SPINNERETS

Filed Nov. 26, 1963 3 Sheets-Sheet 1

Fig. 1

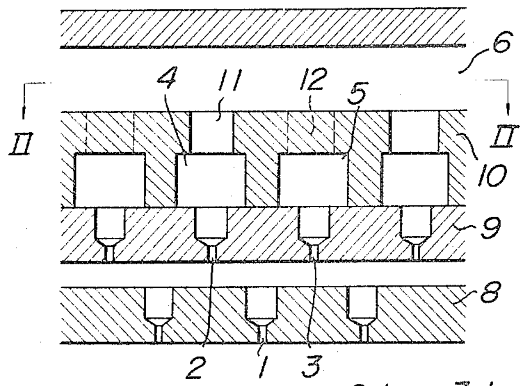

Fig. 2

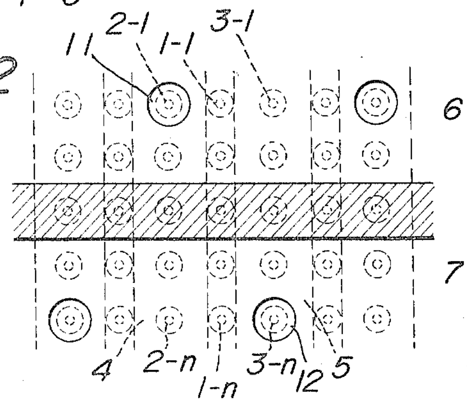

Fig. 3

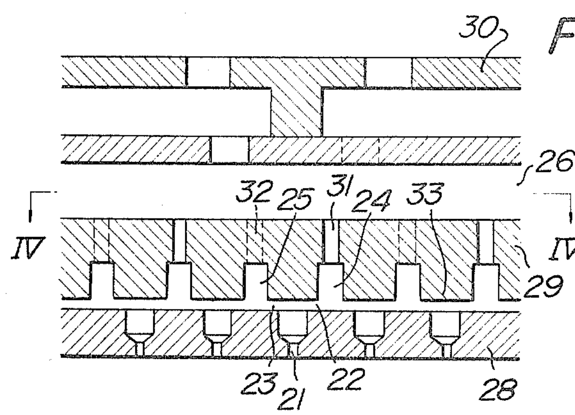

Fig. 4

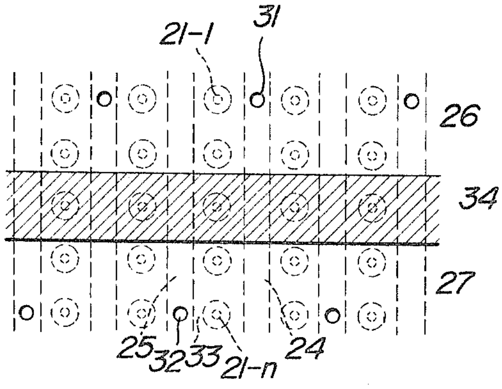
21-1
31
26
34
27
25
32
33
21-n
24

Fig. 6

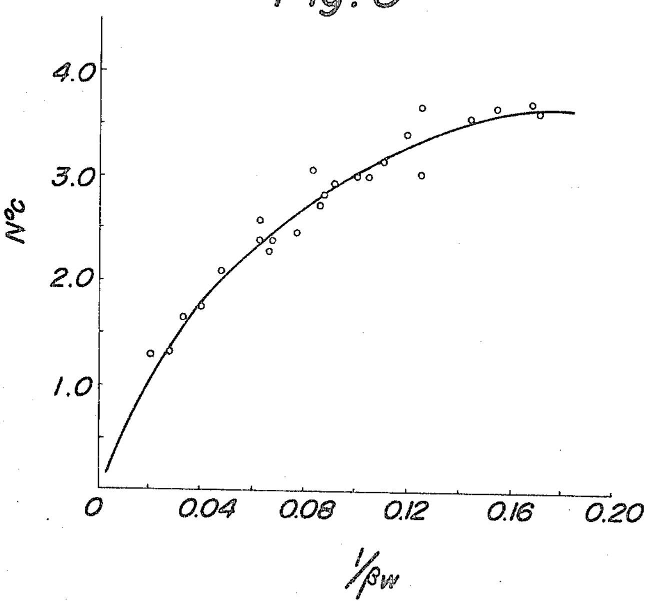
4.0
3.0
2.0
1.0
N°c
0
0.04
0.08
0.12
0.16
0.20
1/βw

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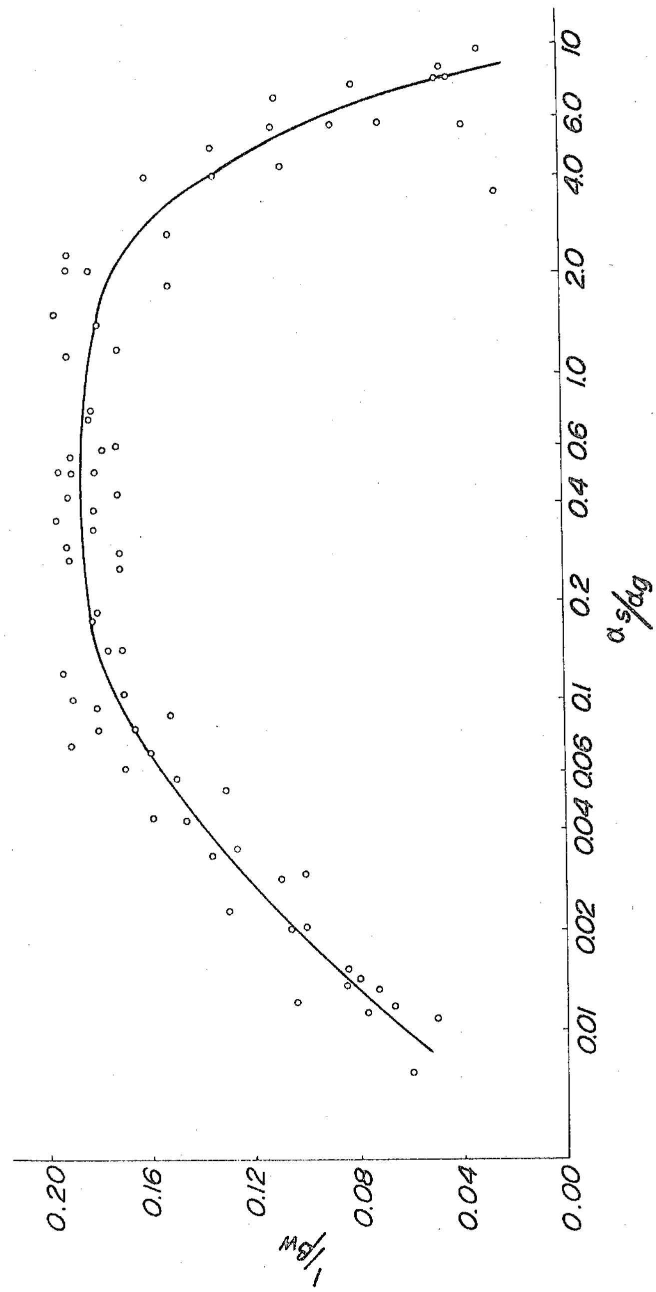
Fig. 5



United States Patent Office

3,289,249
Patented Dec. 6, 1966

3,289,249
SPINNERETS

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Claims priority, application Japan, Nov. 24, 1962, 37/52,837
7 Claims. (Cl. 18—8)

The present invention relates to spinnerets used for producing artificial fibers, and more particularly to those adapted for producing composite filaments. In this invention, the composite filaments, refer to the fiber which contains two distinct polymer components in an eccentric relationship throughout the length of the filament.

The primary object of the invention is to provide a spinneret of improved structure which is most suitable for the production of composite filaments having excellent spiral crimps.

It has been proposed to improve fabric properties by imparting to the artificial fibers helical crimps. Fibers of this type have been prepared by the use of special spinning conditions or after-treatments which bring about differential physical properties in the cross section of single-component filaments, or by spinning together two or more materials to form a composite filament, i.e., one which contains the components in an eccentric relationship over the cross section of the filaments. If the two components of a composite filament possess substantially different shrinkage, spiral crimps are caused by the differential shrinkage of the spun and drawn components. However, it is considerably difficult to develop a spinneret for obtaining the composite filament having such spiral crimps. Especially, it is extremely difficult to develop a spinneret having ten thousands to scores of thousands of spinning orifices such as is used for production of fibers in a wet spinning process.

As a result of a series of studies, the present inventors have discovered that there is an extremely peculiar relation between the structural characteristic of a spinneret and the number of the generated spiral crimps of fibers obtained by the spinneret, when two components having different shrinkage are bonded side by side to each other. The present invention is effective to facilitate the design and manufacture of a novel spinneret which has a high density of spinning orifices and is highly suitable for manufacture of fibers having a satisfactory potential ability for generating the characteristic spiral crimps.

It is generally required that a spinneret used for the industrial production of spirally crimped fibers comprise a multiplicity of spinning orifices. In order to meet the primary purposes in an industrial aspect, it is a requirement that composite filaments delivered from the respective spinning orifices should be as uniform in quality as possible in addition to possessing the spiral crimp property. One of such purposes is disclosed in U.S. Patent No. 2,936,482 in which a method is shown which resides in the interposition of a construction adjacent an inlet of each orifice, said construction being suitable to provide more restriction to the flow of supplied materials than the restriction encountered by the supplied materials in a relatively unconstricted supply channel. This is an extremely practical and common method wherein a pressure loss of fiber-forming liquids in each orifice section during its flow from a fiber-forming liquid supply vessel to each orifice is uniformly regulated by providing the flow at a portion immediately upstream of the orifice section with a far greater pressure loss than that encountered theretofore, or a pressure loss more than 10^3 times the pressure loss encountered theretofore according to an embodiment disclosed therein. In other words, said U.S. Patent No. 2,936,482 is characterized solely by the interposition of the constrictions and no consideration has been given therein with regard to the flow passage upstream of said constrictions. However, the method disclosed in U.S. Patent No. 2,936,482 is assumed to be quite effective to sufficiently regulate the amount of the fiber-forming liquids to be supplied to each orifice.

U.S. Patent No. 2,936,482 is based on the specific case wherein a plurality of core-forming components are injected into a radially converging flow of a sheath-forming component and a unitary body comprising the core components enclosed within the sheath component is extruded and shaped as required. Meanwhile, the present inventors have made careful experiments in an effort to obtain an effective method of manufacturing composite filaments comprising two components A and B having different shrinkage characteristics relative to each other, and establishing a proper ratio between the components A and B in single composite filaments. As a result thereof, the inventors have discovered that mutual uniformity of the combined ratio between two components A and B in the individual single filament so obtained is difficult to be attained solely by simply interposing the constriction immediately upstream of each orifice as described in said U.S. patent. Or more precisely, the inventors have discovered that the effect of the constriction is deeply related with the structure of a fiber-forming liquid supply section connected to the constriction, and the provision of the constriction greater than that required with relation to the liquid supply section, on the contrary, results in non-uniformity of the combined ratio of the two components A and B in each single filament and consequent reduction in the potential ability for generating the spiral crimps. Such result is one of several astonishing facts that cannot be derived from the art.

According to the invention, there is provided a spinneret adapted for producing composite filaments comprising guide passages for separately guiding fiber-forming liquids, and relatively constricted flow passages disposed downstream of said guide passages and upstream of orifices to limit the flow of said fiber-forming liquids therethrough, wherein the relation between a pressure loss α_g at said fiber-forming liquid guide passages and a pressure loss α_s at said relatively constricted flow passages is selected to satisfy a formula $\alpha_s/\alpha_g=0.1\sim4.0$.

Other objects and particularities of the invention which will become obvious from the following description with reference to the accompanying drawings, in which:

FIG. 1 is a sectional view of an embodiment of a spinneret of the invention;

FIG. 2 is a sectional plan view taken along the line A—A of FIG. 1;

FIG. 3 is a sectional view of another embodiment of the invention;

FIG. 4 is a sectional plan view taken along the line B—B of FIG. 3; and

FIGS. 5 and 6 are graphic illustrations for the purpose of explaining the excellent effect attained by the invention.

Now referring to FIGS. 1 and 2, there are shown sectional views of a spinneret of the invention to show the internal structure thereof. In the spinneret shown, fiber-forming liquids A and B are contained in reservoirs **6** and

7, and flow down into guide passages **4** and **5** in back plate **10** by way of respective guide ports **11** and **12** in back plate **10**. At the bottoms of the guide passages **4** and **5**, there are bored in a middle plate **9** a multiplicity of apertures **2–1**, **2–2**, . . . **2–n** and **3–1**, **3–2**, . . . **3–n** which extend in a line longitudinally of said guide passages **4** and **5**, respectively. Orifices **1–1**, **1–2**, . . . **1–n** are bored in a nozzle plate **8** in a manner that the orifice **1–1** corresponds to the apertures **2–1** and **3–1**, the orifice **1–2** corresponds to the apertures **2–2** and **3–2**, and finally the orifice **1–n** corresponds to the apertures **2–n** and **3–n**.

A maximum pressure loss ΔPn, when the liquid A is guided to the guide passage **4** through the guide port **11** and is led to each of the apertures **2–1**, . . . **2–n**, depends on such factors as the cross-sectional area and length of flow passage, amount of flow and viscosity of liquid. This is entirely the same for the fiber-forming liquid B. When, therefore, the apertures **2–1**, **2–2**, . . . **2–n** have the same dimensions, an amount of the liquid A discharged from the apertures **2–1**, **2–2**, . . . **2–n** depends on the distribution of magnitude of pressure loss at the inlet of each aperture **2**. The same relation is applicable to the fiber-forming liquid B. It is considered that the combined ratio of the two liquids, A and B, in a single filament extruded from each of the orifices **1–1**, **1–2**, . . . **1–n** is dependent on the amount of the two liquids A and B discharged from each pair of apertures **2–1** and **3–1**, **2–2** and **3–2**, and the like. Therefore, it is desirable to investigate the change in the combined ratio, ω, of the two liquids A and B in each single filament as the function of a ratio of the maximum pressure loss ΔPn in the liquid guide passages to the pressure loss in the apertures. Here, ω shows a proportion occupied by component A in the cross section of the composite filament. In expressing the change in the combined ratio, ω, we introduced the concept of distribution of the combined ratio ω and employed a parameter β_ω. The combined ratio, ω, indicates a proportion occupied by the component A in the cross-section of each single filament, and the term β_ω is a parameter indicating the extent of distribution of ω. The parameter β_ω is determined as follow. At first, the value of $(\omega-\bar{\omega})/\bar{\omega}$ is obtained for each single filament from a photograph taken on the cross section thereof. Here, $\bar{\omega}$ indicates a mean value of actually measured value of ω. Then the values so obtained are classified into sections of 0.05 and a frequency curve is drawn.

Then, the frequency curve is compared with a group of frequency curves of binomial distribution in which the frequency Wr obtained from the relation $Wr=\beta Cr/\epsilon_\beta Cr$ is plotted against the number of sections r to draw a series of curves for different total numbers β. Then, the most closely approximately value of β obtained by the comparison is employed as a parameter of distribution of ω and the parameter is expressed as β_ω. Therefore, the smaller value of β_ω will show the more sharp distribution, and the larger value of β_ω will show an expanded range of distribution.

FIG. 5 illustrates the result of measurement taken on the parameter β_ω of the combined ratio of the two components when the resistance of the flow passages and the size of the apertures are varied in the spinneret shown in FIG. 1. In FIG. 5, α_s is a numerical value representing the pressure loss in the apertures and α_g is a numerical value representing the pressure loss in the guide passages. Prior to calculation of these values, it is assumed that, the pressure loss in the liquids is proportional to 0.8 power of the length of the flow passages and proportional to 0.5 power of the shearing velocity. Although these assumptions are made for the sake of convenience, it is extremely interesting that the experimental data can be arranged to approximately form a curve, and this fact also supports the justifiability of the assumptions employed herein. Supposing that n is the number of orifices, that the guide passage has a length L, a width a and a height b, and the apertures has a bore diameter ψ and a length l, α_s and α_g can be given as follows:

$$\alpha_g=\frac{2n\cdot L^{0.8}}{D\cdot\sqrt{D\cdot E\cdot X}} \qquad (1)$$

$$\alpha_s=\frac{4\cdot l^{0.8}}{\sqrt{\pi}\psi^2} \qquad (2)$$

In the formulas, the values of D and E are so selected as to correspond to the value of a and b in a manner that the relations $D=b$ and $E=a$, a exist in the case of $a>b$, and the relations $D=a$ and $E=b$ exist in the case of $a<b$. X is a correction factor for flow and can be expressed as

$$X=\frac{16}{3}-\frac{1024}{\pi^2}\cdot\frac{D}{E}\left[\tan h\frac{\pi E}{2D}+\frac{1}{27}\tan h\frac{3\pi E}{2D}+\cdots\cdots\right] \qquad (3)$$

It is extremely difficult to express the data in the form of a curve when, in place of α_s/α_g, a pressure loss ratio α_s'/α_g' calculated on the assumption of Newtonian flow is employed. It is a fact which cannot be foreseen by a common concept that, when a spinneret having the pressure loss ratio α_s/α_g within a range of $0.1\sim4.0$ is employed, β_ω has the smallest value and uniform distribution can be attained. The values of α_s/α_g and α_g are substituted by α_s' and α_g' which are calculated likewise on the assumption of Newtonian flow to obtain a tentative value of α_s'/α_g'. The result of calculation indicates that α_s'/α_g' lies in a range of $10^{-2}\sim10^2$.

In other words, the most desirable result can be obtained with constrictions wherein a pressure loss approximately similar to or slightly less than a pressure loss developed in the upstream passages are provided immediately upstream of the orifices.

Entirely the same result has been obtained after repeated experiments made on a spinneret having narrow gaps as shown in FIG. 3. The spinneret shown in FIGS. 3 and 4 comprises a nozzle plate **28** having a multiplicity of orifices **21–1**, **21–2**, . . . **21–n**, a back plate **29** having projections **33** disposed opposite said orifices, and a distribution plate **30**. The spinneret further comprises reservoirs **26** and **27** for respective fiber-forming liquids A and B partitioned by a partition wall **34** forming part of the distribution plate **30**. The reservoirs **26** and **27** communicate with guide passages **24** and **25** by way of guide ports **31** and **32**, respectively. The guide passages **24** and **25** communicate with the orifices through respective narrow gaps **22** and **23** defined by the nozzle plate and the projections **33** of the back plate **29**. In the case of the spinneret of this type, α_s of the Formula 2 derived from the spinneret of FIG. 1 is slightly varied as

$$\alpha_s=\frac{3}{2}\cdot\frac{l^{0.8}}{h\cdot\sqrt{h\cdot d}} \qquad (4)$$

In the Formula 4, h is height of the narrow gap and d is width of the narrow gap per orifice which is determined by a distance between the adjacent two orifices in the gap, for example, the orifices **21–1** and **21–2**.

From the foregoing description, it will be apparent that, in the spinneret for producing composite filaments generally as shown in FIG. 1 or 3, the distribution of the combined ratio of two components across the cross section of the composite filament can not be improved by merely introducing the narrow gaps which provide a great pressure loss to the flow of fiber-forming liquids, and such improvement in the distribution of ω is related to the size of the solution guide passages upstream of the narrow gaps relative to the size of such narrow gaps. It will be apparent that the most desirable result can be obtained when α_s/α_g is within the range of 0.1~4.0, and this is the most important discovery which constitutes the subject matter of the invention. Various factors may be considered as the cause of such phenomenon, but are still in a stage of assumption, and the experimental results alone have been illustrated in the description. However, it will be understood that, if only the value of α_s/α_g is within said range, it is possible to obtain β_ω of approximately the same value irrespective of the individual values of α_s and α_g, and thus a spinneret having a high orifice density can be manufactured in an extremely easy manner.

The parameter of distribution β_ω is closely related to the crimpability of the composite filaments obtained. The relation between β_ω and NC, when the crimpability of the filaments is expressed in terms of a number of spiral crimps NC per filament length of 10 mm., is as shown in FIG. 6. From FIG. 6, it will be known that B_ω is primarily related with NC, and the smaller β_ω provides the more the number of helical crimps. The curve shown in FIG. 6 is a summary of results derived from the relation between β_ω and NC obtained on a combination of polymers shown in the Example 1 which will be described hereinunder. However, it has been ascertained that, upon investigation with many other combinations, that only the value of NC varies and a relation which can be expressed by a single curve always exists between β_ω and NC. It will be understood, therefore, that, the fibers spun through the spinneret with specific structure of α_s/α_g being 0.1~4.0, posses the extremely strong potential ability of generating the characteristic spiral crimps, and the crimpability based on the differential shrinkage of two components can most satisfactorily be utilized.

Example 1

This example relates to a spinneret as shown in FIG. 3. Or more precisely, each of the fiber-forming liquid guide passages **24** and **25** has a width of 0.4 mm., depth of 0.5 mm. and length of 5 mm. Each projection **33** has a width of 0.6 mm., and each orifice has a bore diameter of 0.08 mm. The space between the two adjacent orifices such as **21–1** and **21–2** is 0.6 mm., and thirty thousand orifices are provided in total. The value of α_s/α_g is 0.43 according to calculation. The component A is a copolymer having a molecular weight of 78,000 comprising 91.5% by weight of acrylonitrile, 8% by weight of methyl acrylate and 0.5% by weight of methallyl sulfonate. The component B is a mixture comprising said polymer and polyacrylonitrile (molecular weight 80.000) mixed at a ratio of 6:4. In order to prepare fiber-forming liquids, the components A and B are separately dissolved into sufficiently refined 70% nitric acid solution so that a concentration of 27 gr. per 100 gr. solvent may be obtained at a temperature of −5° C. Either liquid has a viscosity of about 1,000 poises at a temperature of 0° C.

Two liquids A and B so prepared are simultaneously extruded into 33% aqueous nitric acid solution at a temperature of =3° C. through the spinneret, and thus it is possible to obtain composite filaments wherein the components A and B are combined in a bimetallic manner. The fiber-forming liquids, A and B, are each extruded at a rate of 750 c.c. 1 min. The velocity of fibers leaving the coagulating bath is 6 m./min. Then, coagulated filaments are thoroughly washed and then stretched to 7 times their length in hot water. The final spinning velocity is 48 m./min. The filaments obtained are treated with steam at a temperature of 120° C. for 10 minutes and show the following crimp property when measured in accordance with the method stipulated in Japanese Industrial Standards: Number of spiral crimps per 25 mm. of fiber length, 22~18; degree of crimps, 25~21%. The parameter of distribution β_ω obtained from a photograph taken on the cross section has a value of about 7.

Example 2

In this example, a spinneret as shown in FIG. 1 is used. Each of the liquid guide passages has a width of 0.6 mm. and depth of 0.5 mm. Each of apertures **2** and **3** has a bore diameter of 0.2 mm., and each orifice has a bore diameter of 0.08 mm. The space between adjacent orifices is 0.6 mm. and 27,000 orifices are provided in total. The value of α_s/α_g equals almost 0.55. The spinneret of the above construction is used for the spinning operation performed in entirely the same manner as in Example 1. Filaments obtained are treated with steam at a temperature of 120° C. to provide spiral crimps therein. The following spiral crimp property is obtained when measured in accordance with the method stipulated in Japanese Industrial Standards: number of spiral crimps per 25 mm. of fiber length, 21~18; degree of crimps, 28~24%. The value of β_ω obtained from a photograph taken on the cross section is about 6.

What is claimed is:

1. A spinneret adapted for producing composite filaments comprising a first body having guide passages for separately guiding fiber-forming liquids, a second body having relatively constricted flow passages disposed downstream of said guide passages and in communication therewith for the flow of said fiber forming liquids, and means defining orifices located downstream of the guide passages and in communication therewith for limiting the flow of said fiber-forming liquids therethrough, said guide passages and flow passages being respectively dimensioned to produce respective pressure losses in the fiber-forming liquids flowing therethrough, the ratio of the pressure loss in the guide passages relative to that in the flow passages being between 0.1 and 4.0.

2. A spinneret as claimed in claim **1** wherein said constricted flow passages are apertures in said second body.

3. A spinneret as claimed in claim **1**, wherein said orifices are at least five thousand in number.

4. A spinneret adapted for producing composite filaments comprising a pair of reservoirs adapted for respectively containing different kinds of fiber-forming liquids, a back plate located beneath the reservoirs and having a plurality of longitudinal guide passages and a plurality of guide ports for respectively introducing one kind of fiber-forming liquid from the reservoirs to each of said guide passages, a middle plate positioned beneath the back plate and having rows of apertures extending longitudinally of said guide passages, and a nozzle plate located beneath said middle plate but slightly spaced apart therefrom, said nozzle plate being provided therein with rows of orifices each located substantially beneath the middle of two adjacent rows of said apertures, said guide passages and apertures being respectively dimensioned to produce respective pressure losses in the fiber-forming liquids flowing therethrough, the ratio of the pressure loss in the guide passages to that in the apertures being between 0.1 and 4.0.

5. A spinneret as claimed in claim **4** in which at least five thousand orifices in number are provided.

6. A spinneret as claimed in claim **4** in which at least five thousand orifices in number are provided in a density higher than 100 orifices/cm².

7. A spinneret as claimed in claim **4** wherein said guide passages and apertures are respectively dimensioned to satisfy the following relationship:

$$0.1<\alpha_s/\alpha_g<4.0$$

wherein

$$\alpha_s=\frac{4l^{0.8}}{\sqrt{\pi\psi^2}}$$

and

$$\alpha_g = \frac{2nl^{0.8}}{D\sqrt{DEX}}$$

and

l=length of each aperture
ψ=diameter of each aperture
n=number of apertures
L=length of each guide passage
D=the width or the height of the guide passage whichever is greater
E=the width or the height of the guide passage whichever is less, and

$$X = \frac{16}{3} - \frac{1024}{\pi^2}\frac{D}{E}\left[\tan h\frac{\pi E}{2D} + \frac{1}{27}\tan h\frac{3\pi E}{2D} + \cdots\right]$$

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