MELT SPINNING APPARATUS


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4 Claims. (Cl. 18—8)

This invention relates to the melt spinning of artificial yarns and filaments from synthetic polymeric materials. The production of yarns, filaments, ribbons and the like from molten organic filament-forming compositions is commonly carried out by a process which comprises allowing solid particles of an organic filament-forming composition to fall from a hopper onto a grid which is heated, the composition melts on the grid and falls through the interstices to form a pool of the molten composition from which pool the molten composition is drawn off to be melt-spin.

This prior process suffers from the disadvantage that the rate of extrusion cannot exceed the rate at which the viscous melt can pass through the grid. The total throughput can only be increased by enlarging the grid, but this tends to make the apparatus unwieldy both in size and operation. A further disadvantage of the prior process is that the formation and maintenance of a pool of molten material tends to bring about the degradation of some of the synthetic polymeric materials with which this invention is concerned.

An object of the present invention is to provide a continuous process for the production of yarns and filaments from molten organic compositions in which the rate of spinning is higher than the rate obtainable by methods of the prior art.

A further object of the invention is the provision of a small, compact and easily maintained and worked apparatus which provides a high rate of melt of the filament-forming material.

According to the present invention there is provided an apparatus for the production of yarns and filaments from organic filament-forming compositions which comprises a device for supplying and holding under pressure solid particles of filament-forming material against a plate containing a multiplicity of apertures and maintained at a constant temperature sufficient to render the filament-forming material fluid, so that the fluid material is forced in a stream through the plate and along ducts to a metering pump which pumps the fluid material to a spinneret or spinnerets.

According to a further feature of the invention there is provided an apparatus for the production of yarns and filaments from organic filament-forming compositions which comprises a device for supplying and holding under pressure solid particles of filament-forming material against a plate containing a multiplicity of apertures and which is provided with a heating means for maintaining the plate at a constant temperature sufficient to render the filament-forming material fluid and a system of heated ducts to collect the molten material and lead it to a metering pump, which pumps it to a spinneret or spinnerets.

For the high speed commercial operation of the apparatus of this invention it is necessary that there should be a constant and uniform supply of molten material to the metering pump. To achieve this it is necessary to supply solid particles of the filament-forming material to the plate at a uniform rate and to maintain a pressure on the particles sufficient to melt them at substantially the same rate; this rate being slightly greater than the rate at which the molten material is drawn away by the pump. The surplus liquid which is not pumped away tends to increase the thickness of the liquid film between the solid particles and the heated plate, so reducing the rate of heat transfer from the plate to the particles. In this way the rate of melting is self-balancing and adjusts itself to the rate at which liquid is pumped away.

In one simple form of apparatus for carrying out the process of this invention the solid particles are held against the perforated plate by means of a single ram acting in a cylinder. This ram is preferably adapted to move in a vertical direction in such a way that the particles in the cylinder are under pressure when the ram moves in a downwards direction. Directly below the cylinder, there is a metal plate drilled with multiplicity of holes, and provided with means for heating it to the required temperature to melt the filament-forming composition.

In operation the ram holds the particles of the filament-forming composition against the heated plate where they are melted, forced through the holes in the plate and forced directly to the pump and spinneret without remaining in a pool of molten material before being extruded.

As the material under the ram is melted and forced away it must be replenished. This may be done by imparting to the ram a reciprocatory motion so that the ram exerts pressure on the solid particles during its downward movement while on the upward return stroke provision is made for the material below the ram to be replenished. New material may be added to the space below the ram by a variety of ways; for example, by providing the ram with holes, so that solid material drops from a hopper above the ram through the holes during the upward stroke of the ram. When the ram is provided with holes they must be of such a size that the ram forces the particles of filament-forming composition downwards onto the heated plate but does not substantially force them upwards through the holes in the ram. Further, they must be of such a size that on returning the piston quickly to the top of its stroke particles fall through the holes and replenish the stock between the ram and the heated plate. The size of the holes required to fulfil these two conditions will depend on the particle size of the solid material and its free flowing properties. If the properties of the material are such that both these conditions cannot be satisfied the holes may be fitted with hinged valves. Alternatively solid material may be fed in through a port in the side of the cylinder which is uncovered when the piston is at the top of its stroke. It is not advisable to use an arrangement of this type unless the material is finely powdered; if there are any large pieces in the material, such pieces might project partly out of the entry port and jam the ram on its downward stroke.

With the arrangement already described using a single ram there will be short intervals when the ram is returning to the top of its stroke when no pressure is exerted on the solid particles to hold them against the plate, so substantially no melting is taking place; this tends to cause irregularities in the flow of melt to the pump, which irregularities may be manifest in the spun product.

These intervals when melt flow may cease are avoided by dividing the cylinder into at least two parts by a vertical wall or walls in the cylinder. In the case of a cylinder divided into two equal parts, the pressure may be applied by segmental rams which work alternately on either side of the dividing wall. Each ram or cylinder
has suitably disposed entry ports as described above. In operation the two rams on their downward strokes are out of step, so that for the major part of the strokes of both rams the particles are being held against the plate by both rams. One ram reaching the bottom of its stroke before the other, the particles will for a short time be under compression from only one ram; a quick return of the first ram to the top of its stroke, however, leading to a resumption of pressure by both rams ensures that a substantially uninterrupted flow of molten material through the heated plate is maintained.

Unless the rate of supply of solid particles is exactly the same as the melt rate, the amount of material between the rams and the plate will increase or decrease. Any increase will cause an increase in the back pressure exerted on the rams and may damage the mechanism; any decrease is liable to impair the flow of material to the plate. To overcome these difficulties some "give" must be allowed for in the mechanism. Using rams, this can be done simply by interposing between the driving mechanism and each ram, a compression spring. The cylinder in which solid particles to the apparatus can not be limited. On each upward stroke, solid particles will enter the space between the ram and the plate to replace any which have melted and the downward stroke will only be long enough to displace the material at the rate at which it is melted, any further movement of the driving mechanism being absorbed by compression of the spring.

In another modification of the invention the solid particles are fed downwards in a cylinder and held against the heated plate, by a rotating screw which may be one or more continuous flights or a number of separate blades set at an angle to the rotating shaft in the centre of this cylinder. In yet other modifications the solid material is moved by paddles attached to chains or any other device commonly employed for conveying solid materials, which permits feeding and holding of the solid particles against the plate.

If a screw or other mechanism is used it may conveniently be driven through a friction clutch which exerts a constant torque but which only transmits the movement required and which slips more or less continuously to dissipate any excess movement of the driving member and so maintain a substantially constant pressure of the solid particles against the plate. Alternatively the screw may be driven pneumatically, hydraulically, electrically or by any other means which allows for regulating the driving force according to the resistance to the motion of the screw, thereby resulting in a substantially constant torque being applied to the screw.

The cylinder or cylinders down which the solid particles are fed must not become so hot as to cause the solid particles being fed to the hot plate to melt and stop the smooth working of the screw. To prevent this the cylinder may be insulated from the heated plate, e.g. by quartz or asbestos. This ensures that the particles in the cylinder are not prematurely melted, and thereby reduces degradation of the filament-forming composition. To the furtherance of the same end the cylinder may be surrounded with a cooling system, e.g. coils in which a cooling medium circulates.

The heating plate will usually be of metal and may be of a variety of materials. For example, it may take the form of a simple plate with holes drilled through, a helical spiral, a series of concentric rings or a cone shaped structure. It is however essential that the total cross-sectional area of the aperture is sufficient to carry away the molten material formed, and leaves a sufficient proportion of solid plate for heating the plate and conducting the heat to the solid particles. In one simple modification a number of holes are drilled in a plate, which holes increase in size so that the upper surface of the plate is reduced substantially to a series of knife edges between round holes. The solid material is thereby forced by the piston into conical recesses leading to the holes. It will be appreciated that the material of which the plate is made must be a good thermal conductor, for example, silver or aluminium, which does not tend to degrade the synthetic polymeric materials.

To convey the molten material to the pump, heated ducts are used. The design of these will depend on the type of plate used. Using the simple type of plate described above, the rows of holes in the plate are connected together for passage of the molten material on the lower side of the plate by rows of, for instance, parallel slots. These slots are in turn connected by a further slot, which connects the first mentioned slots, preferably by bisecting them at right angles. This slot must be of a cross sectional area which substantially equals the combined cross sectional areas of the first mentioned slots in order to provide an uninterrupted flow of molten material throughout the plate. The first mentioned slot may be formed in the top surface of a supporting block on which the heated melting plate is mounted. From this slot a conduit carries away the molten material to the gear pump situated below the plate. It will be appreciated that the supporting block must be heated to maintain the material in a molten state; it is, in fact, possible to use the supporting block indirectly as the heating means. By making the lower surface area of the block larger than the top, i.e. larger than the perforated plate, it is possible to use a larger heating element positioned on the lower surface of the block which will concentrate the heat conveyed by conduction through the supporting block to the perforated plate. Care must be taken using this method of heating that the molten material passing through the conduit in the supporting block is not overheated. Furthermore the supporting block may contain the gear pump, or may be separate therefrom. This system of slots provides ducts, whereby the material which is melted on the plate may be forced away, by the pressure holding the particles against the heated plate, to the gear pump and spinneret or spinnerets. The ducts on the underside of the heated plate must be as short as possible to reduce the time that the material is molten before it is spun. Because the molten material flows under the pressure applied to the solid particles the cross section of the ducts can be kept small and need not be increased anywhere to form a pool in which degradation of the molten material can take place.

Heating of the plate may be accomplished by any known means, for example, by hot circulating fluids or by electrical methods, preferably by an electrical resistance element positioned underneath or outside the drilled portion of the plate. The temperature of the plate may be considerably higher than the melting point of the filament-forming material since the time of contact of the molten material with the heated plate is very short, and little degradation takes place. It is possible by altering the temperature of the plate to alter the rate of production of yarn or filaments. The higher the plate temperature the higher the maximum rate at which the melt can be formed and therefore the higher the rate at which it can be pumped away.

From the plate the molten material is led through the ducts in the plate and the duct and central conduit in the supporting block to a pump enclosed in a block heated to maintain the molten material at the required temperature for spinning. The heated block may, as indicated above, be the supporting block as well. The pump may be one of those commonly used but is preferably a gear pump.

From the heated pump the molten material is passed through apparatus as commonly used, e.g. sand filters, to the spinneret or spinnerets.
The chips of material in the feed hopper and also in the cylinder may be blanketed with an inert gas by maintaining a pressure of the gas in an air tight hopper. This ensures that very little degradation of the material takes place due to oxidation. Alternatively the chips may be kept in vacuum.

Referring to the accompanying drawings which show, by way of example, methods by which the present invention may be put into effect and apparatus to be used in such methods:

Fig. 1 is a cross section on a diameter of a heating plate.

Fig. 2 is a view of the bottom of the heating plate.

Fig. 3 is a view of the top of the heating plate.

Fig. 4 is a diagramatic side-elevation of one form of apparatus according to the invention, using rams as the compressing means.

Fig. 5 is a graph showing the relative movements in operation of the two rams of the apparatus illustrated in Fig. 4.

Fig. 6 is a general diagramatic view of an apparatus using a screw mechanism to feed and press the particles.

A simple form of the heating plate is illustrated in Figs. 1, 2 and 3. Referring now to these drawings the circular plate of silver 6 is drilled with holes 16. These holes are countersunk to form sharp edges 17 between the holes so that the melt may be forced away without impediment to its flow. Parallel slots 18 are formed in the bottom surface of the plate to collect the melt from the rows of holes. The heating element 19 is fastened to the thinner outer rim of the plate. The melt is collected from the slots 18 by a duct formed in the block below the plate, which block also contains the gear pump. This duct bisects each slot at right angles and connects with a further conduit which leads the melt to the gear pump.

As indicated hereinbefore the heated plate must be made of a material with a high coefficient of thermal conductivity. This will prevent, in this case where the plate is heated by an electrical resistance clamped to the periphery of the plate outside the drilled portion, a steep temperature gradient being set up between the outside of the plate, i.e. next to the heating element, and the centre of the drilled portion of the plate. If such temperature gradient was high it would be desirable to heat the outside of the plate to a higher temperature than is necessary, in order to ensure that melting takes place over the total area of the drilled portion of the plate. In Fig. 4 which shows an alternative plate assembly the plate is shown heated by thermal conduction through an intermediate block of material of high thermal conductivity. The drilled plate 6 of silver, is clamped to an aluminium block 8, to the bottom surface of which is secured the heating element 9. The lower surface of the block 8 may be of larger surface area than the drilled portion of the plate 6, thereby permitting a larger heating element 9 to be used, and concentrating the heat onto the melting surface of the drilled plate. The duct 12 in the top surface of the block 8 leads away the melt forced into the parallel slots 18. This melt then passes through the central conduit 11 to the gear pump. For the sake of clarity only a few holes and slots are illustrated in this drawing. It will be appreciated that a plate similar to that shown in Figs. 1, 2 and 3 would be used.

Referring further to Fig. 4 a circular cylinder 1, divided into two equal volumes by a baffle wall 2, is surrounded by a cooling jacket 3, provided with entry and exit ports 4 and 5 for the ingress and egress of the cooling fluid. To the bottom of the cylinder is clamped the heated plate structure already described, a layer 7 of heat-insulating asbestos material between the contacting surfaces. Two segmental rams 14 operated by rods 19 work in the cylinders 15. A hopper 20 is connected directly to the cylinder by a gastight joint 21. The hopper is provided with a filling and inspection cover 22 and an entry port 23 for supplying inert gas to the hopper and a gauge 24 for measuring the pressure of such gas in the hopper. The two rods 19 pass through the lid of a hopper and are sealed by bellows 25. To the top of the rods 19 are attached hollow cylindrical sleeves 26. In these hollow cylindrical sleeves are two further rods 27, connected to the sleeves by pins 28 working in slots 29 in the sleeves 26. Springs 30 under compression between collars 31 and the tops of the cylindrical sleeves 26 maintain the pins 28 at the top of the sleeves 27. The rods 27 are driven by eccentric mechanisms not shown in the drawing.

In operation the rods 27 have oscillating motions in a vertical direction. This motion is transmitted to the rods 19 by means of the springs 30 and the collars 26. If the space below the rams 14 is empty the rods 27 and 19 will move as a whole since the springs 30 will maintain the pins 28 at the top of the slots 29. If, however, the space beneath one or both rams is filled with solid particles being forced onto the hot plate at a rate higher, due to the speed at which the eccentric mechanisms are driven, then the rate at which the particles are melted on the plate the motion of the rod or rods 19 is modified by compression of the spring or springs 30. Pressure on the particles will, moreover, be maintained by the spring or springs.

In Fig. 4 the left hand ram is at the top of its stroke. The spring 30 is fully extended and the rods 27 and 19 will move as a single rigid unit to compress particles below the piston 14. At, say, a position intermediate to that of the piston in the left hand cylinder and that of the ram in the right hand cylinder the particles cannot be compressed onto the plate any further, the spring 30 therefore compresses, maintaining a pressure on the particles, allowing the rod 27 to complete its oscillatory motion separate from the rod 19. When the eccentric mechanism (not shown) has made one complete rotation the spring 30 will decompress and the rods 27 and 19 move as a whole so that the ram 14 moves to the top of its stroke. During this upward movement particles of solid filament-forming material contained in the hopper 20 fall through holes 33 in the pistons 14, to replenish the supply of particles to be melted on the plate. The two rams move relatively in a manner indicated in Fig. 5 which is a graph showing the position of each piston in its cylinder at any time. The graph denotes time and the ordinate the position of each ram in its cylinder. The motions of the two rams are indicated by the lines ABCD in full line and abcd in broken line. The lines AB, CD, ab and cd indicate that the rams are moving downwards and are therefore compressing the particles onto the plate. The lines BC, de and cd indicate that the rams are moving upwards. It will be apparent, therefore, that for a time x both rams will be compressing particles onto the plate, while for a time y compression will be by one ram only. In the optimum condition the time y will be short compared with the time x.

Referring to Fig. 6 which is a general diagramatic view of a further method of carrying out the process of this invention using a rotating screw to supply and hold the particles against the heated plate, a rotating shaft 34 carrying a continuous flight 35 is driven by a mechanism 36 which consists of, preferably, an electric motor supplying the rotary motion to the shaft through a slipping clutch. The screw rotates in the cylinder 1, which is connected with the heated plate and the hopper as hereinbefore described with reference to Fig. 4. We have found it advisable to use a cylinder having a roughened or grooved internal surface. This ensures that the polymer mass does not rotate with the screw.

In operation the screw rotates in such a way that particles of solid filament-forming material are forced onto the heated plate. When the screw has compressed the solid particles onto the plate to such an extent that the
rate of melting is lower than the rate of arrival of fresh particles at the heated plate, the screw will slow down since the resistance to motion of the screw will cause the clutch in the driving mechanism 36 to slip. When, however, further melting has taken place, this resistance to motion will be removed and the screw will again rotate at its normal speed to press further particles onto the plate. Pressure will therefore be continuously maintained to force the melt through the plate to the gear pump.

Example

A tow of polyethylene terephthalate filaments was spun using the apparatus described and illustrated in Fig. 4. Details of the apparatus were as follows:

Diameter of operative (i.e., drilled) 3 in.
Diameter of holes in plate ¼ in.
Diameter of holes in pistons ¼ in.
Length of stroke of each piston 1½ in.
Pressure on each spring ca. 350-lbs.
Speed of eccentric mechanisms 200 R. P. M.
Pressure of N₂ 10–20-lbs./sq. in.

By increasing the temperature of the plate the melt rate is increased according to the table.

<table>
<thead>
<tr>
<th>Temperature of plate (°C.)</th>
<th>260</th>
<th>265</th>
<th>270</th>
<th>280</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature of melt (°C.)</td>
<td>260</td>
<td>260</td>
<td>260</td>
<td>260</td>
</tr>
<tr>
<td>Melt Rate (lbs./hr.)</td>
<td>1.5</td>
<td>4</td>
<td>8</td>
<td>16.5</td>
</tr>
<tr>
<td>Denier of Tow</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
</tr>
</tbody>
</table>

When melting by conventional methods it is common to find that the polymer deteriorates if the temperature is above 300° C. or, if the throughput is less than 2 lbs./hr.

The melt from this apparatus was used for making yarn at 1.5, 4 and 8 lbs./hr, and in no case was thermal degradation of the material observed. At a melt rate of 15.5 lbs./hr, no yarn was spun, but the melt passing through the gear pump was not visibly suffering from degradation. Thus, using the process and apparatus according to this invention it is possible to produce yarns and filaments at a wide range of rates. Since high rates of production are attainable the invention is particularly useful for the production of tows for conversion by cutting into staple fibres.

This invention may be used for the production of yarns and filaments from all materials which may be melt spun, but is particularly useful for the production of yarns and filaments from synthetic polymeric materials, of which materials nylon and polyethylene terephthalate are illustrative examples.

We claim:

1. An apparatus for melt spinning which comprises a feed hopper, a plate containing a multiplicity of apertures, a mechanical device for supplying and holding under substantially constant pressure solid particles of filament forming material against said plate and for feeding said solid particles of filament forming material from said hopper to a position between itself and said plate, said plate being provided with heating means for maintaining a constant temperature sufficient to render the filament forming material fluid, a heated duct below the plate to collect the fluid material, a metering pump connected to said duct and a spinneret connected to said pump.

2. An apparatus as recited in claim 1 in which said device for supplying and holding the solid particles under pressure comprises at least one reciprocating ram acting in vertical cylinders with alternate pressure and return strokes.

3. An apparatus as recited in claim 2 in which there is interposed between each ram and its driving mechanism, a compression spring which permits the stroke of the ram to be reduced as the material between the ram and the plate increases.

4. An apparatus as recited in claim 1 in which the device for supplying and holding the solid particles under pressure comprises a screw acting in a cylinder.

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