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(54) **PROCESS FOR MANUFACTURING FILAMENTS FROM AN OPTICALLY ANISOTROPIC SPINNING SOLUTION**

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PROCEDE DE FABRICATION DE FILAMENTS A PARTIR D'UNE SOLUTION A FILER OPTIQUEMENT ANISOTROPE

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**EP-A- 0 168 879** **BE-A- 550 684**  
**DE-C- 820 948** **FR-A- 1 102 056**

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**Description**

**[0001]** The invention pertains to a process for manufacturing filaments from an optically anisotropic spinning solution in which the spinning solution is extruded through spinning orifices grouped in at least one spinning section and in which the extrudates are passed through an inert gas and a coagulation bath in succession.

**[0002]** Such a process is known from Japanese laid-open No. 1986-239012, which describes a method of spinning filaments from poly(para-phenylene-terephthalamide) (PPTA) where the filaments are spun through spinning orifices grouped to form a rectangle. The ratio of the rectangle's long side length to its short side length has to be at least 4. In the coagulation bath a hole, also rectangular, is provided beneath the spinning section. Since both the spinning section and the hole in the coagulation bath are rectangular, the bundle of filaments is rectangular also. As a result of this rectangular shape of the bundle, very few vortexes are created in the coagulant, a portion of which is discharged from the coagulation bath together with the filaments. This leads to a substantial reduction of filamentation in the coagulation bath (where the filaments are not yet fully coagulated) and makes it possible to increase the spinning speed.

**[0003]** In the examples of said Japanese patent specification filaments of good strength are made. This strength is to be attributed first of all to the coagulant's low concentrations of sulphuric acid (0 and 10%) and the wideness on average of the spacing of the spinning orifices (the so-called pitch). The low acid concentration, which can only be maintained by treating the coagulant and replenishing it, and the large pitch, which makes it necessary to employ a large apparatus in relation to the number of produced filaments, make the described process into an expensive one with a very large waste stream.

**[0004]** Furthermore, at high spinning speeds there will have to be a subatmospheric pressure beneath the coagulation bath, this in order to further accelerate the speed of the coagulant and so reduce the tension in the filaments.

**[0005]** If in the process according to the Japanese patent specification the pitch of the spinning orifices is reduced in order to increase their number (and hence the number of filaments) per unit of area, the filaments in the coagulation bath will stick together at the spinning speeds mentioned, rendering the end product unsuitable for use in the envisaged high-grade applications (e.g., woven fabrics or composite reinforcement).

**[0006]** The invention has for its object to provide a process enabling the highspeed spinning ( $\geq 300$  m/min) of a plurality of filaments having good to very good physical properties. This object is attained by providing a process for manufacturing filaments from an optically anisotropic spinning solution in which the spinning solution is extruded through spinning orifices grouped in at least one spinning section and the extrudates are passed through an inert gas and a coagulation bath in succession, characterised in that the spinning section or spinning sections are rectangular, and that the ratio of the pitch to the width of the spinning section is more than 0.15 and less than 0.7, the pitch being defined as the average distance between the spinning orifice centres of adjacent spinning orifices, and the width of the spinning section is less than 5 mm.

**[0007]** Preferably, said ratio (which is easily calculated by dividing the pitch, in millimeters, by the width of the spinning section, also in millimeters) is in the range of 0.20 to 0.55, the spinning section has a width in the range of 1.5 to 4 mm, and the pitch is in the range of 0.3 to 0.7 mm.

**[0008]** Surprisingly, it was found that using this process makes it possible to manufacture filaments having good physical properties at a small pitch (and hence a large number of filaments per unit of area) at a comparatively high acid concentration in the coagulation bath, resulting in an economical process with a small waste stream. As can be seen from the example, the number of stickings occurring during the process (from filaments making contact before there has been sufficient coagulation of the outer shell) is low.

**[0009]** The process according to the invention makes it possible to use a comparatively compact spinning apparatus or to equip existing spinning apparatus with spinneret plates with a higher number of spinning orifices. For instance, the production of an existing spinning apparatus can be increased from 1000 to 2000 or 3000 filaments per spinning position.

**[0010]** The favourable results are probably attributable to the low resistance experienced by the coagulant as it flows to the core of the filament bundle (alternatively, this may be referred to as high filament bundle permeability). The resistance depends on the route to be travelled, i.e., half of the width of the filament bundle, and the space between the various filaments (the pitch).

**[0011]** Preferably, the spinning orifices are grouped in more than one spinning section. The separate sections can then be positioned vis-à-vis one another such as to ensure the least possible hindrance of the coagulant's approaching flow and the fullest possible avoidance of disturbing the coagulation bath.

**[0012]** Also, the separate spinning sections preferably are positioned such that the maximum space between the outermost fibres is relatively small at the moment of extrusion from the spinning orifices of the different spinning sections, so that the convergence to, say, a guide may be low.

**[0013]** One highly effective way of positioning the rectangular spinning sections takes the form of the spinning sections being distributed equidistantly over a circle, with the longitudinal direction of each of the spinning sections coinciding with a radius. Such positioning hinders the approaching flow of the coagulant hardly (if at all) and gives a low

convergence for each of the filament bundles.

**[0014]** To further reduce convergence in the filament bundle or filament bundles it is preferred to provide the bottom of the coagulation bath per spinning section with a rectangular opening which has a greater length than the spinning section and is somewhat narrower in width. In that case neither the length nor the width of the opening in the bottom of the coagulation bath will give rise to filament bundle convergence, and the filaments are prevented from being pressed together or suffering damage from scraping along the edge of the opening.

**[0015]** The physical properties of the filaments obtained by the process according to the invention can be enhanced still further by selecting a range for the distance travelled by the threadlike extrudates through the gaseous inert medium (the air gap) of more than 0.5 mm and less than 8 mm.

**[0016]** When very small air gaps are employed (say, smaller than 2 mm), there is a risk of the coagulant, which will always display some motion under the influence of the filament bundle (vibrations, small waves, etc.), making contact with the spinneret plate. When this happens, the process may be disturbed to such a degree as will require it to be stopped. Hence, if very small air gaps are to be used, it is of the essence to have the calmest possible coagulation bath surface. Surprisingly, it was found that the extent to which the coagulation bath surface is in motion is highly dependent on the geometry of the coagulation bath's bottom. If use is made of more than two spinning sections and a corresponding number of discharge openings in the bottom of the coagulation bath, the extent to which there is motion at the coagulant surface can be reduced substantially by introducing variations in height in or on the bottom. A very simple and effective embodiment of this is the one where the edges of adjacent openings are at different heights ("on different levels"). A possible explanation of this phenomenon is given below.

**[0017]** At the edges of the discharge openings the liquid which is entrained by the outgoing filament bundle is stopped or scraped off. Because of inertia, the liquid retains (part of) its speed and flows parallel to the bottom in the direction of the adjacent discharge opening. However, coagulant flow approaches also from the direction of this adjacent discharge opening, resulting in the collision of streams flowing in opposite directions. The liquid is pushed up as a result, and the coagulation bath surface rises above this stagnation point. Obviously, the damming up of the coagulant constitutes a significant restriction when selecting the air gap; after all, the coagulant has to be prevented from making contact with the spinneret plate.

**[0018]** When the aforementioned streams come together at different levels, the disclosed damming up does not arise. On the contrary, because the speed of one of the streams (i.e., the one flowing from the lowest edge) already has a component going in the direction of the liquid surface, there is extinction and the liquid surface remains calm.

**[0019]** When the coagulation bath has a depth of more than 10 mm and less than 20 mm (preferably less than 15 mm), on the one hand the filaments encounter only slight resistance in the bath and the use of coagulant is low, and on the other hand the residence time in the coagulation bath is long enough to achieve the required coagulation.

**[0020]** It should be noted that EP 172 001 discloses a process for spinning aramid yarns in which use is made of rectangular spinning sections of narrow width and a small pitch. However, this process is substantially different from the process according to the invention, since the coagulant is not contained in a bath but supplied in the form of a waterfall. Because of the strong current in the waterfall and the small number of rows of filaments, the resistance encountered by the coagulant in the filament bundle does not play an essential part.

**[0021]** The process according to EP 172 001 involves very high coagulant consumption. Moreover, in the examples only water (0% sulphuric acid) is employed. As a result, the (very large) stream of coagulant has to be subjected to extensive post-treatment and/or neutralisation.

**[0022]** It should also be noted that in Japanese laid-open No. 1985-065110 a process is described which uses a spinneret plate having 2 spinning sections each with 50 spinning orifices. The pitch is 1.5 mm, giving a small number of filaments per unit of area.

**[0023]** The coagulant used in the process in question is water containing 0% or 10% of sulphuric acid, so this process is likewise attended with a large waste stream.

**[0024]** It is noted that FR-A-1 102 056 (filing date June 16, 1947) discloses a very small spinneret with a large number of spinning orifices. Such spinnerets can only be used in true wet spinning processes, i.e., those spinning processes which do not comprise an air gap (for instance, viscose spinning) and wherein the extruded filaments are immediately contacted with the coagulant and coagulated. True wet spinning processes therefore are not confronted with filament sticking and problems occurring at the free surface of the coagulant. Further, in said publication it is prescribed that if the spinning orifices are grouped in spinning sections, the width of the groups should not exceed two orifices, whereas the invention allows greater widths.

**[0025]** EP-A-0 168 879 pertains to a process involving the use of two or more separate, spaced spinning sections. The sections according to EP-A-0 168 879 are rather large and filaments obtained with this process leave much to be desired in terms of mechanical properties and yarn regularity, especially if the process is carried out at high speed.

**[0026]** Within the framework of the invention the term pitch is used to indicate the average distance between the spinning orifice centres of adjacent spinning orifices.

**[0027]** The invention will be further illustrated below with reference to an example and figures. Needless to say, the

invention is illustrated but not limited by this example.

Figure 1 shows a bottom view of a spinneret according to the invention provided with eight rectangular spinning sections.

Figure 2 shows two of the eight spinning sections of the spinneret according to Figure 1 in greater detail.

Figure 3 shows a bottom view of a spinneret serving as comparative example.

Figure 4 shows one of the spinning sections of the spinneret according to Figure 3 in greater detail.

EXAMPLE

[0028] In analogous manner to the procedure described in Example 6 of US 4,308,374 poly(para-phenylene terephthalamide) was prepared using a mixture of N-methyl pyrrolidone and calcium chloride. After neutralisation, washing, and drying a polymer having an inherent viscosity of 5.4 was obtained.

[0029] The polymer was dissolved in sulphuric acid of 99.8% concentration in the manner described in Example 3 of US 4,320,081. The thus prepared spinning solution had a polymer concentration of 19.4%.

[0030] The spinning solution was spun using different spinnerets.

[0031] A first circular spinneret 1, depicted in Figures 1 and 2, having an outer diameter of 57 mm (in the Table this spinneret is indicated with the code S1) was provided with eight rectangular spinning sections 2 (2.58 mm wide, indicated with 3 in Figure 1, and 9 mm long) each having 125 spinning orifices 4. The spinning orifices 4 had a diameter of 65 µm and a distance of one to the other (pitch) 5 of 0.5 mm (the ratio of the pitch 5 to the width 3 of the spinning section 2 thus was 0.2).

[0032] A second circular spinneret 6, depicted in Figures 3 and 4 (in the Table this spinneret is indicated with the code S2), serving as a comparative example, had an outer diameter of 57 mm and was provided with four spinning sections 8 (having a constant width 7 of 9.5 mm) each following the curve of the circumference of the circular spinneret and each comprising 250 spinning orifices. The spinning orifices had a diameter of 65 µm and a distance of one to the other 9 of 1.0 mm (the ratio of the pitch 9 to the width 7 of the spinning section 8 thus was 0.11).

[0033] The spinning solution was spun through an air gap, as indicated in the Table. The same-level or flat bottom of the coagulation bath (having a depth of 10 mm) was provided with eight and four openings, respectively (S1: rectangular 2.0 mm x 15 mm; S2: circular with a diameter of 5 mm) each positioned directly beneath a spinning section.

[0034] The coagulant was made up of water having a sulphuric acid concentration of 20% and a temperature of 10°C. The spinning speeds and the draw ratios are indicated in the Table. The physical properties were determined in accordance with ASTM D885.

[0035] The term fluffs is used to indicate various irregularities (resulting from breaks, filament lapping around rolls, etc.) in the manufactured yarn.

[0036] The degree of sticking was evaluated visually. 1 indicates that there was little or no sticking (less than 1% of the filaments subject to sticking), 5 indicates a very strong degree of sticking (over 25% of the filaments subject to sticking).

TABLE

Spinning rate (m/min)	300	400	300	400	300
Draw ratio	7.1	9.5	7.1	9.5	7.1
Spinneret S1	Tenacity (mN/tex):		Fluffs per 15 min):		Sticking (-):
Air gap	3 mm	2218	2162	0	1
	4 mm	2179	2143	1	0
	6 mm	2181	2177	0	0
	8 mm	2158	2032	2	1
Spinneret S2					
Air gap	8 mm	1912	1879	5	40
	8 mm	1864	1873	1	34
	8 mm	1902	1955	5	33
	8 mm	1921	1953	4	6

[0037] The filaments manufactured using S1 have significantly higher tenacity than those made using S2. Also, the number of stickings is far lower. Furthermore, in view of the available space, the number of spinning sections in a

spinneret such as S1 can be increased to, say, 12 or 16, whereas S2 provides no such opportunity.

[0038] A third circular spinneret (S3; this spinneret, unless specified otherwise, corresponds to S1) having an outer diameter of 75 mm was provided with eight rectangular spinning sections (2.58 mm wide and 18 mm long) each having 250 spinning orifices, giving 2000 filaments in all. The spinning orifices had a diameter of 65 µm and were spaced 0.5 mm apart.

[0039] Spinneret S3 was used to spin the spinning solution described above (under conditions which, unless specified otherwise, correspond to those disclosed above) employing an air gap of 6 mm and a spinning speed of 300 m/min. The resulting yarn had a tenacity of 2202 mN/tex. The number of fluffs per 15 minutes was 4, and there was no sticking.

## Claims

1. A process for manufacturing filaments from an optically anisotropic spinning solution in which the spinning solution is extruded through spinning orifices grouped in at least one spinning section and the extrudates are passed through an inert gas and a coagulation bath in succession, characterised in that the spinning section or spinning sections are rectangular, and that the ratio of the pitch to the width of the spinning section is more than 0.15 and less than 0.7, the pitch being defined as the average distance between the spinning orifice centres of adjacent spinning orifices, and the width of the spinning section is less than 5 mm.
2. A process according to claim 1, characterised in that the spinning orifices are grouped in more than one spinning section.
3. A process according to claim 2, characterised in that the spinning sections are distributed equidistantly over a circle, and the longitudinal direction of each of the spinning sections coincides with a radius.
4. A process according to claim 2 or 3, characterised in that the bottom of the coagulation bath is provided per spinning section with a rectangular opening which has a greater length than the spinning section and is narrower in width.
5. A process according to claim 4, characterised in that the bottom of the coagulation bath is provided with at least two openings, and the adjacent edges of adjacent openings are at different levels.
6. A process according to any one of the preceding claims, characterised in that the distance travelled by the threadlike extrudates through the gaseous inert medium is more than 0.5 mm and less than 8 mm.

## Patentansprüche

1. Verfahren zur Herstellung von Filamenten aus einer optisch anisotropen Spinnlösung, bei dem die Spinnlösung durch Spinndüsenöffnungen extrudiert wird, die in mindestens einem Spinnabschnitt gruppiert sind, und bei dem die Extrudate durch Inertgas und anschließend durch ein Koagulationsbad hindurchgeleitet werden, dadurch gekennzeichnet, daß der Spinnabschnitt oder die Spinnabschnitte rechteckig ausgebildet sind und daß das Verhältnis der Teilung zur Breite des Spinnabschnitts mehr als 0,15 und weniger als 0,7 beträgt, wobei die Teilung als durchschnittlicher Abstand zwischen den Mittelpunkten benachbarter Spinndüsenöffnungen festgelegt ist, und daß die Breite des Spinnabschnitts weniger als 5 mm ist.
2. Verfahren nach Anspruch 1, dadurch gekennzeichnet, daß die Spinndüsenöffnungen in mehr als einem Spinnabschnitt gruppiert sind.
3. Verfahren nach Anspruch 2, dadurch gekennzeichnet, daß die Spinnabschnitte mit gleichem Abstand über einen Kreis verteilt sind und daß die Längserstreckung eines jeden Spinnabschnitts mit einem Radius zusammenfällt.
4. Verfahren nach Anspruch 2 oder 3, dadurch gekennzeichnet, daß der Boden des Koagulationsbades für jeden Spinnabschnitt mit einer rechteckigen Öffnung ausgestattet ist, die eine größere Länge als der Spinnabschnitt aufweist und die enger in der Breite ist.
5. Verfahren nach Anspruch 4, dadurch gekennzeichnet, daß der Boden des Koagulationsbades mit mindestens zwei Öffnungen ausgestattet ist und daß benachbarte Kanten von benachbarten Öffnungen sich auf unterschiedlichen Niveaus befinden.

6. Verfahren nach einem der vorangehenden Ansprüche, dadurch gekennzeichnet, daß der Abstand, der von den fadenartigen Extrudaten durch das gasförmige Edelgasmedium zurückgelegt wird, mehr als 0,5 mm und weniger als 8 mm beträgt.

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### Revendications

1. Procédé de fabrication de filaments à partir d'une solution à filer optiquement anisotrope, dans lequel la solution à filer est extrudée à travers des orifices de filage groupés dans au moins une section de filage et les extrudats passent successivement à travers un gaz inerte et dans un bain de coagulation, caractérisé en ce que la ou les sections de filage sont rectangulaires, et en ce que le rapport du pas à la largeur de la section de filage est supérieur à 0,15 et inférieur à 0,7, le pas étant défini comme étant la distance moyenne entre les centres des orifices de filage d'orifices de filage adjacents, et la largeur de la section de filage est inférieure à 5 mm.
2. Procédé selon la revendication 1, caractérisé en ce que les orifices de filage sont groupés dans plus d'une section de filage.
3. Procédé selon la revendication 2, caractérisé en ce que les sections de filage sont réparties à égale distance sur un cercle, et la direction longitudinale de chacune des sections de filage coïncide avec un rayon.
4. Procédé selon la revendication 2 ou 3, caractérisé en ce que le fond du bain de coagulation est muni d'une section de filage ayant une ouverture rectangulaire qui a une longueur supérieure à la section de filage et qui a une largeur plus étroite.
5. Procédé selon la revendication 4, caractérisé en ce que le fond du bain de coagulation est muni d'au moins deux ouvertures, et les bords adjacents des ouvertures adjacentes sont à des niveaux différents.
6. Procédé selon l'une quelconque des revendications précédentes, caractérisé en ce que la distance parcourue par les extrudats en brin à travers le milieu gazeux inerte est supérieure à 0,5 mm et inférieure à 8 mm.

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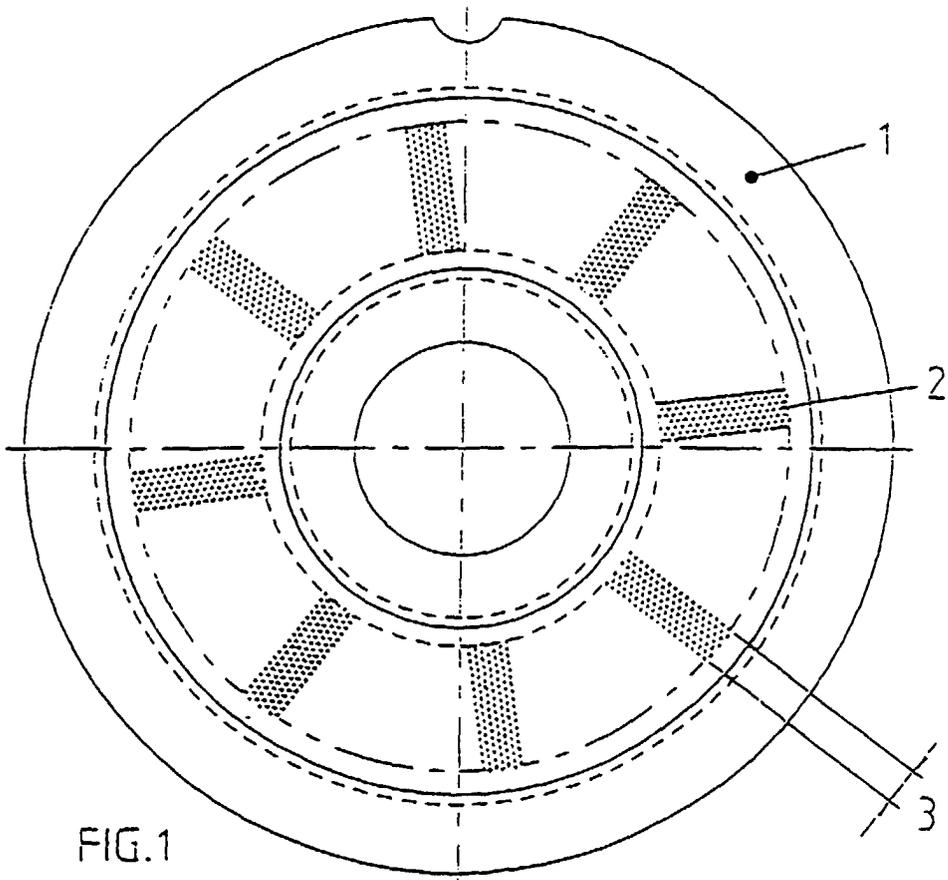


FIG. 1

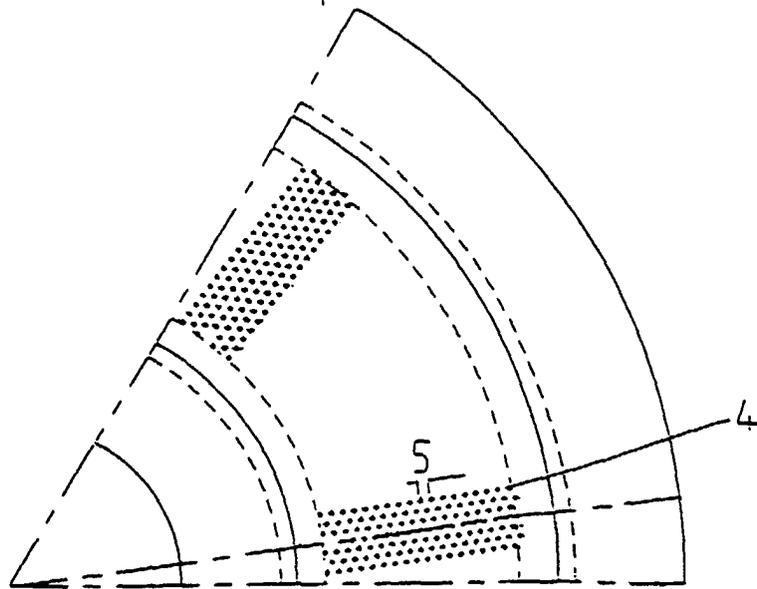


FIG. 2

