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DRY SPINNING PROCESS AND APPARATUS

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FIG. 1

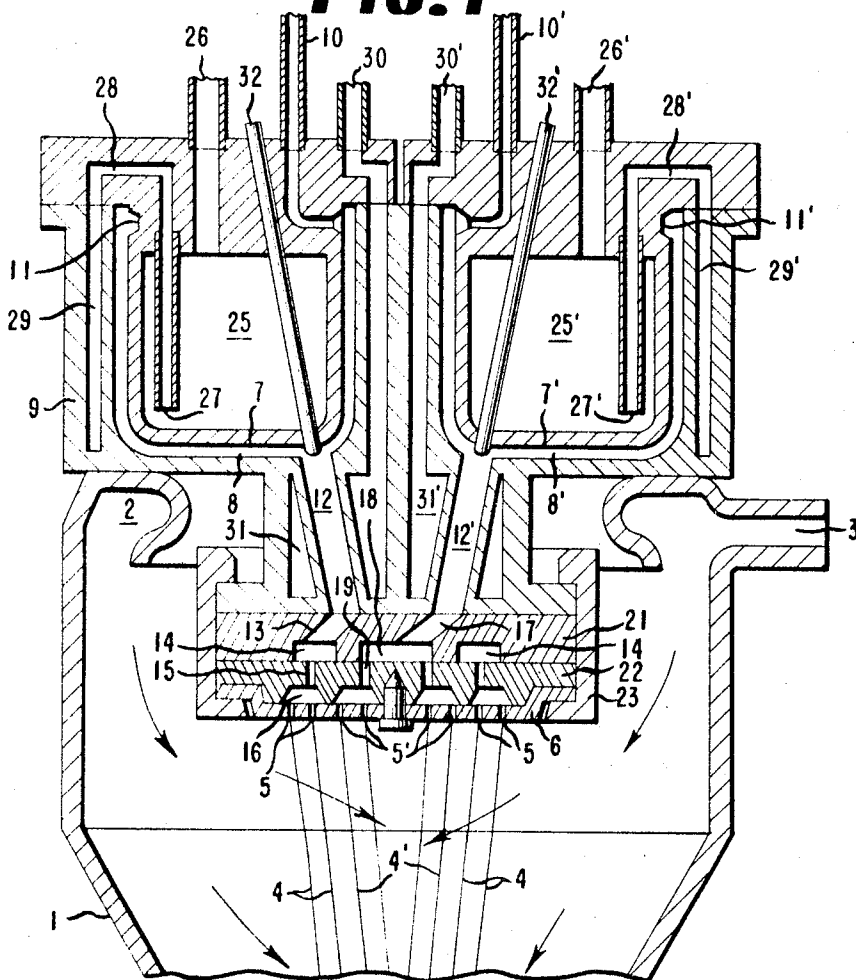
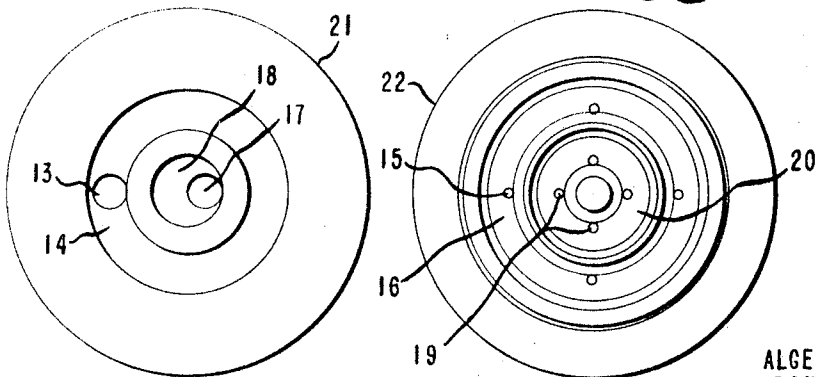


FIG. 2

FIG. 3



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DRY SPINNING PROCESS AND APPARATUS
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ABSTRACT OF THE DISCLOSURE

An improved process and apparatus for evaporative spinning of fibers wherein streams of polymer solution are extruded and impinged upon by hot gas to remove the solvent. The improvement provides extruding the solution streams at different temperatures to make the rate of solvent evaporation more uniform.

This invention relates to the preparation of fibers from synthetic linear polymers, and more particularly to a novel evaporative spinning ("dry spinning") process and novel apparatus for carrying out the process.

Objects of the invention

An object of this invention is to provide an evaporative spinning process by which highly uniform fibers can be made at a very high volume of fiber output. Another object is to provide apparatus in which highly uniform fibers can be spun with high productivity.

The process of the invention

In accordance with this invention an improvement is provided in an evaporative spinning process. The process generally comprises extruding through the orifices of a spinneret a multiplicity of streams of a solution of fiber-forming polymer dissolved in evaporable solvent for the polymer and impinging a gas hotter than said solution against the extruded streams to evaporate the solvent and form filaments of the polymer. The impingement is characterized by at least a portion of the gas flowing transverse to the streams. The improvement comprises extruding the streams of solution at different temperatures, the streams being arranged in such a way that the cooler streams are those upon which the hot gas first impinges prior to the impingement of the gas upon the hotter streams.

The improved process of this invention has the effect of making more uniform the rate of evaporation of the solvent from the extruded streams of solution. The rate of evaporation from the streams upon which the hot gas last impinges is therefore comparable to the rate of evaporation from the streams of solution upon which the gas first impinges. The amount of solvent remaining in the polymeric filaments at any given distance below the spinneret is thus more uniform throughout the filament bundle. As a part of this invention, it has been realized that in prior art processes the temperature of the gas falls very sharply as it passes from the periphery of the spinneret to the interior, and that this also sets up a spinneret temperature gradient with the high temperature at the outside, so that the solvent evaporates much more rapidly from the outside streams than from the inside streams.

By using this invention, spinning output can be greatly increased as compared with conventional dry spinning procedures at given standards of filament uniformity for the product. Alternately, the invention can be used to improve the quality of the product without sacrificing output. The precise temperature differentials which will give the best result will obviously vary somewhat with

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variations in the polymer being spun and the solvent used to dissolve it, the numbers of filaments spun from a given spinneret, and the properties desired in the filaments, among other factors. Selection of the optimum conditions will be apparent to those skilled in the art and is well within the scope of this invention.

The apparatus of the invention

This invention also includes a novel apparatus for dry spinning. The apparatus generally comprises means for heating spinning solution, means for feeding the heated solution to a spinneret containing a multiplicity of orifices and extruding streams of the solution through said orifices, and a gas source means for impinging hot gas upon the streams of solution as they are extruded from the spinneret orifices. In the improved apparatus, means are provided for heating separate portions of the solution at different temperatures, feeding one portion of the solution to the orifices positioned nearest the source of hot gas, and feeding at least one other portion of the solution to orifices positioned farther from the source of hot gas than the first group of orifices.

Preferred embodiments of the invention

The multiplicity of solution streams may be extruded into a variety of arrays. A preferred array is cylindrical with the individual streams being concentrically arranged, such as by extrusion through a circular spinneret with orifices thereof arranged in concentric circles. In such an array, the cooler solution is delivered to the orifices on circles at or near the periphery of the spinneret while the hotter solution is delivered to orifices on circles nearest the center of the spinneret.

The solution streams are preferably extruded at two different temperatures for simplicity of construction. In such cases, the temperature difference is preferably greater than about 5° C. and preferably less than about 75° C., although higher or lower temperature differences are also suitable for most purposes. A temperature difference range of from about 10° to 50° C. is most preferred. Although two are preferred, three or more different temperature solution streams may be employed. An apparatus heating three or more portions of solutions to different temperatures exemplifies a suitable apparatus for this purpose. The coolest of the three or more solutions extruded is first impinged by the hot gas and prior to impingement on successively hotter streams.

The solutions may be heated in various ways. The apparatus, shown in the drawing, provides solutions which are at different temperature prior to extrusion by heating them in separate chambers. In a preferred embodiment of the apparatus, the separate portions of solution are heated in separate chambers by the condensation of a vapor in equilibrium with its condensate; and means for regulating the vapor at different pressures in the separate chambers are included. In a particularly preferred embodiment, the chambers in which the solutions are heated are annular chambers heated both internally and externally by the condensation of the vapor. In more detail, such apparatus includes means for supplying additional quantities of the vapor as it becomes required and removing the condensate as excess quantities of it accumulate, means for providing a continuous supply of the spinning solution to the separate heating chambers; and passages for transmitting the heated solutions to the spinneret orifices in the desired pattern. In practice, the apparatus is easily regulated by adjustment of the pressure of the condensable vapor to provide optimum spinning conditions. As noted above, balancing the rate of evaporation of solvent from the extruded streams of solution so that the rate is substantially constant from the periphery of the spinneret to the interior has been determined to be an im-

portant factor for uniform dry spinning in accordance with the invention.

However, the solutions may be of substantially uniform temperature prior to being extruded and acquire differing temperatures during extrusion. A non-uniform degree of heat transfer between the solution and the spinneret would provide this. (For example, a heat source such as an electrical core, placed at the center of the spinneret, would heat the interior solution streams to a greater extent than the peripheral solution streams.)

In the above exemplary heating techniques, the temperature differential was created by the addition of heat to the solution or solution streams. As is well understood a differential removal of heat may also be used to achieve the same result.

The invention is well suited to the dry spinning of acrylic, spandex, vinyon, and cellulosic fibers as well as other polymers which are suitable for dry spinning. The inert solvent employed must of course be a solvent for the particular polymer and be volatile. The particular choice of solvents is based upon considerations such as solvent power, boiling point, heat of evaporation, stability, toxicity, ease of recovery, etc., well understood by those skilled in the art. Similarly the hot gas employed to evaporate the solvent is chosen based upon the particular polymer and solvent used; air or an inert gas are commonly employed. It is preferred that the gas impinged upon the extruded solution streams be hotter than any of the streams. Generally, the gas should be at least about 100° C. hotter than the coolest of these streams. In a preferred embodiment of this invention wherein acrylic fibers are prepared, the solvent preferably employed is dimethylformamide and the gas is Kemp gas, essentially a mixture of about 87% nitrogen and 13% carbon dioxide. The invention is also suitable for spinning two or more fiber-forming polymers simultaneously such as different acrylic polymers or an acrylic and a spandex polymer. The solvent employed must be a suitable solvent for the particular polymer which may require the use of a different solvent for each polymer.

Drawings

The invention will be further described with reference to the following drawings in which;

FIGURE 1 is a cross section of an evaporative spinning apparatus constructed in accordance with the present invention, including means for heating the spinning solution;

FIGURE 2 is a view of the lower side of the upper distribution plate in the spinneret head; and

FIGURE 3 is lower view of the lower distribution plate in the spinneret head.

Referring now to the figures, a dry, heated gas is introduced into spinning cell 1 from annular gas source 2 supplied by gas inlet 3. Outer streams 4 and inner streams 4' of a solution of a fiber-forming polymer dissolved in an evaporable solvent are extruded through outer orifices 5 and inner orifices 5', respectively, of spinneret plate 6. The spinneret plate is circular and the gas flows from the periphery of the plate towards its center, first contacting outer streams 4 of the extruded solution near the periphery of the spinneret plate and then inner streams 4' of extruded solution near the center of the plate, as shown by the arrows.

Solvent is evaporated from the streams and the polymeric filaments so formed are forwarded from or collected at the bottom of the cell in the conventional manner, while gas is removed at or near the bottom of the cell.

In the upper part of the apparatus as shown in the figures, inner shells 7 and 7' are mounted in the cavities 8 and 8' of outer shell 9. Inner shell 7 is slightly smaller than the cavity 8 in the outer shell and the space between the inner shell and the wall of the cavity 8 constitutes a heating chamber for one portion of the spinning solution. Solution inlet 10 at the top of the inner shell com-

municates with annular groove 11 around the outside of the inner shell, at the top of the heating chamber. Channel 12 leads from the bottom of the heating chamber to upper passage 13 and annular supply chamber 14 in the upper distribution plate 21, communicating in turn with outer passages 15 and outer annular recess 16 in the lower distribution plate 22 just above outer orifices 5. Ring nut 23 and cap screw 24 are provided to hold the assembly together.

Similarly, the space between the wall of cavity 8' and inner shell 7' constitutes a heating chamber for the other portion of the spinning solution fed by solution inlet 10' through annular groove 11'. Channel 12' leads from the bottom of the heating chamber to central passage 17 and central supply chamber 18 in the upper distribution plate 21, which communicates in turn with inner passages 19 and inner annular recess 20 in the lower distribution plate 22 just above inner orifices 5'.

The solution fed through solution inlet 10' is heated to a higher temperature than the solution fed through solution inlet 10. The solution heated to the higher temperature is passed from channel 12' to inner annular recess 20 as described and extruded through orifices 5' arranged on concentric circles nearest the center of the spinneret. The solution fed through solution inlet 10, the cooler of the two solutions, is passed from channel 12 to outer annular recess 17 and extruded through orifices 5 arranged on concentric circles at the periphery of the spinneret plate.

Inner shells 7 and 7' are hollow. Steam or other condensable vapor is introduced into wells 25 and 25' through vapor inlet 26 and 26', flows through pipes 27 and 27' and channels 28 and 28' to annular wells 29 and 29' and is exhausted through outlet 30 and 30'. Condensate collects in wells 25 and 25' to the level of the bottom of pipes 27 and 27' and in lower wells 31 and 31' communicating with annular wells 29 and 29', any excess condensate being exhausted by the steam through outlet 30 and 30'. Thermocouple wells 32 and 32' permit accurate determination of the temperature to which each portion of the solution is heated. The pressure of the steam supplied to each of the vapor inlets is regulated by means not shown to regulate the temperature of the solutions which are to be spun, the temperature in well 25' and the remainder of its circulatory system being higher than the temperature in well 25 and its circulatory system.

Example

The invention will be further illustrated by the following example; parts and percentages are by weight unless otherwise indicated:

In a practical demonstration of the process of this invention, a 32 wt. percent solution of acrylonitrile in dimethylformamide was divided into two portions which were then heated separately in apparatus of the general type shown in the figures to 130° C. and 155° C. respectively. The 130° C. solution was extruded through a pattern of 1000 orifices arranged in an annular pattern at the periphery of the spinneret, while the 155° C. solution was extruded through 1000 orifices arranged in an annular pattern surrounding the center of the spinneret. Kemp gas at 350° C. was introduced continuously into the spinning cell and removed at the bottom of the cell. With the filaments spun in streams at two different temperatures in this manner, a highly uniform product was obtained at the rate of 70 lbs./hr. (32 kg./hr.). Operating under the same conditions, with the exception that all the streams of polymer solution were spun at the same temperature of 140° C., the highest rate of productivity which could be achieved at the same level of uniformity was 60 lbs./hr. (27 kg./hr.).

Modifications

Various modifications of the invention will be apparent. Various systems of distribution channels may be de-

vised for optimum flow of the heated spinning solutions to obtain uniform rates of flow, optimum pressure drops, and the like. The condensate wells may be extended more closely to the spinneret to maintain the polymer solutions at precisely regulated temperatures as closely as possible to the actual moment of extrusion of the streams from the orifices. Insulation may be employed around and within the spinneret and distribution plates. For instance, the ring nut surrounding the spinneret may be highly polished, or covered with aluminum foil or other insulation to protect the spinneret from over-heating by the hot gas passing by it.

Since these and many other variations may be made without departing from the spirit and scope of this invention, it is to be understood that it is limited only in accordance with the claims which follow.

What is claimed is:

1. In an evaporative spinning process comprising: extruding solution of fiber-forming polymer dissolved in a solvent through the orifices of a spinneret to form a multiplicity of solution streams, and impinging a gas upon the extruded polymer solution streams with at least a portion of the impinged gas flowing transverse to said solution streams, said gas being at a temperature higher than the temperature of the said solution streams to evaporate said solvent and form filaments of said polymer; the improvement which comprises: extruding the said solution streams at different temperatures and impinging said gas upon the lower temperature solution streams, prior to the impingement of said gas upon the higher temperature solution streams.

2. Evaporative spinning process according to claim 1 wherein the said extruding concentrically arranges the said multiplicity of solution streams in a cylindrical array, the said lower temperature solution streams being in the peripheral portions of said cylindrical array and the said impinging gas contacts the peripheral portions of said cylindrical array prior to contacting the interior portions thereof.

3. Evaporative spinning process according to claim 1 wherein said solution streams are extruded at two different temperatures.

4. Evaporative spinning process according to claim 3 wherein the said temperature difference is greater than about 5° C.

5. Evaporative spinning process according to claim 3 wherein the said temperature difference is between about 5° C. and 75° C.

6. Evaporative spinning process according to claim 3 wherein the said temperature difference is between about 10° C. and 50° C.

7. Evaporative spinning process according to claim 1 wherein said solution streams are extruded at at least three different temperatures.

8. Evaporative spinning process according to claim 1 wherein at least two of said solution streams are heated to different temperatures prior to being extruded to form said solution streams.

9. Evaporative spinning process according to claim 1 wherein said solution is of substantially uniform temperature prior to being extruded, said solution streams being of different temperatures due to a non-uniform heat transfer between said solution and said spinneret during extrusion.

10. Evaporative spinning process according to claim 1 wherein said fiber-forming polymer is an acrylic polymer.

11. Evaporative spinning process according to claim 1 wherein said fiber-forming polymer is a spandex polymer.

12. Evaporative spinning process according to claim 1

wherein the said impinging gas is at a higher temperature than the temperature of any of the said solution streams.

13. Evaporative spinning process according to claim 1 wherein the temperature of the said impinging gas is at least about 100° C. higher than the temperature of any of the said solution streams.

14. Evaporative spinning process according to claim 1 wherein at least two fiber-forming polymers are each dissolved in a suitable solvent.

15. In an evaporative spinning apparatus comprising means for heating polymer solution, means for feeding the heated solution to a spinneret containing a multiplicity of orifices and extruding streams of the solution through said orifices, and gas source means for impinging hot gas upon the streams of solution as they are extruded from the said spinneret orifices, the improvement which comprises:

heating means for heating separate portions of solution to different temperatures, and

feeding means for feeding one lower temperature portion of solution to said orifices positioned nearest to the flow of hot gas from the said gas source means and for feeding at least one other higher temperature portion of the solution to other of said orifice positioned farther from said flow of hot gas.

16. Evaporative spinning apparatus according to claim 15 wherein said spinneret is circular and said orifices are concentrically arranged, and said gas source means impinges hot gas upon the solution streams being extruded through the orifices of said circular spinneret, said gas flowing inwardly from an area beneath the periphery of the said circular spinneret to the center thereof, said feeding means feeding said one lower temperature portion of solution to the said peripheral orifices and feeding said other portions to more centrally positioned orifices.

17. Evaporative spinning apparatus according to claim 16 wherein said heating means is a vapor condensation heating means comprising means for supplying vapor and for removing condensate.

18. Evaporative spinning apparatus according to claim 16 further comprising separate chamber containing polymer solution wherein said heating means supplies heat to said chamber by condensation of vapor within said chambers.

19. Evaporative spinning apparatus according to claim 16 further comprising separate annular chambers each having an interior well and an outer annular groove surrounding the walls of said well, said annular groove containing polymer solution, and said heating means supplies heat by vapor condensation within said well.

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