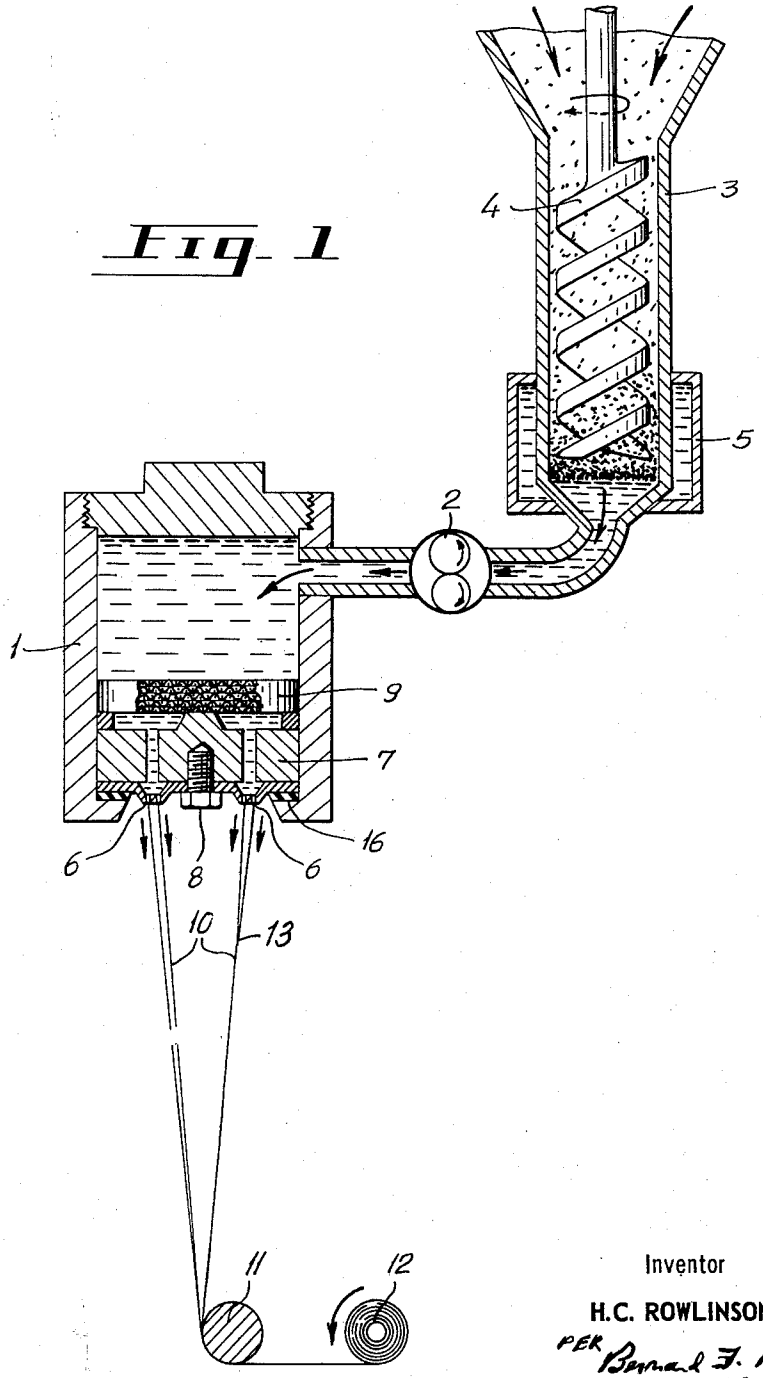
July 9, 1963 H. C. ROWLINSON 3,097,056

MELT-SPINNING OF POLYMERS

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Fig. 1



Inventor

H.C. ROWLINSON

PER Bernard J. Rowlinson

AGENT

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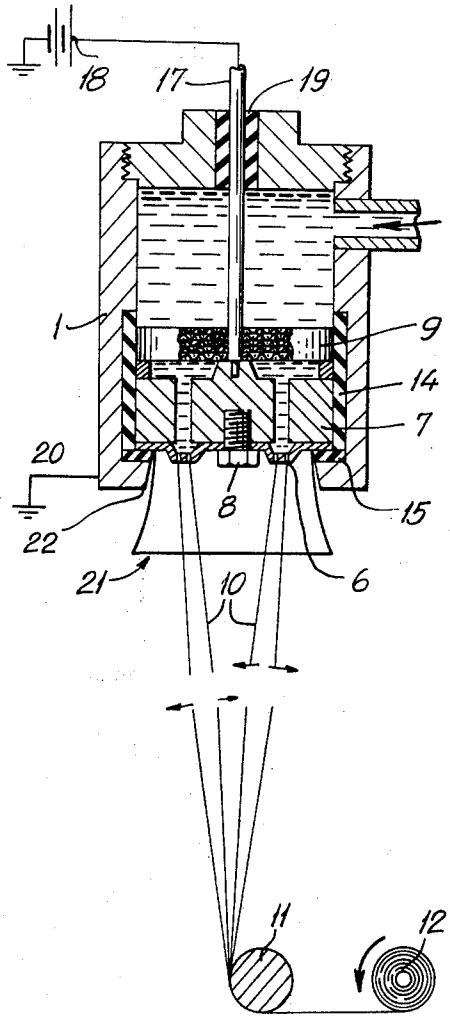


Fig. 2

Inventor

H.C. ROWLINSON

PER Bernard F. Rowan

AGENT

United States Patent Office

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MELT-SPINNING OF POLYMERS

Hugh Charles Rowlinson, St. Hilaire Station, Quebec, Canada, assignor to Canadian Industries Limited, Montreal, Quebec, Canada, a corporation of Canada

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This invention is concerned with the melt spinning of fibre-forming polymers wherein molten fibre-forming polymeric material is forced through a plurality of fine holes and thereafter solidifies to give a bundle of approximately parallel filaments. It is particularly concerned with the prevention of coalescence of these filaments during the gathering up of the bundle thereof to form a multifilamentary yarn.

The practice of melt spinning arose with the advent of thermo-plastic fibre-forming polymers, in particular nylon. Such polymers in the molten state are forced through a spinneret plate provided with about 50 or even up to 200 holes of small diameter, for example of 0.002 inch diameter and the resultant filaments of extruded polymer are allowed to solidify by cooling. The resulting bundle of filaments is wound up on a reel to give a multifilamentary yarn. It has however been found that, as the process is speeded up, the filaments do not solidify sufficiently rapidly to prevent some of them from touching before they are solid and thus becoming welded together. A small imperfection in the resulting yarn is thus formed and may be particularly accentuated during subsequent drawing operations wherein the minutely thickened portion is more resistant to elongation than the rest of the yarn. Defects such as knots and loose or broken filaments result, and quite noticeable irregularity in dye take-up has also been experienced in uneven yarn, caused by the coalescence of melt-spun filaments.

The fibre-forming polymers which are currently melt-spun include the nylons, being a well-known group of linear polyamides, polyvinylidene chloride, polyformaldehydes, polyurethanes, linear polyesters such as polyethylene terephthalate, and polyolefinic resins such as polyethylene and polypropylene. This list is not exhaustive; particularly in the future, it may be that other polymers, such as copolymers and homopolymers of higher aliphatic monoolefines, may be melt-spun, and the spinning thereof may suitably be conducted by the process of this invention.

It is an object of this invention to provide a process for the multifilament melt-spinning of fibre-forming polymers whereby the occurrence of defects due to the coalescence of filaments is avoided or reduced. Another object is to provide an improved process for the multifilament melt-spinning of fibre-forming ploymers characterized in that the filaments are separated from each other by electrostatic repulsion during cooling.

Broadly speaking, the improved process for the multifilament melt-spinning of fibre-forming polymers provided by this invention is characterized in that a similar electrical potential is applied to each filament during extrusion, thereby causing said filaments to repel each other.

More narrowly, the process of this invention comprises melting a fibre-forming polymer by heating and forcing the melted polymer under pressure through a plurality of fine holes in a spinneret plate, said spinneret plate being electrically insulated from ground and having applied thereto a substantial electrical potential.

The process is specifically restricted to melt spinning wherein the fibre-forming polymer is forced through fine holes to yield a continuous filament at each hole. Other processes, such as that used to make glass fibre wherein the melt is extruded through comparatively coarse holes into a rapid gas stream, are excluded. In the latter case the melt is blown into a mass of interwoven filaments by the force of the gas stream. It has also been found that the charge must be applied to the molten material during extrusion since physical contact with a charged body is necessary in order that the filaments may become suitably charged. Thus the most practical manner to apply the charge is to the spinneret plate itself.

The process of this invention will be more clearly understood by reference to the accompanying drawing, wherein FIG. 1 represents a diagrammatic cross-section of a melt-spinning means without the modifications necessary for the practice of the present invention, and FIG. 2 shows a similar spinning means with the process of this invention being practised thereon.

In both FIG. 1 and FIG. 2 a cylindrical heated container for molten polymeric material, usually called the spinning pack, is shown at **1**. The fluid polymer is fed to the spinning pack **1** by the pump **2** which in turn is fed with polymer added as chips to the hopper **3**, and thence forced by the screw conveyer **4** through the heater **5**. The latter provides the heat to melt the polymer. The molten polymer is forced by the pressure of pump **2** through fine holes in the spinneret plate **6**, which is held to the supporting block **7** by the bolt **8**. Additionally a filter plate is shown at **9**. The edge of the spinneret plate **6** is supported and sealed against the pressure of molten polymer by the seal ring **16**.

The spinneret plate **6** is circular and, as shown in cross section, contains two concentric rings of fine orifices of which four orifices are shown. From these orifices four extruded filaments are shown at **10**; they solidify by cooling before they reach guide **11** and are collected on the wind-up reel **12**. In FIG. 1 it can be seen that two filaments have coalesced at **13** and will cause a fault in the yarn wound up on reel **12**.

In FIG. 2 however (wherein feed means **2**, **3**, **4** and **5** are omitted), the spinneret plate **6**, together with its supporting block **7**, bolt **8** and filter **9**, are electrically insulated from the pack **1** by insulating sheath **14** and insulating ring **15**. A D.C. voltage is applied to the spinneret plate **6** by the lead **17** from the voltage source **18**, this lead **17** being insulated from pack **1** by insulating bushing **19**. The pack **1** is grounded as at **20**.

It can be seen in FIG. 2 that the application of a voltage to plate **6** has caused the filaments **10** to "dilate" or repel each other, thus reducing the chance of coalescence as at **13** in FIG. 2.

Furthermore, in the design shown in FIG. 2, it is desirable to include the horn **21**, which is itself raised to the potential of plate **6**, in order to prevent the charged filaments from being attracted to ground on the spinning pack **1** at, for example, point **22**.

It is to be appreciated that the arrangement shown is only one of a great number of suitable devices for the practice of the present invention. Even in the device of FIG. 2 numerous changes can be made without affecting the operation of the invention. For example the lead **17** need not pass through the pack **1** via the bushing **19**, but may instead be attached directly to bolt **8** or horn **21**. Similarly, slight modification to the design of the spinning pack **1** could eliminate the need for horn **21** altogether.

From the above description of suitable spinning apparatus, it can be seen that fibre-forming polymers for use in the improved melt-spinning process of the present invention must possess certain properties. They must of course be suitable for melt-spinning, i.e. they must melt without excessive degradation and be capable of solidifying into filaments. Furthermore neither the solid nor the molten polymer can be highly electrically conducting, and finally the polymer must be capable of picking up electrical charge.

It is in these last two properties that polymers differ, and such differences dictate the details of the manner of practising the present invention. For example certain molten fibre-forming polymers, in particular certain nylons, have a significant electrical conductivity. Thus in order to prevent an excessive leak of current to ground it is necessary to insulate not only the spinneret plate **6** as in FIG. 2 but also the spinning pack **1**. This is most suitably accomplished by putting the electrical insulation before the heater **5**, and raising all the apparatus downstream of the hopper **3** to a high voltage. The ground connection at **20** is in this case removed.

Other molten fibre-forming polymers, in particular polyethylenes, have a very high electrical resistance and thus the charged spinneret plate of FIG. 2 does not appear to provide an adequate time of contact for charge collection by the filaments. In this case also the spinning pack **1** should be insulated so that the whole part can be charged; it is not however necessary to insulate the pump **2** and the heater **5**. The device of FIG. 2, wherein only the spinneret plate **6** and its surroundings are charged, has been found particularly effective with fibre-forming polymers of intermediate properties, such as polyethylene terephthalate.

The voltage required on the filaments is not easy to measure, but may be determined by increasing the voltage applied to the polymer until the required dilation of the filaments is obtained. In general quite low voltages, about 1000 v. or so, are required when the filaments are falling under their own weight, but as the speed of the wind-up spool **12** is increased, the voltage necessary to observe dilation increases also. At high production speeds, dilation may never be observed, and in this case the effectiveness of the present invention is shown by the improvement in yarn quality, particularly in evenness of dye take-up. In addition the voltage which must be applied to the charged plate, or electrode, will vary sharply from polymer to polymer, and may be as low as 500 volts for polyethylene terephthalate. By "substantial electrical potential," used herein, is meant a voltage, either positive or negative but not alternating, about 500 volts, with an upper limit set by the useful dilation achieved or by safety considerations. In general the upper safe limit has been found to be about 20 kv. but with special precautions higher voltages could be used within the scope of this invention.

A further advantage of the process of this invention is observed when a spin finish is applied to the multifilamentary yarn, suitably before the yarn reaches guide **11**. By charging the nozzle of the spin finish applicator to an opposite polarity to that of the spinneret plate, the stream or mist of spin finish is electrostatically attracted to the yarn thus resulting in complete coverage and less wastage of the spin finish.

The following example illustrates the process of this invention, which is in no manner to be restricted by the details therein.

Example

In a test of the process of this invention, a special die was made of metal, and had four holes 0.009 inch in diameter, 0.125 inch long and separated from each other by 0.20 inch. The voltage was applied directly to the die. The spinning pack was electrically heated, and the fibre-forming polymers were put therein as chips and allowed to melt. The polymers were then extruded from the die in four filaments by nitrogen pressure applied to the pack above the molten polymers. The results achieved on various polymers are given in Table I, the visible dilation being caused by mutual repulsion of the filaments.

Table I

Polymer	Temperature, ° C.	Nitrogen pressure, p.s.i.	Result
Polyethylene (high pressure process). Melt Index 0.5., Density .92.	190	600–800	No visible dilation up up to 4 kv., but charge pick-up proved.
Polyethylene +43% Carbon Black.	190	600–800	Large dilation at 2 kv.
Polyethylene Terephthalate.	260	200–400	Clear dilation at 800 v.; Large dilation at 1 kv.
Nylon	240	200–400	No visible dilation at 3 kv., but charge pick up proved.

In the last experiment (with nylon) the molten sample had appreciable electrical conductivity and the whole apparatus was insulated from ground and then raised to the electrical potential.

In the cases where clear dilation was not observed, the following tests showed that charge pick up had occurred. A grounded object was moved towards the falling filaments, and an instant attraction towards the object was observed. Thus under true spinning conditions when the filaments were pulled into close propinquity, sufficient repulsion was present to avoid coalescence.

What I claim is:

1. In a process for the continuous multifilament melt-spinning of a fibre-forming polymer wherein said polymer is melted by heating and forced under pressure through a plurality of fine holes in a spinneret plate, the improvement which comprises insulating said spinneret plate from ground and applying to said plate a substantial electrical potential.

2. In a process for the continuous multifilament melt-spinning of a fibre-forming polymer wherein said polymer is melted by heating and forced under pressure through a plurality of fine holes in a spinneret plate to yield a plurality of filaments, said filaments being solidified by cooling and wound up to give a multifilamentary yarn, the improvement which comprises insulating said spinneret plate from ground and applying to said plate a substantial electrical potential, whereby said filaments collect a like charge and repel each other.

3. A process according to claim 1 wherein the polymer is selected from the group consisting of nylons, polyformaldehyde, polyvinylidene chloride, polyethylene terephthalate, polyethylene and polypropylene.

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