Oct. 29, 1968 J. R. BRAYFORD 3,408,433
METHOD AND APPARATUS FOR SPINNING HETEROFILAMENTS
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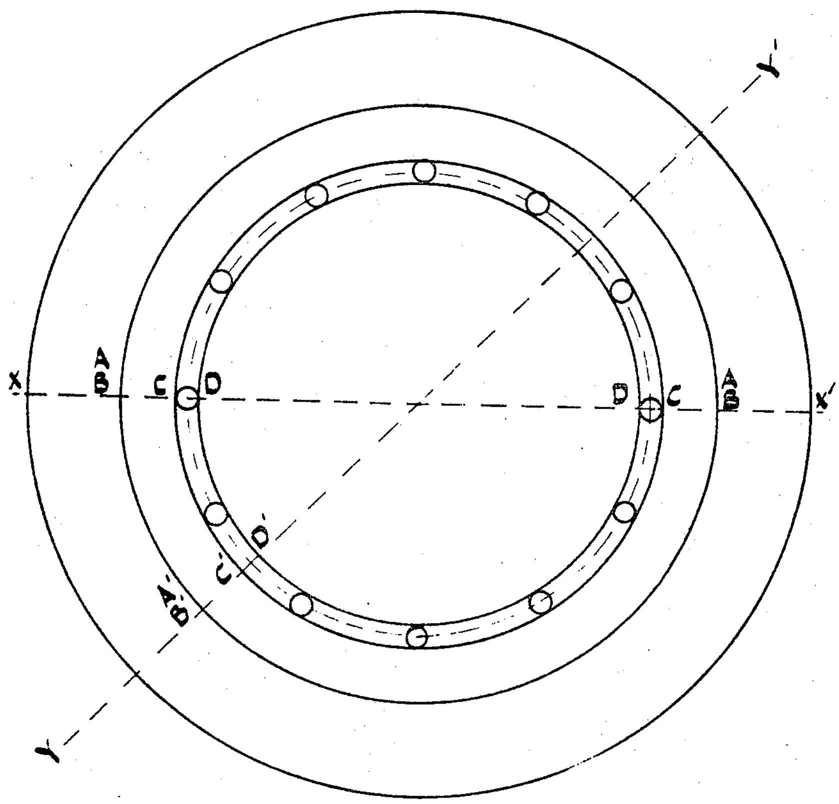

FIG. 1

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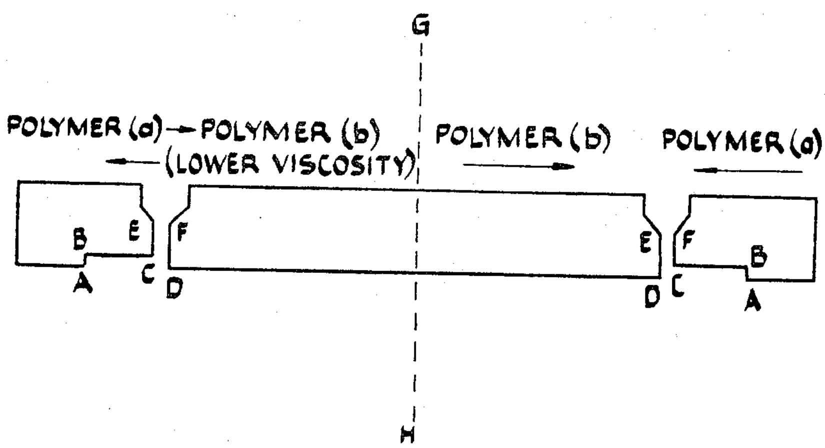

SECTION XX'

FIG. 2

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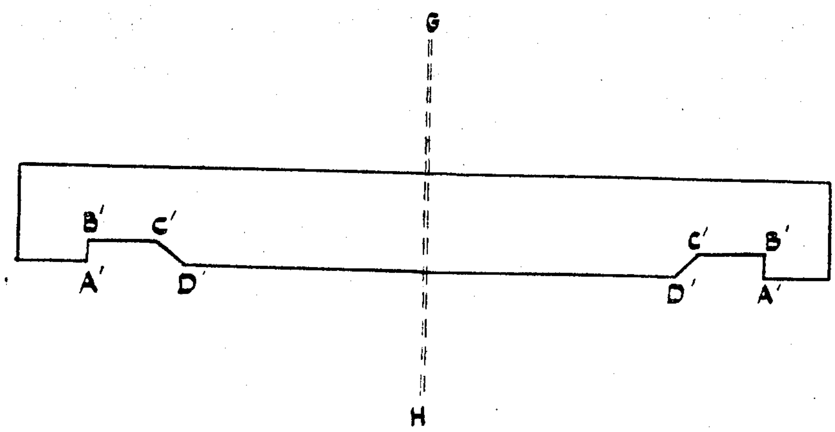

Y-Y'

FIG. 3

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3,408,433
METHOD AND APPARATUS FOR SPINNING HETEROFILAMENTS

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ABSTRACT OF THE DISCLOSURE

Each spinneret hole of a spinneret plate is constructed with one wall portion of relatively great length in the extrusion direction and another parallel wall portion of relatively short length. Composite, side-by-side filaments are made by forcing two polymer components of significantly different melt viscosities through each hole in a manner such that the lower viscosity component contacts the longer wall portion and the higher viscosity component contacts the shorter wall portion, whereby the components issue from the hole at uniform velocity and the threadline exhibits no appreciable deflection from the axis of the hole.

The present invention relates to the spinning of side by side heterofilaments, more particularly to the spinning of side by side heterofilaments from two polymers of significantly different melt viscosities.

According to the present invention we provide a process for the manufacture of composite filaments and yarns containing them by forcing a stream of molten polymer of higher viscosity side by side with a stream of molten polymer of lower viscosity through a spinneret hole of which the wall length is non-uniform, the major part or all of the polymer of lower viscosity being in contact with the major part or all of a portion of the wall of the spinneret hole extending further than the remainder of the wall of the spinneret hole at the exit so as to counteract substantially the tendency to deflection of the polymer stream resulting from the difference in melt viscosity between the two polymer streams.

According to our invention we also provide a spinneret comprising a spinneret plate bearing a multiplicity of spinneret holes substantially perpendicularly disposed to the face of the spinneret plate, at least a portion of the wall of each of the said spinneret holes being significantly longer than at least another portion of the wall of each of said spinneret holes.

By the term "significantly longer" we mean longer by an amount sufficient to produce a sufficient differential exit velocity between the two streams of polymer flowing side by side resulting in the necessary correcting influence according to the requirements as hereinafter described. The ambit of our invention includes, for example, the case of a stepped exit wherein a shorter portion of the wall of the hole is all of one length and a longer portion all of another length, a bevelled exit wherein the wall length varies linearly across the hole as well as other obvious equivalents.

An advantage of the process of our invention employing the spinneret according to our invention is that by means of it side by side heterofilaments may be spun using pairs of polymers of significantly different melt viscosities using a relatively cheaply manufactured spinneret. Such heterofilaments have a potential crimp which may be developed by subsequent treatment and this renders them particularly suitable for many textile purposes.

In the spinning of side by side heterofilaments from

two polymers of different melt viscosities, the two polymers in the molten state are forced simultaneously into the spinneret hole thus producing a composite stream within the spinneret hole. Thus a portion of the spinneret hole is constantly contacted by the one polymer while the remainder of the wall of the spinneret hole is constantly contacted by the other polymer. If the wall in contact with each polymer is of the same length, the lower viscosity of the one polymer will result in an asymmetrical velocity distribution across the combined stream at the exit of the spinneret hole thus causing deviation of the issuing threadline from the desired path in line with the axis of the spinneret hole. This is known as "kneeing." Severe kneeing can lead to poor yarn quality and even breakdown. In the case of polyesters and polyamides for example, melt viscosity differences for best crimp potential are such as to produce a tendency for kneeing which prohibits satisfactory spinning with the normal spinneret holes. By the use of a spinneret hole according to our invention in the manner according to our invention, the two parts of the composite stream issuing from the spinneret hole can be arranged to have a sufficiently symmetrical velocity distribution to ensure that the threadline takes the desired path on issue from the spinneret hole enabling satisfactory filament spinning. We believe this to be the explanation of the effectiveness of the process of our invention, however we do not wish the scope of our invention to be limited thereby.

It should be understood that the utility of our invention is confined to the spinning of pairs of polymers which differ significantly in melt viscosity. By this we mean that the difference in the melt-viscosities between the two polymers under the conditions of shear and temperature pertaining within the spinneret orifice must be sufficient so that the velocity distribution across the composite stream issuing from the spinneret hole should be significantly asymmetrical that is, that there should be a sufficiently large kneeing tendency. Polymers which fulfill this requirement are those of which the flow behaviour is predominantly Newtonian or pseudoplastic, for example polyesters and polyamides. Polymers which may not fulfill this requirement are those of which the melt is predominanlty viscoelastic, for example, fibre-forming polyolefines.

The tendency for the occurrence of an asymmetrical velocity distribution across the composite stream at the exit of the spinneret hole increases as the difference between the melt-viscosities of the pair of polymers under the conditions pertaining in the spinneret hole increases, which in turn is the result of differences which may, for example, be chemical, physical or the result of additives. The impressed correcting influence, which tends to neutralise the resultant velocity differential, depends on the continuance of the drag effect resulting from the extended time of contact and extent of contact of one member of the pair of polymers with the wall of the spinneret hole at the exit.

Our invention is applicable to the ranges of hole dimensions throughputs and melt viscosities commonly used in melt spinning, for example diameters from 0.007 to 0.020 inch, throughputs 0.5 to 2.5 g. per minute, melt viscosities from 200 to 10,000 poises. The combined kneeing tendency which has to be corrected, and hence the magnitude of the differential length results, from the combination of the above parameters, decreased diameter, increased throughput and increase in melt viscosity difference working in the same direction .

From the point of view particularly of manufacture of the spinneret we prefer spinneret holes of either of two kinds:

(1) those in which, as the circumference of the hole is

traversed, the wall length changes gradually, producing a bevelled hole; this is of patricular advantage from the point of view of wiping of drips from the spinneret, and

(2) those in which, as the circumference of the hole is traversed, the wall length changes suddenly, producing a stepped hole (for which the extended portion is of uniform length). Both effects may of course be combined to produce a variety of profiles.

In the case, for example, of a stepped exit to the spinneret hole it is not necessary that the interface between the two streams of polymer should coincide with the line of occurrence of the step differential but the two polymer components should each be uniformly distributed about a line at right angles to the line of occurrence of the step differential.

In the term "spinneret hole" we include only the substantially parallel sided portion of the orifice through which the molten polymer is forced. We exclude any lead-in portion of wider bore than the parallel sided portion, which has a negligible effect on the velocity of the polymer streams.

The pairs of polymers of different melt viscosity may be of different chemical composition, for example polyester with polyamide, of modified chemical composition, for example polyester with copolyester, or of different molecular weights for the same polymer. Otherwise the difference in melt viscosity may be produced by some other means, for example a difference in temperature or the use of a particular polymer paired with the same polymer in admixture with a modifying agent; an example of such a modifying agent is a finely divided chemically inert material.

In order that the process of our invention may be of the more fully understood, we described hereinafter, by way of example, the form and use of a spinneret according to our invention with particular reference to FIGURES 1, 2 and 3 in which FIGURE 1 shows a circular spinneret plate viewed from below.

FIGURE 2 shows a section through the spinneret plate on the line X–X′.

FIGURE 3 shows a section through the spinneret plate on the line Y–Y′.

A spinneret was fabricated consisting of a spinneret plate of circular form in which were bored 12 equidistant spinneret holes of 0.015 inch (0.38 mm.) diameter, of which the axes were perpendicular to the face of the spinneret plate and the centres of which were on a circle concentric with the spinneret plate and of diameter 2¹¹⁄₁₆ inches (6.8 cm.). From the outer face of the spinneret plate was machined a circular

groove (shown in cross section through a diameter as A, B, C, D in FIGURE 2 or A′, B′, C′, D′ in FIGURE 3) of such dimensions that each of the spinneret holes was modified so that the length of the wall of the straight portion F, D of the spinneret hole at the point nearest to the axis (G, H) of the spinneret plate was .050 inch (1.27 mm.) the length of the wall E, C at the point farthest from the axis of the spinneret plate was .030 inch (0.76 mm.) and wall lengths between these two points were intermediate in a smooth gradation.

Side by side heterofils were spun from two poly(ethylene terephthalate) polymers (a) and (b) otherwise identical but differing in melt viscosity by a factor of approximately 4:1 due to molecular weight difference. This difference is most easily expressed by saying that the intrinsic viscosity as measured on a 1% solution in orthochlorophenol at 25° C. was 0.62 dl./g. for polymer (a) and 0.47 dl./g. for polymer (b). By means not shown in the figure, equal weights per minute of each of the two polymers were forced through each of the spinneret holes, the interfaces of the two streams of polymer being tangential to the circle passing through the axis of the spinneret holes and polymer (b) being on the side of the interface nearer to the axis (G, H) of the spinneret plate. Stable spinning resulted giving satisfactory heterofilaments.

A further experiment carried out under exactly the same conditions as hereinbefore described and with the sole distinction that the holes of the spinneret used were of the conventional type, resulted in all filaments kneeing into the spinneret face.

In order to demonstrate conditions under which the apparatus of our invention is effective in minimizing spinning defects in the spinning of composite fibres, experiments were carried out in each of which one of the components from which the composite fibre was prepared was poly(ethylene terephthalate) of intrinsic viscosity 0.67 as measured on a 1% solution in orthochlorophenol at 25° C., the second component being of the same or a different intrinsic viscosity as measured in the same manner, but otherwise of the same polyester. In Table 1 given hereinafter, the position of the polyester of each viscosity in the spinneret hole is indicated by the letter C or D corresponding to the positions indicated by these letters in FIGURES 1 and 2. The direction of kneeing, if it occurs, is also indicated by the letter C or D. The letters *st*, standing for straight, are shown in cases where no kneeing is observed. Where satisfactory spinning was impossible, the sign X is shown. In Table 2 are given the characteristics of the spinneret hole used for each of the experiments referred to in Table 1.

TABLE 1.—KNEEING TENDENCY

[1st Component=0.67 I. V.]

Second Component, I. V.[1]	0.67				0.60				0.50				0.40			
Second Component Low Shear Viscosity,[2] poises	3,100				1,500				570				220			
Position of 1st Component	C				C				C				C			
Position of 2nd Component	D				D				D				D			
Throughput/hole (Total) gm./min	0.94	1.88	1.88	1.88	.94	1.88	1.88	1.88	.94	1.88	1.88	1.88	.94	1.88	1.88	1.88
Throughput/hole (1st Component) gm./min	0.47	0.94	1.42	0.47	.47	.94	1.42	.47	.47	.94	1.42	,.47	.47	.94	1.42	.47
Component Ratio 1st:2nd	1:1	1:1	3:1	1:3	1:1	1:1	3:1	1:3	1:1	1:1	3:1	1:3	1:1	1:1	3:1	1:3
Hole No.:																
1	D	D	D	D	*st*	*st*	D	D	C	C	C	C	C	C	C	C
2	D X	D X	D X	D X	D	*st*	D	D X	C	C	C	D	C	C	C	C
3	D	D	D	D	*st*	*st*	D	D	C	C	D	C	D	D	D	C
4	D X	D X	D X	D X	D	D	D X	D X	D	D	D	D	D X	D	D X	C
5	D X	D X	D X	D X	D X	D X	D X	D X	D	D	D	D X	D X	D	D X	D
6	------	------	------	------	------	------	------	------	C	C	D	C	D	D	------	C
7	------	------	------	------	------	------	------	------	C	C	*st*	C	C	C	------	C
8	------	------	------	------	------	------	------	------	C	C	*st*	C	C	C	------	C
9	------	------	------	------	------	------	------	------	C	C	*st*	C	D	D	------	C
10	------	------	------	------	------	------	------	------	C	C	D	C	D	D	------	*st*

[1] I.V. (that is Intrinsic Viscosity measured as in Example 1) and melt viscosity are as measured on the starting polymer before meltspinning.
[2] At 290° C. and 10 sec.:1 shear rate.

TABLE 2.—SPINNERET HOLE DETAILS

[Hole Diameters All 15×10^{-3} inch]

Hole No.	1	2	3	4	5	6	7	8	9	10
Max. length $\times 10^3$ inch	20	20	50	50	50	50	30	30	50	50
Min. length $\times 10^3$ inch	15	10	45	40	30	45	25	25	45	45
Differential $\times 10^3$ inch	5	10	5	10	20	5	5	5	5	5
Percent differential	25	50	10	20	40	10	17	17	10	10
Step or bevel	(1)	(1)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
Sharp edged bevel	----	----	----	----	----	----	----	no	no	yes

[1] Step. [2] Bevel.

What I claim is:

1. A process for the manufacture of composite filaments and yarns containing said filaments by forcing a stream of molten polymer of higher viscosity side by side with a stream of molten polymer of lower viscosity through a spinneret hole disposed substantially perpendicularly to a spinneret plate, of which the wall length is non-uniform, the major part or all of the polymer of lower viscosity being in contact with the major part or all of a portion of the wall of the spinneret hole extending further than the remainder of the wall of the spinneret hole at the exit.

2. A process according to claim **1** wherein the portion of the wall extending further is of uniform further extension.

3. A process according to claim **1** wherein the exit of the spinneret hole is bevelled.

4. A process according to claim **1** wherein the molten polymer of higher viscosity is of viscosity at the temperature of spinning of from 1,000 to 10,000 poises, the viscosity of the polymer of lower viscosity is of at least 500 poises less than the viscosity of the polymer of higher viscosity, the ratio in which the two components are forced through the spinneret is 1:5 to 5:1, the hole diameter is not less than 0.007 and not greater than 0.020 inch, the hole length is not less than 0.01 and not greater than 0.05 inch, the difference between the longest and shortest lengths of the spinneret walls is not less than 0.002 and not greater than 0.020 inch, preferably not less than 0.004 and not greater than 0.010 inch and the throughput of the combined stream of polymer is from 0.5 g. to 2.5 g. per minute per hole.

5. A process according to claim **1** wherein the molten polymer of higher viscosity is of viscosity at the temperature of spinning of from 1,700 to 3,000 poises, the viscosity of the polymer of lower viscosity is of at least 1,500 poises less than the viscosity of the polymer of higher viscosity, the ratio in which the two components are forced through the spinneret is 1:3 to 3:1, the hole diameter is not less than 0.009 and not greater than 0.015 inch, the hole length is not less than 0.02 and not greater than 0.05 inch, the difference between the longest and shortest lengths of the spinneret walls is not less than 0.002 and not greater than 0.020 inch, preferably not less than 0.004 and not greater than 0.010 inch and the throughput of the combined stream is from 0.5 to 2.5 g. per minute per hole.

6. A spinneret comprising a spinneret plate bearing a multiplicity of spinneret holes substantially perpendicularly disposed to the face of the spinneret plate, at least one portion of the wall of each of the said spinneret holes extending substantially further at the exit in a direction parallel to the direction of extrusion than at least one other parallel portion of the wall of each of said spinneret holes.

7. A spinneret according to claim **6** wherein the extended portion of the wall is of uniform length.

8. A spinneret according to claim **6** wherein the exit of the spinneret holes are bevelled.

9. In a process for the manufacture of composite filaments which includes forcing two polymers of significantly different melt viscosities in side-by-side relationship through a spinneret hole having a wall which extends perpendicularly through a spinneret plate, the improvement which ensures that the composite stream issuing from the spinneret hole will have substantially symmetrical velocity distribution across its cross section at the exit of the spinneret hole and will thereby produce a threadline which is substantially in line with the spinneret hole, said improvement comprising contacting at least the major part of the polymer component of lower viscosity moving through said spinneret hole with a relatively longer length of the wall which defines said hole and simultaneously contacting at least the major part of the other polymer component with a relatively shorter length of said wall thereby preventing any appreciable deviation of the threadline from its in-line direction of travel which would result from the formation of an asymmetrical velocity distribution across the cross section of the stream issuing from said hole.

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