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SPINNERETTE PACK FOR MELT SPINNING

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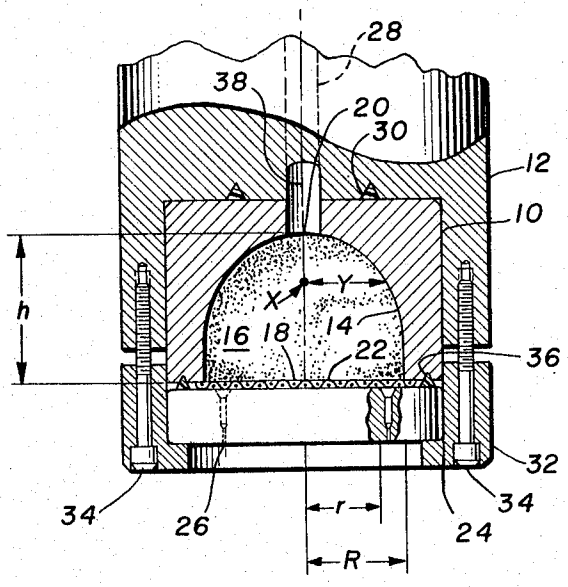


FIG. 1.

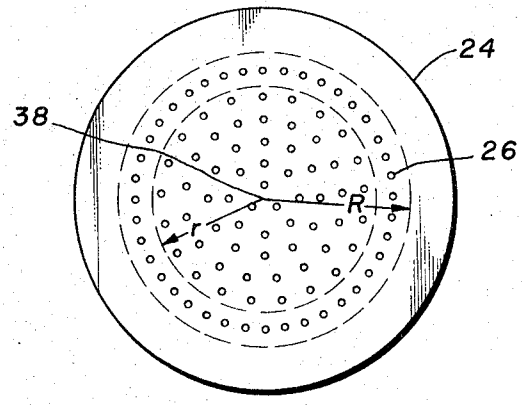


FIG. 2.

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SPINNERETTE PACK FOR MELT SPINNING

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This invention relates to spinnerette packs. More particularly, it pertains to a spinnerette pack for melt spinning having a substantially dome-shaped pack cavity therein.

Most customary spinnerette packs have pack cavities of such shape that there are areas within which prevent free polymer flow, thus resulting in stagnant polymer flow in certain areas within such cavity. Stagnant polymer remains in a pack cavity for extended periods, much longer than free flowing polymer. Because of being held up, stagnant polymer polymerizes to a higher degree than free flowing polymer. This stagnant, highly polymerized polymer in time breaks loose and attempts to pass out of the pack through the capillaries in the spinnerette plate. Thus, the capillaries become plugged, resulting in uneven polymer flow and a reduced number of filaments in the filament bundle produced by the spinnerette pack.

Furthermore, in the greater portion of contemporary spinnerette packs, pressure distribution on the upstream side of the spinnerette plate is quite uneven. This condition is thoroughly undesirable, for the optimum condition for melt spinning through a spinnerette plate is equal pressure at the entrance to and equal flow through every capillary in the spinnerette plate. Equal pressure and equal flow through identical capillaries within a spinnerette plate produce filaments of substantially equivalent size and quality, thus a better quality filament bundle results.

Therefore, it is an object of this invention to provide a spinnerette pack having a cavity of such shape that stagnant polymer areas are substantially eliminated.

A further object is the provision of a spinnerette pack having a pack cavity wherein the pressure at the entrance to every capillary in the spinnerette plate is substantially equal.

Other objects will become apparent from the following descriptive material.

In the drawing, FIGURE 1 is an elevational view, in section, of the inventive spinnerette pack mounted in a pack holder. FIGURE 2 is a top plan view of the spinnerette plate shown in FIGURE 1. The dotted circles represent radial distances rather than structure.

In general and in accordance with FIGURE 1, the above objects are achieved in the provision of spinnerette pack **10** mounted within pack holder **12** and containing substantially dome-shaped pack cavity **14**. Pack cavity **14** contains inert packing material **16**, has a base **18**, and includes a polymer entrance port **20** substantially at the top thereof. A screen **22** is fitted across pack cavity base **18**. Spinnerette plate **24** containing capillaries **26** is sealingly clamped into position below pack cavity base **18** and screen **22**.

With particular detailed reference to FIGURE 1, spinnerette pack **10** is fixedly positioned within pack holder **12**. Substantially dome-shaped pack cavity **14** is connected through polymer entrance port **20** and conduit **28** to a suitable source of molten polymer under high pressure. Gasket **30** makes a seal between pack holder **12** and spinnerette pack **10**. Spinnerette plate **24**, containing a plurality of capillaries **26**, is held in position below pack cavity base **18**. A screen **22**, generally a wire screen, is positioned across base **18** to prevent particles of finely divided inert material **16** from entering capillaries **26**. This finely divided inert material can be made of metal, ceramic, glass, and the like materials. However, sand is generally preferred. In conjunction with the finely divided particles, it is preferred that the entrances to capillaries **26** should be counterbored to a diameter that is larger (3–5 times as large) compared to the average diameter of the packing material.

Pack holder **10**, finely divided inert material **16**, screen **22**, and spinnerette plate **24** are fixed in position by clamp **32** held by bolts **34** bolted into pack holder **12**. Gasket **36** seals the joint between spinnerette pack **10** and spinnerette plate **24**.

The centers of both polymer entrance port **20** and spinnerette plate **24** are axially aligned on centerline **38**. The distance from centerline **38** to the wall of pack cavity **14** at base **18** is shown as base radius R. Intermediate base radius r is representative of any radial distance from centerline **38** at pack cavity base **18**, wherein the value of r is greater than zero but less than base radius R.

The distance from pack cavity base **18** to polymer entrance port **20** is shown as height h which is assigned the value of unity and is to be taken as the reference dimension.

The general shape of the pack cavity of the spinnerette pack is dome-like. Nevertheless, the preferred dome-shaped cavities take the form of "Rankin Bodies" (reference: Streeter, Fluid Dynamics, McGraw-Hill Book Co., New York, 1948, p. 59). The preferred pack cavity shape is given by a curve rotated about centerline **38**, which is also an axis of symmetry. This curve is defined by the equation

$$y^2=-C_1-C_2\left[\frac{x-1}{\sqrt{(x-1)^2+y^2}}-\frac{(x+1)}{\sqrt{(x+1)^2+y^2}}\right]$$

Equation 1

wherein x is a height above pack cavity base **18** on centerline **38** within pack cavity **14** and has a value from zero to unity; y is the radial distance from the upper limit of height x to the walls of pack cavity **14**; C_1 is a positive number greater than zero but less than twice C_2; C_2 is a finite positive number. C_1 and C_2 must satisfy Equation 2 (set forth below) for any given base radius R.

When x equals zero, y equals base radius R and Equation 1 reduces to

$$R^2=-C_1+C_2\left[+\frac{2}{\sqrt{1+R^2}}\right]$$

Equation 2

wherein R, C_1, and C_2 are as defined hereinabove. C_1 and C_2 must, for any given base radius, satisfy the equation.

Equation 1 determines the shape of a pack cavity which produces a polymer flow such that the pressure at every point at the base of the pack cavity is approximately equal to every other point. To take advantage of this equally distributed pressure at the pack cavity base requires that the capillaries in the spinnerette plate be properly distributed. Thus, the capillaries should be distributed according to the equation

$$N_r=N_R\left(\frac{Q_r}{Q_R}\right)$$

Equation 3

wherein N_r is the number of capillaries within an intermediate base radius r (defined above), N_R is the total number of capillaries within base radius R, Q_R is the total polymer flow through the pack cavity, and Q_r is the polymer flow through the area circumscribed by the above noted intermediate base radius r. The value of Q_r/Q_R can be determined by the equation

$$\frac{Q_r}{Q_R}=\frac{r^2+2C_2\left(1-\frac{1}{\sqrt{1+r^2}}\right)}{R^2+2C_2\left(1-\frac{1}{\sqrt{1+R^2}}\right)}$$

Equation 4

wherein Q_r, Q_R, r, R, and C_2 are as defined hereinbefore. For any particular spinnerette pack the values for C_1 and C_2 must be the same for every equation set forth herein.

Generally, the total number of capillaries within base radius R is determined by the number of filaments that are to be produced. From this information and from Equation 4 the number of capillaries N_r within an intermediate base radius r can be calculated. If the number is calculated to be a whole number plus a fraction, the fraction should be rounded off to the nearest whole number.

An example of the invention is set forth hereinafter. This example is intended to illustrate and should not be construed as a limitation upon the invention.

EXAMPLE

In this exemplary spinnerette pack cavity, height h is taken as unity and is the reference dimension. Base radius R is 0.655 of the pack cavity height. There are 101 capillaries through the spinnerette plate and constant C_1 is 0.800 and constant C_2 is 0.735, both constants being dimensionless. Table 1 is a tabulation of various values of x (height above the pack cavity base) with the corresponding values of y (radial distance from the upper limit of height x to the walls of the pack cavity). The values of x were arbitrarily set and the corresponding radial distances y were calculated by using Equation 1. At x equals zero, y equals the above base radius, 0.655.

Table 1.—Values of y for certain values of x

x	y	x	y
0.000	0.655	0.600	0.560
0.100	0.653	0.700	0.519
0.200	0.649	0.800	0.456
0.300	0.636	0.900	0.351
0.400	0.619	0.950	0.259
0.500	0.596	1.000	0.000

To locate the capillaries in the spinnerette plate, that portion of the surface of the plate filling over the pack cavity base corresponding to the radius of the pack cavity base, 0.655, was measured to determine a series of concentric circles having radii of 0.1, 0.2, 0.3, 0.4, 0.5, and 0.655 of the reference dimensions. Then by Equation 4 the flow through each circle was calculated. The capillaries were then spaced so that the number between any two successive circles has the same ratio to the total number of capillaries as the flow between the circles does to the total flow. Fractional values were rounded to the nearest whole number. The capillaries which were calculated to be between any two successive circles were then equally spaced in the center of and around the annular ring formed between the successive circles. Table 2 shows the number of capillaries within the various selected radii. The number of capillaries shown is the total number of capillaries within the circle bounded by each radius.

Table 2.—Capillaries within circles of given radii

Radius:	Capillaries
0.100	3
0.200	11
0.300	23
0.400	40
0.500	61
0.655	101

The spinnerette pack of the present invention provides many advantages. Paramount among such advantages is the equal polymer pressures on a plane across the base of the pack cavity such plane substantially corresponding to the top of the spinnerette plate. With proper capillary distribution according to the disclosure herein, the flow through each capillary is substantially the same, assuming, of course, that the capillaries have the same dimensions.

Equal pressure, resulting in equal flow, produces filaments of equal size, a quite desirable result.

Furthermore, the pack cavity of the instant spinnerette pack has no areas therein where polymer will stagnate, thereby producing a highly polymerized material called "gel" which tends to plug capillaries when it breaks loose and attempts to pass through the capillaries. A still further advantage is that in the instant spinnerette pack there is no necessity for a distribution plate; therefore the apparatus is simpler than most spinnerette packs in present use.

The invention has been described by referring to specific illustrations and embodiments. Nevertheless, no limitation should be placed upon the scope of the invention other than that of the appended claims.

What is claimed is:

1. A spinnerette pack for melt spinning filaments from molten polymer comprising in combination in fixed adjacent relationship:

(a) walls defining a substantially dome-shaped spinnerette pack cavity having finely divided inert material therein, a polymer entrance port substantially at the top thereof, and a base of radius R, the center of both said port and said base being axially aligned on a centerline;

(b) screening means across said base of said dome-shaped cavity; and

(c) a spinnerette plate in sealed relationship with said walls defining said base of said cavity, said spinnerette plate having a plurality of capillaries therethrough, the number of capillaries within an intermediate base radius r being determined by the equation

$$N_r = N_R\left(\frac{Q_r}{Q_R}\right)$$

wherein N_R is the total number of capillaries through said spinnerette plate within said base radius R, N_r is the number of capillaries within intermediate base radius r wherein r is less than base radius R but more than zero, Q_R is the total polymer flow through said cavity and Q_r is the polymer flow through the area of the base circumscribed by intermediate base radius r.

2. A spinnerette pack for melt spinning filaments from molten polymer comprising in combination in fixed adjacent relationship:

(a) walls defining a substantially dome-shaped spinnerette pack cavity having a height of unity, a substantially circular base of radius R, and a polymer entrance port substantially at the top thereof, said cavity having finely divided inert material therein, the center of both said entrance port and circular base being axially aligned on a centerline, said walls being defined by a curve rotated about said centerline, said curve being defined by the equation

$$y^2 = -C_1 - C_2\left[\frac{(x-1)}{\sqrt{(x-1)^2+y^2}} - \frac{(x+1)}{\sqrt{(x+1)^2+y^2}}\right]$$

wherein

x is a height above said base on said centerline within said cavity having a value from zero to unity,

y is the radial distance from the upper limit of said height above said base to said walls,

C_1 is a positive number from zero to less than twice C_2, C_2 is a finite positive number, wherein said C_1 and C_2 must satisfy the equation

$$R^2 = -C_1 + C_2\left[+\frac{2}{\sqrt{1+R^2}}\right]$$

for any given value of base radius R;

(b) screening means across said base of said cavity;

(c) a spinnerette plate in sealed relationship with said walls defining said base of said dome-shaped cavity, said spinnerette plate having a plurality of capillaries

therethrough, the number of capillaries within an intermediate base radius r being determined by the equation

$$N_r = N_R\left(\frac{Q_r}{Q_R}\right)$$

wherein

N_R is the total number of said capillaries in said spinnerette plate within said base radius R,

N_r is the number of capillaries in said spinnerette plate within intermediate base radius r when r is less than R but more than zero,

Q_R is total polymer flow through said cavity and Q_r is the polymer flow through the area of the base circumscribed by said intermediate base radius r.

3. The spinnerette pack of claim 2 wherein the finely divided inert material is sand.

4. The spinnerette pack of claim 2 wherein the screening means is a wire screen.

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