METHOD AND APPARATUS FOR PRODUCING ARTIFICIAL STRUCTURES

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This invention relates to the extrusion of molten organic filament- and film-forming compositions in the form of filaments, yarns, ribbons, sheets, tubing, and the like, and more particularly to the extrusion of molten filament- and film-forming synthetic linear polymers hereinafter referred to as superpolymers.

The synthetic linear polymers with which this invention is particularly concerned may, for example, be prepared by the condensation reactions described in U. S. Patents Nos. 2,071,250, 2,071,252, and 2,071,253. The most valuable of these superpolymers for filaments, yarns and films are the superpolyamides. These superpolyamides are of two types, one obtained from monoaminoanilino-carboxylic acids or their amide-forming derivatives, including caprolactam, and those obtainable from the reaction of suitable diamines and dibasic carboxylic acids. This latter type of polyamide is more fully described in U. S. Patent No. 2,130,948. These superpolymers are capable of being extruded in the molten state directly into the form of filaments, yarns, bristles, ribbons and the like. This process is hereinafter referred to as melt spinning.

These polymers are best prepared in a large autoclave without a solvent and under conditions so that at the end of the polymer-making cycle there is produced a large volume of the material in the form of a very viscous liquid, 10°—20° above its melting point. While it is possible to produce filaments, yarns, ribbons and like structures by melt spinning directly from the molten mass in the autoclave, there are several reasons why this has never been considered practical. First, because of the high viscosity of the molten composition and its nearness to its solidification temperature, it cannot be satisfactorily transported in its molten state to spinning machines which are located at a distance from the autoclave. Secondly, if a spinning mechanism is attached directly to the autoclave satisfactory filaments, yarns, ribbons and the like cannot be spun continuously for an extended period of time. Because of the large quantity of molten polymer in the autoclave and the relatively low rate at which it is consumed in the spinning machine, the accumulation of decomposition products and the bubbles they produce may become very serious.

These polymers tend to decompose slowly at temperatures above their melting points. One result of this decomposition is the evolution of small quantities of gaseous products with the formation of bubbles, which tend to cause denier differences in the case of filaments and yarns, and voids in the case of bristles and films. While these variations in filament denier are small, these yarns are used for the very finest textiles and any variation is serious. Likewise, even microscopic voids in bristles or films weaken them and detract greatly from their value. While the quantity of gaseous decomposition products in the melt can be materially reduced by applying a vacuum, this cannot be done without interrupting the flow of molten material to the extrusion device; hence the accumulation of gaseous decomposition products cannot be conveniently removed without interrupting spinning.

To avoid these difficulties it has been the practice heretofore to quickly freeze the molten material by rapid discharge from the autoclave into a cooling medium, or by casting the same onto a cold surface in the form of rough ribbons or rods of large cross-sectional area. These massive ribbons or rods are then broken up and fed to a melting device and melted adjacent to the extrusion spinning device at a rate substantially equal to that of the rate of extrusion, thereby keeping to a constant minimum period the exposure of the composition to temperatures at which decomposition occurs.

This procedure operates very successfully but it is inefficient because of the time and power consumed in freezing, chopping, and remelt- the filament-forming composition.

It is, therefore, an object of this invention to provide an improved method and apparatus for the melt spinning of synthetic polymer filaments, yarns, ribbons and the like from film- and filament-forming compositions which are subject to bubble formation.

It is a further object of this invention to provide an improved method and apparatus for the melt spinning of such polymers directly from the reaction vessel in which the polymer is synthesized.

Other objects of this invention will hereinafter become apparent.

The objects of this invention are accomplished, in general, by transferring portions of the molten fiber-forming polymer from the vessel in which it is synthesized through a lock or valve into an auxiliary chamber, where it may be subjected to pressure and/or vacuum and from whence it is led by suitable valves, conduits, etc., to an extrusion device such as a spinneret and spun in the form of filaments, yarns, ribbons and the like.

The preferred embodiments of this invention
are shown diagrammatically in the accompanying drawing in which:

Figure 1 is a diagrammatic cross-sectional view of one modification of this invention.

Figure 2 is a diagrammatic cross-sectional view of another modification of the invention.

In Figure 1 it is shown a closed polymerizing autoclave 8 with a conduit 10, provided with a three-way valve 12 for removing or introducing gases. The autoclave is shown partially filled with the molten composition 14. The auxiliary feeding chamber 20 has a conduit 21, provided with a three-way valve 22 adapted to admit or remove gases as desired. The autoclave 8 and auxiliary chamber 20 may also be joined by the conduit 24 to permit transfer of the gas which is displaced during a transfer of the composition 14 from 8 to 20. The conduit 24 is provided with a valve 26. A conduit 28, provided with a valve 30, connects chamber 20 to the pump 32. The pump 32 is adapted to meter the molten material from chamber 20 to the spinneret assembly 34. The molten composition is forced through the spinneret assembly 34, and as a consequence is spun in the form of filaments or the like which are drawn off and collected in an orderly manner.

To describe more particularly one method of operation of the invention, after the polymerizing reaction has taken place in the suitably heated autoclave 8, a small portion of the molten material 14 is admitted to the smaller chamber 20 through the passage 16 by opening the valve 18. The gas displaced from the chamber 20 through the valve 18 is drawn through the conduit 21 and valve 22 as shown in the case of the removal of the gas through conduit 21 and valve 22 the transfer may be facilitated by applying pressure in the autoclave 8 through the conduit 10 and valve 12 and/or by creating a reduced pressure in chamber 20 through the conduit 24 and valve 26. In the event of the removal of the gas through conduit 21 and valve 22 the transfer may be facilitated by applying pressure in the autoclave 8 through the conduit 10 and valve 12 and/or by creating a reduced pressure in chamber 20 through the conduit 24 and valve 26.

When a sufficient quantity of the material 14 has been admitted to chamber 20, the valve 18 is closed and vacuum is applied to the chamber 20, through the conduit 24 and valve 22. The vacuum in chamber 20 removes gaseous decomposition products from the molten material 14. The valve 22 is then reversed and gas admitted to the system. This increase in pressure tends to dissolve any remaining bubbles and to keep in solution any additional decomposition products formed. Since the solution of bubbles can be increased and further bubble formation inhibited by applying super-atmospheric pressures through the valve 22, this is usually preferred.

The valve 30 is then opened, the molten material led through the passage 28 to the pump 32 which meters it to the spinneret assembly 34 from which it is forced in the form of a plurality of continuous filaments 36 which are collected in an orderly manner in the form of a yarn. As the supply of the material 14 in the chamber 20 is being consumed, vacuum is applied to the autoclave 8 through the valve 12 and conduit 10 to remove bubbles, after which the valve 12 is reversed and gas is admitted to autoclave 8 until a pressure equal to or slightly in excess of that in chamber 20 is reached. When the supply of the material 14 in the chamber 20 is nearly exhausted, the valves 18 and 26 are opened and the supply of material 14 in the chamber 20 is replenished without interrupting the spinning.

The valves 18 and 26 are then closed and the pressure in the autoclave 8 released through the valve 12 and the steps of applying a vacuum and pressure to autoclave 8 are repeated. When the supply of material in the chamber 20 again approaches exhaustion, the transfer of an additional quantity of polymer from 8 to 20 is repeated.

Since it may sometimes be desirable to avoid the application of pressure and/or vacuum directly to the autoclave, it is generally preferred to have two auxiliary feeding chambers connected between the pump and autoclave so that one chamber may be filled with the molten composition from the autoclave and subjected to pressure and/or vacuum while the other is feeding the composition to the pump and spinneret assembly.

Such an apparatus is shown in Figure 2 of the drawing. In this apparatus the conduit 16 is split into conduits 16a and 16b, each provided with a valve 16a and 16b. Conduit 16a is connected to an auxiliary feeding chamber 20a having an outlet conduit 26a and a valve 36a. Likewise, conduit 16b is connected to an auxiliary feeding chamber 20b having an outlet conduit 26b and a valve 36b. Conduits 26a and 26b lead to a single conduit 31 which is connected to pump 32. Each of the auxiliary feeding chambers 20a and 20b may be connected to the autoclave 8 by means of a return pipe 24 and valve 26 as shown in Figure 1. The chambers 20a and 20b are provided with conduits 28a and 28b and valves 22a and 22b respectively. These conduits and valves serve as means through which a pressure or a vacuum may be applied to these chambers.

The two auxiliary feeding chambers 20a and 20b, together with their respective conduits and valves, offer parallel lines of flow between the autoclave 8 and pump 32. The molten composition may be fed to pump 32 from one feeding chamber, for example chamber 20a, during the same period that the other feeding chamber 20b, is being charged and subjected to pressure and/or vacuum from the autoclave 8. The procedure may then be reversed to feed pump 32 from chamber 20b during the same period as chamber 20a is being charged from the autoclave. The actual steps of charging, and subjecting to pressure and/or vacuum, the feeding chambers and feeding of the composition to the pump will be the same as those above described with reference to Figure 1.

Depending, in general, on the time required for the various steps, the rate of spinning, etc., three feeding chambers may be used to serve two spinning positions.

While an autoclave of substantially any type or size may be used for the synthesizing of the molten organic filament-forming composition, from a standpoint of economy in commercial operations the autoclave should have a capacity of at least 100 pounds and preferably at least 250 pounds, and preferably be made of mild steel and uniformly heated the reactants to the desired temperature, and maintain the molten composition at a substantially constant temperature.

The size of the auxiliary chambers and the quantity of material admitted will depend on several factors. It will depend, on the one hand,
synthetic polymers such as ethylene polymers, vinyl polymers, polystyrene and polyacrylic acid derivatives may also be spun with advantage in accordance with the present invention. The filament-forming material used in accordance with the present invention may contain modifying agents; e.g., duster-modifying agents, plasticizers, pigments and dyes, anti-oxidants, resins, etc. The modifying agents may be added either to the composition in the autoclave or in the auxiliary feeding chamber. The present invention can be used to advantage in extruding film- or filament-forming compositions in which the bubble formation is caused by the presence of a modifying agent.

By the practice of this invention, it is possible to continuously spin molten organic filament-forming compositions directly on a commercial scale from the melt produced in their synthesis without solidifying it and remelting it. It is thus possible to produce formed structures much more easily and economically.

While in the figures this invention has been illustrated by the spinning of yarn from a single position, this invention is not so limited. Similarly, as indicated previously, this invention may be used in the production of film, ribbons, bristles and the like, or may be used for the coating of wire, fabrics, etc.

Since it is obvious that many changes and modifications can be made in the above-described details without departing from the nature and spirit of the invention, it is to be understood that the invention is not to be limited thereto except as set forth in the following claims.

I claim:

1. In the continuous melt spinning of filaments, yarns, ribbons and the like from molten synthetic superpolymers which are subject to bubble formation above their melting points, the steps comprising withdrawing, in a closed system from a given quantity, successive fractional portions of molten superpolymer and extruding said successive portions in a continuous extrusion operation through a structure-forming device, continuously maintaining said withdrawn portions, during the extrusion thereof, at a pressure sufficiently high to eliminate bubbles therefrom, and during said extrusion of one of said successive portions subjecting at least a portion of the remainder of said given quantity of said superpolymer to a pressure substantially below said extrusion pressure, and then to a pressure at least equal to said extrusion pressure, and then passing, under pressure, another of said successive portions from said remainder of said given quantity of superpolymer, for said continuous extrusion through said structure-forming device.

2. In the continuous melt spinning of filaments, yarns, ribbons and the like from molten synthetic superpolymers which are subject to bubble formation above their melting points, the steps comprising withdrawing, in a closed system from a given quantity, successive fractional portions of molten superpolymer and extruding said successive portions in a continuous extrusion operation through a structure-forming device, continuously maintaining said withdrawn portions, during the extrusion thereof, at a superatmospheric pressure sufficiently high to eliminate bubbles therefrom, and during said extrusion of one of said successive portions subjecting at least a portion of the remainder of said given quantity of said superpolymer to a pressure substantially below said extrusion pressure, and then to a pressure at least equal to said extrusion pressure, and then passing, under pressure, another of said successive portions from said remainder of said given quantity of superpolymer, for said continuous extrusion through said structure-forming device.

3. In the continuous melt spinning of filaments, yarns, ribbons and the like from molten organic filament-forming compositions directly on a commercial scale from the melt produced in their synthesis without solidifying it and remelting it. It is thus possible to produce formed structures much more easily and economically.

While in the figures this invention has been illustrated by the spinning of yarn from a single position, this invention is not so limited. Similarly, as indicated previously, this invention may be used in the production of film, ribbons, bristles and the like, or may be used for the coating of wire, fabrics, etc.

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2. In the continuous melt spinning of filaments, yarns, ribbons and the like from molten synthetic superpolymers which are subject to bubble formation above their melting points, the steps comprising withdrawing, in a closed system from a given quantity, successive fractional portions of molten superpolymer and extruding said successive portions in a continuous extrusion operation through a structure-forming device, continuously maintaining said withdrawn portions, during the extrusion thereof, at a superatmospheric pressure sufficiently high to eliminate bubbles therefrom, and during said extrusion of one of said successive portions subjecting at least a portion of the remainder of said given quantity of said superpolymer to a pressure substantially below said extrusion pressure, and then to a pressure at least equal to said extrusion pressure, and then passing, under pressure, another of said successive portions from said remainder of said given quantity of superpolymer, for said continuous extrusion through said structure-forming device.

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While in the figures this invention has been illustrated by the spinning of yarn from a single position, this invention is not so limited. Similarly, as indicated previously, this invention may be used in the production of film, ribbons, bristles and the like, or may be used for the coating of wire, fabrics, etc.

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2. In the continuous melt spinning of filaments, yarns, ribbons and the like from molten synthetic superpolymers which are subject to bubble formation above their melting points, the steps comprising withdrawing, in a closed system from a given quantity, successive fractional portions of molten superpolymer and extruding said successive portions in a continuous extrusion operation through a structure-forming device, continuously maintaining said withdrawn portions, during the extrusion thereof, at a superatmospheric pressure sufficiently high to eliminate bubbles therefrom, and during said extrusion of one of said successive portions subjecting at least a portion of the remainder of said given quantity of said superpolymer to a pressure substantially below said extrusion pressure, and then to a pressure at least equal to said extrusion pressure, and then passing, under pressure, another of said successive portions from said remainder of said given quantity of superpolymer, for said continuous extrusion through said structure-forming device.

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3. In the continuous melt spinning of filaments, yarns, ribbons and the like from molten synthetic superpolymers which are subject to bubble formation above their melting points, the steps comprising withdrawing, in a closed system from a given quantity, successive fractional portions of molten superpolymer, not to exceed one-fifth of said given quantity, and extruding said successive portions in a continuous extrusion operation through a structure-forming device, continuously maintaining said withdrawn portions, during the extrusion thereof, at a superatmospheric pressure sufficiently high to eliminate bubbles therefrom, and during said extrusion of one of said successive portions subjecting at least a portion of the remainder of said given quantity of superpolymer to a pressure substantially below said extrusion pressure, and then to a pressure at least equal to said extrusion pressure, and then passing, under pressure, another of said successive portions from said remainder of said given quantity of superpolymer, for said continuous extrusion through said structure-forming device.

4. In the continuous melt spinning of filaments, yarns, ribbons and the like from molten synthetic superpolymers which are subject to bubble formation above their melting points, the steps comprising withdrawing, in a closed system from a given quantity, successive fractional portions of molten superpolymer and extruding said successive portions in a continuous extrusion operation through a structure-forming device, continuously maintaining said withdrawn portions, during the extrusion thereof, at a superatmospheric pressure sufficiently high to eliminate bubbles therefrom, and during said extrusion of one of said successive portions subjecting the remainder of said given quantity of superpolymer to a pressure substantially below said extrusion pressure, and then to a pressure at least equal to said extrusion pressure, and then passing, under pressure, another of said successive portions from said remainder of said given quantity of superpolymer, for said continuous extrusion through said structure-forming device.

5. In the continuous melt spinning of filaments, yarns, ribbons and the like from molten synthetic superpolymers which are subject to bubble formation above their melting points, the steps comprising withdrawing, in a closed system from a given quantity, successive fractional portions of molten superpolymer and extruding said successive portions in a continuous extrusion operation through a structure-forming device, continuously maintaining said withdrawn portions, during the extrusion thereof, at a pressure sufficiently high to eliminate bubbles therefrom, and during said extrusion of one of said successive portions subjecting another of said successive portions of said given quantity of superpolymer to a pressure substantially below said extrusion pressure, and then to a pressure at least equal to said extrusion pressure, and then passing, under pressure, said other of said successive portions of said given quantity of superpolymer, for said continuous extrusion through said structure-forming device.

6. In the continuous melt spinning of filaments, yarns, ribbons and the like from molten synthetic superpolymers which are subject to bubble formation above their melting points, the steps comprising withdrawing, in a closed system from a given quantity, successive fractional portions of molten superpolymer and extruding said successive portions in a continuous extrusion operation through a structure-forming device, continuously maintaining said withdrawn portions, during the extrusion thereof, at a pressure sufficiently high to eliminate bubbles therefrom, and during said extrusion of one of said successive portions subjecting another of said successive portions of said given quantity of superpolymer to a vacuum substantially below said extrusion pressure, and then to a pressure at least equal to said extrusion pressure, and then passing, under pressure, said other of said successive portions of said given quantity of superpolymer, for said continuous extrusion through said structure-forming device.

7. In a melt spinning apparatus, a reaction vessel for synthesizing a linear superpolymer at a temperature above the melting point thereof, a closed auxiliary feeding chamber connected to said reaction vessel, whereby a portion of said superpolymer from said vessel may be passed to said chamber, means for passing gas from the chamber to said vessel, means for closing the connection between said vessel and chamber, means for evacuating said vessel, means for passing a gas into said chamber, means for passing said polymer from said chamber into a pump, a spinneret assembly, and means for passing said polymer from said pump to said spinneret assembly.

8. In a melt spinning apparatus, a closed system comprising a reaction vessel for synthesizing a linear superpolymer at a temperature above the melting point thereof, an auxiliary feeding chamber, conduit means connecting said chamber to said vessel, means for closing said conduit means, conduit means for passing a gas from said chamber to said vessel, means for evacuating said vessel, means for evacuating said chamber, means for passing a gas into said vessel, means for passing a gas into said chamber, a pump, conduit means connecting said pump to said chamber, a spinneret assembly, and conduit means connecting said spinneret assembly to said pump.

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