of the lengths being measured along the axis of the orifice. The resulting filaments passed through a 12-foot updraft in a spinning cabinet at 35 degrees centigrade and were taken up on a bobbin at a linear speed of 300 meters per minute after being withdrawn from the spinning cabinet. The yarn was wound onto one pound packages and had an average tenacity of 1.33 grams per denier and an average elongation of 49.0 percent.

TABLE IV

Bobbin No.	Denier	Tenacity, g./d.	Elongation, percent
1	74.6	1.32	51.5
2	72.8	1.33	49.2
3	76.8	1.36	48.9
4	74.3	1.35	48.0
5	73.1	1.33	47.8
6	75.5	1.35	49.0
7	75.0	1.33	49.2
8	75.2	1.32	47.1
9	76.0	1.30	49.7
10	75.0	1.32	46.8
11	75.7	1.35	49.0
12	72.9	1.35	47.1
13	75.5	1.32	51.1
14	74.7	1.34	51.1
15	74.7	1.35	49.9
Average	74.8	1.33	49.0

Spinning speeds in excess of 1000 meters per minute are easily achieved utilizing the process and spinneret of this invention. In addition, the life of the spinneret in use ranges from about 1000 to 1500 hours, as compared with a useful life of 600 hours for the prior art Manning spinneret.

The embodiments of the invention in which an exclusive property or privilege is claimed as defined as follows:

1. A spinneret having at least one orifice including a cylindrical portion at its outlet end, a first frusto-conical portion connecting with said cylindrical portion, a second frusto-conical portion connecting with said first frusto-conical portion and having a larger apex angle than said first frusto-conical portion, and a third frusto-conical portion connecting with said second frusto-conical portion and having an apex angle larger than that of said second frusto-conical portion, each of said frusto-conical portions being divergent toward the inlet end of said orifice.

2. A spinneret having at least one orifice with a shape including a cylindrical portion at the outlet end of said orifice, a first frusto-conical portion connecting with said cylindrical portion, a second frusto-conical portion connecting with said first frusto-conical portion and having an apex angle of at least about 13 degrees greater than that of said first frusto-conical portion and a third frusto-conical portion connecting with said second frusto-conical portion and having an apex angle of at least about 30 degrees greater than that of said second frusto-conical portion, each of the frusto-conical portions being divergent toward the inlet end of said orifice.

3. The spinneret of claim **2** wherein said orifice is up to about 1.016 mm. long and said cylindrical portion is a right circular cylinder and has a diameter area of less than about 0.060 mm.

4. A spinneret having at least one orifice up to about 1.016 mm. long, said orifice having a cylindrical portion at its downstream end with a diameter up to about 0.060 mm. and a length in the range of about ½ to 1½ times its diameter, a first frusto-conical portion connecting with said cylindrical portion and having an apex angle in the range of about 12 to 17 degrees, and a length in the range of about ½ to 1 times the diameter of said cylindrical portion, a second frusto-conical portion connecting with said first frusto-conical portion and having an apex angle of at least about 13 degrees larger than that of said first frusto-conical portion and a length in the range of about 3 to 8 times the diameter of said cylindrical portion and a third frusto-conical portion connecting with said second frusto-conical portion and having an apex angle of at least about 30 degrees larger than that of said second frusto-conical portion and a length of about 20 to 30 times the diameter of said cylindrical portion, each of said frusto-conical portions being divergent toward the inlet end of said orifice.

5. A spinneret having at least one orifice including a cylindrical portion at the outlet end of said orifice having a diameter no greater than 0.034 mm. and a length of about ½ times the diameter of said cylindrical portion, a first frusto-conical portion connecting with said cylindrical portion and having an apex angle of about 17 degrees and a length of about 1 times the diameter of said cylindrical portion, a second frusto-conical portion connecting with said first frusto-conical portion and having an apex angle of about 30 degrees and a length of about 6.0 times the diameter of said cylindrical portion, and a third frusto-conical portion connecting with said second frusto-conical section and having an apex angle of about 60 degrees and a length of about 22.4 times the diameter of said cylindrical portion, each of said frusto-conical portions being divergent toward the inlet end of said orifice.

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