

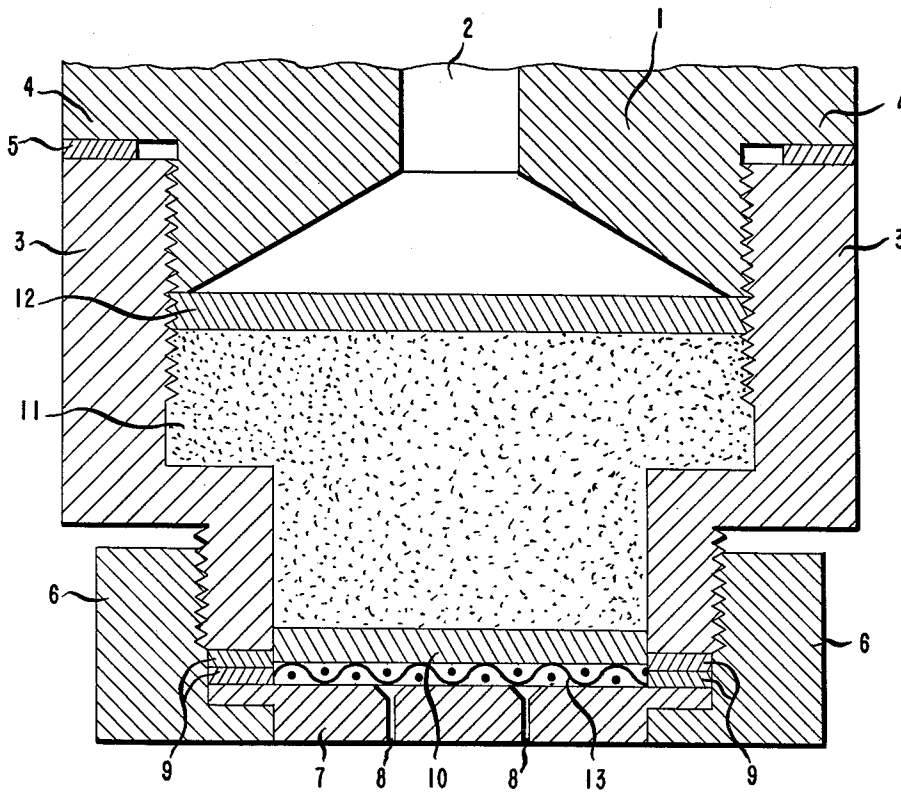
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SPINNERET PACK

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SPINNERET PACK

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This invention relates to a new and useful apparatus for the production of filaments and the like from a synthetic polymeric material and, more particularly, for the melt extrusion of filaments from a synthetic linear polyamide, polyester, or a similar material.

When extruding a molten organic filament-forming composition through a spinneret to form filaments, it is necessary that the molten composition be homogeneous and free from lumps and foreign material. Such non-homogeneous elements obstruct the passages of the spinneret orifices, cause irregularities in the diameter of filaments, plug up the spinning orifices, and often result in filament breakage during subsequent operations, furthermore, the flow of material into the spinneret orifices must be uniform and evenly distributed to the orifices of a multi-hole spinneret to produce a uniform diameter for all filaments.

In the production of filaments from molten compositions, the molten material is fed to the spinneret under suitable pressure and at suitable temperature from a supply duct leading from the melt pool, usually containing a metering pump or other device regulating the total rate of flow of molten polymer. A spinneret pack is interposed between the supply duct and the spinneret orifice for the purpose of preventing incompletely fused polymer, foreign matter, aggregates of delustering materials, and the like, from reaching the spinneret.

The spinneret packs conventionally used consist of a number of metal screens, or of a bed of granular material of various sizes of sand, metal, glass, ceramics, and the like, or of one or more porous metal blocks or plates. All these conventional spinneret packs act in the manner described, but possess disadvantages in that they frequently cause such variations in intrapack temperatures and melt distribution, such "channeling" of the bed of granular material, such pump slippage at high back pressures, and such premature release of dissolved gases, that inferior performance is experienced because of excessive broken filaments, draw-twist breaks, and draw-roll wraps.

Beds of finely divided inert granular material are taught in U.S. Patent 2,266,363 and in U.S. Patent 2,266,368. In operation of these beds, it has been found that gel particles which possess characteristics common to both liquids and solids change shape and exert forces which move sand particles apart, creating temporary, larger voids. Thus, the gel particles frequently pass through mobile filter beds of fine mesh size and go on to clog the spinneret capillaries.

Porous metal blocks or plates, while providing uniform temperature distribution within the spinneret pack, when

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used alone, do not provide the controlled pressure drop for the denier uniformity required to produce continuous filament yarns, for instance, of nylon. Furthermore, porous or sintered metal plates, when used alone as taught in the art such as in British Patent 751,853, are highly susceptible to clogging particularly with delustered polymers. This results in spinning interruptions due to pack failures, leaks, and poor denier control, i.e., poor quality and poor operability.

This invention has as an object to provide an improved spinneret assembly for the melt extrusion of filaments.

Another object of this invention is to provide an apparatus for substantially reducing the variations in intrapack temperature and melt distribution that occur in conventional spinneret packs.

A further object of this invention is to provide a spinneret pack wherein "channeling" of the bed of granular material is substantially eliminated.

A still further object of this invention is to provide a spinneret pack that performs to deliver filaments with substantially lower rejects from broken filaments, quality defects, draw-twist breaks, and draw-roll wraps.

Other objects will appear hereinafter.

These objects are accomplished by the following invention, a spinneret pack comprising in fixed adjacent relationship, in the direction of molten polymer flow, a bed of finely divided inert granular material, a porous metal plate with immobile voids, lateral distribution means, and a spinneret plate containing extrusion orifices, with the granular bed and the porous metal plate in such combination that the shear factor, L/NR^4 , is within the range of from 1 to 30 for a pack inlet pressure within the range of from 3300 to 7700 pounds per square inch.

A sintered metal plate is an example of a porous metal plate with immobile voids, and it is produced by heating small granules of steel or other metal or metals in a fixed form under pressure so that the granules fuse but the metal does not melt, thus preserving the pores and forming a coherent structure. The pore size is controlled by the process conditions and the size of the metallic granules. Production of such particles is described in U.S. Patent 2,554,343.

Flow of molten polymer through a spinneret pack is governed by the Hagen-Poiseuille law for isothermal streamline motion in well-developed incompressible flow, and L/NR^4 in the Hagen-Poiseuille equation is the factor for the shearing effect. In the equation L is the mean length of the capillaries, N is the number of capillaries and R is the mean radius of the capillary openings. Each of these values can be determined microscopically employing known statistical average methods. As will be described in greater detail hereinafter, there is no need to measure these values because the L/NR^4 factor can be determined knowing inlet pressure, throughput, and viscosity.

L/NR^4 values for each of a series of inert material fractions and sintered metal discs are given in Table I. Discs over $\frac{1}{4}$ inch in thickness can be achieved by combining two or more thinner discs.

TABLE I

Inert Material Mesh Size		L/NR ⁴ Value for 1 ml. of Inert Material		
		Col. 1	Col. 2	Col. 3
		Circular Pack, 1.48 sq. in. area	Non-Circular Pack, 2.30 sq. in. area	Non-Circular Pack, 1.58 sq. in. area
150-200		1.02	0.49	0.71
100-150		0.67	0.33	0.48
80-100		0.31	0.14	0.20
60-80		0.21	0.10	0.14

Porous Disc		L/NR ⁴ Value for Each Disc		
Thickness, inches	Mean Pore Diameter ¹	Col. 1	Col. 2	Col. 3
		Circular Pack 1.48 sq. in. area	Non-Circular Pack, 2.30 sq. in. area	Non-Circular Pack, 1.58 sq. in. area
1/4	165	(²)	(²)	(²)
1/4	65	2.1	1.0	1.4
1/4	35	14.6	7.0	10.1
1/4	20	Unsuitable	Unsuitable	Unsuitable
1/4	10	Unsuitable	Unsuitable	Unsuitable
1/8	165	(²)	(²)	(²)
1/8	65	0.3	0.18	0.23
1/8	35	2.7	1.3	2.0
1/8	20	9.4	4.5	6.2
1/8	10	19.1	9.2	10.3
1/16	165	(²)	(²)	(²)
1/16	65	0.19	(²)	0.10
1/16	35	1.2	0.6	0.84
1/16	20	4.6	2.2	3.0
1/16	10	9.6	4.6	6.5

Porosity (void fraction) of all discs are approximately 0.5. Unsuitable discs have an L/NR⁴ value greater than about 18.

¹ Microns.

² Less than 0.1.

As will be apparent from the foregoing table, with a constant mean pore diameter the L/NR⁴ value of the disc increases as the thickness of the disc increases. Because L/NR⁴ values for a combined disc and inert material assembly in excess of 30 do not provide an efficient filtering means, it is necessary that the thickness of the disc adjacent the spinneret plate in such an assembly not exceed about 1/2 inch. Disc thicknesses below about 1/16 inch become excessively friable and also are unsuitable. While seemingly adjacent the spinneret plate a disc thickness greater than about 1/2 inch could be employed provided that the mean pore diameter was sufficiently large, in practice it has been found that for efficient filtering action the mean pore diameter should be in the range from about 5 to about 200 microns, although preferably 10 to 165 microns.

It is preferred that the inert material comprising the granular portion of the spinneret pack be of relatively fine particle size. Desirably that portion of the granular material adjacent the disc, preferably all of the granular material in the assembly, is of such size that at least 95% by weight will pass a 60 mesh screen. For most purposes the thickness of the layer of such material in the spinneret pack should be 0.5 to 0.94 inch. Preferably several layers of granular material will be employed with the particle size decreasing in the direction of the spinneret plate.

The L/NR⁴ values for inert granular material and the porous disc respectively are additive to give a total L/NR⁴ value for the combination. As indicated hereinbefore, it is critical that the total value be within the range of from 1 to 30 for a pack inlet pressure within the range of from 3300 to 7700 pounds per square inch. Desirably the disc or discs are of such character that their total L/NR⁴ value accounts for about 5 to 60% of the total L/NR⁴ value of the pack. Thus the inert granular material accounts for the remaining 40 to 95% of the total L/NR⁴ value. Within these ranges and as will be apparent from the examples an usually high degree of filtration efficiency is achieved.

When it is desired to employ an assembly comprising in the direction of polymer flow, a coarsely porous metal

plate, a granular bed of inert material, a finely porous metal plate, lateral distribution means, and a spinneret plate, it is desirable that the sum of L/NR⁴ values for both plates account for 5 to 60% of the total shear factor of the pack. It is essential in this instance that the shear factor of the finely porous metal plate be greater, preferably by at least a factor of 3, than the shear factor of the coarsely porous metal plate. Aside from that requirement the thickness and mean pore diameter of the coarsely porous metal plate are not particularly critical since its main function is to evenly distribute the polymer over the bed of granular material. Thicknesses greater than 1/2 inch can therefore be employed. For most purposes the mean pore diameter of the coarsely porous metal plate should be greater than 65 microns.

It will be further apparent from Table I that the L/NR⁴ values also vary somewhat depending upon the shape of the area.

The preferred embodiment of this invention uses one disc with a mean pore diameter greater than 20 microns and thickness between 1/16 inch and 1/4 inch. Preferred combinations of granular bed with porous metal plate have L/NR⁴ within the range of from 5 to 25.

The preferred pack inlet pressure is within the range of from 4500 to 6500 pounds per square inch.

A typical embodiment of the invention is shown in the FIGURE.

With reference to the FIGURE, the base portion of a melt extrusion apparatus 1 has a polymer feed duct 2 communicating with a suitable source of molten material being supplied at a controlled rate and under pressure. The tubular, internally threaded, spinneret pack retainer 3 is screwed onto the externally threaded portion of extrusion apparatus 1 which is provided with a shoulder 4 against which retainer 3 is adapted to abut with an annular gasket 5 interposed to give a tight joint between extrusion apparatus 1 and the spinneret assembly proper.

The lower end of retainer 3 is externally threaded and has screwed thereon the internally threaded annular spinneret holder 6 which carries the spinneret disc 7, having spinneret holes 8 through which the molten material is extruded to form filaments. Between the spinneret 7 and the bottom of retainer 3 are interposed one or more annular gaskets 9 which insure a tight joint between retainer 3 and spinneret holder 6 as well as insuring the firm setting of spinneret disc 7 in spinneret holder 6.

Retainer 3 is filled with a spinneret pack comprising a sintered metal disc 10, supporting a body of finely divided inert material 11 which in turn is covered by a sintered metal disc 12. Disc 10 is separated from spinneret 7 by a coarse wire screen 13, which permits the lateral distribution of the molten polymer over the face of the spinneret 7. Disc 12 is made of larger granules and is more porous than disc 10. The spinneret pack is placed in the spinneret assembly before that assembly is attached to extrusion apparatus 1. Since a tight contact is required to avoid leakage past gasket 5 the total height of the layers of discs and finely divided inert granular material must not be so great as to prevent screwing the spinneret assembly and gasket 5 tightly up against apparatus 1. The disc 12 may be replaced by a coarse screen or may be omitted entirely. The finely divided inert material 11 is of such nature that it will not mat on the sintered disc 10. It may consist of finely divided iron filings or beads, stainless steel filings, ceramic materials, steel "BB's," zirconia sand, or numerous other materials. Silica sand has been found to be highly satisfactory, being cheap, inert, granular, and having no tendency to mat down and stop-up the openings in the porous metal disc. It may be useful to employ sand of different finenesses in different layers such as taught by G. D. Graves, U.S. 2,266,363 and Hull et al., U.S. 2,266,368. The wire screen 13 may be replaced with any suitable material which both supports the disc 10 and permits the lateral distribution of the molten polymer.

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In the operation of the apparatus as described, the molten material is delivered at a controlled rate and under pressure from a suitable pumping device through polymer feed duct 2, is forced down and through the spinneret pack and out through the holes 8 in the spinneret 7 to form filaments. The molten material first encounters the coarse disc 12 which serves chiefly to hold the inert material in place, to distribute the molten polymer over the entire surface of the bed of finely divided inert material, to insure uniform temperature of the molten material and to filter out larger aggregates of fillers, incompletely fused polymer or foreign materials, and thus prolong the useful life of the assembly. The molten material then passes through the bed of finely divided inert material 11 which catches and retains the finer particles of foreign matter and through a shearing action breaks up the aggregates of delustrant or filler materials which may have formed during the earlier handling of the polymer. The molten polymer then reaches the final sintered metal disc 10 to give a final filtering action to the polymer and to assure once more that all the molten material is at a uniform temperature when it reaches the spinneret after lateral distribution by wire screen 13.

The invention will be more readily understood by reference to the examples. For the purposes here described, improvements in spinneret packs are evaluated in terms of the quality of the extruded filaments, i.e., their uniformity, freedom from included foreign particles and non-homogeneities. Evaluation is also made according to the length of time which a given spinneret assembly can be used before it has to be replaced and cleaned. In particular, this latter criterion of "pack life" is most important in determining the productivity of a given spinning machine. The sintered metal discs employed in the examples are produced from powdered stainless steel.

Example I

Polyhexamethylene adipamide (66 nylon) melt containing 0.3% TiO_2 is spun at 1300 yards per minute through a pack with 1.58 sq. in. area to give a 13 filament undrawn yarn bundle of a total denier of 130. The pressure at the inlet of the spinneret pack is 5800 pounds per square inch. The test spinneret pack comprises, in fixed adjacent relationship and in the direction of molten polymer flow, 5.6 ml. of 60-80 mesh sand, next 7.2 ml. of 100-150 mesh sand, next 7.2 ml. of 150-200 mesh sand, next a $\frac{1}{4}$ inch thick sintered metal disc of 65 micron mean pore diameter, next a coarse wire screen as a lateral distribution means, and finally a spinneret plate containing extrusion orifices. The L/NR^4 value of the test filtering media is 10.76. The cross sectional area of the pack is 1.58 square inch, non-circular, as per col. 3 of Table I. In the control spinneret pack all conditions are identical except that the $\frac{1}{4}$ inch thick sintered metal disc is not present, and that sufficient additional sand is added to have substantially the same spinning speed at substantially the same inlet pressure. The filaments produced with the test spinneret pack are acceptable and superior to those produced with the control. The results are shown in Table II.

In a second test, (b), use of the same disc, under a bed of 20-50 mesh sand (affording essentially a zero L/NR^4 value and no filtering action), drawing performance was exceptionally poor because adequate pressure could not be attained. The L/NR^4 value for the disc alone was 1.4. The pressure was below 2000 p.s.i.

Example II

A test similar to the one described in Example I is carried out except that the polymer contains 2.0% by weight TiO_2 as a delustrant. The filaments produced with the test spinneret are acceptable, and the results are shown in Table II.

The use of powdered metal instead of sand yields a performance and operability comparable to what may be

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obtained with sand. Such a pack has the advantage that it does not require extensive disassembly for cleaning prior to re-use. An integral metal pack, firmly gasketed together, is found capable of repeated re-use after a simple dry heat cleaning, i.e., polymer burn-off.

Example III

A pack composed of powdered metal fractions comparable to the sand fractions of Example I is sandwiched between $\frac{1}{4}$ inch coarse and fine discs. The coarse disc at the top of the sandwich has a mean pore diameter of 165 microns. The fine disc at the bottom of the assembly has a mean pore diameter of 65 microns. The L/NR^4 value of the test filtering media is 10.8. The control for this test is the same as the control for Example II since all other conditions are held constant. The filaments produced with the test pack are acceptable and much superior to those produced with the control because of the use of the sandwich effect with the two discs. The results are shown in Table II.

Example IV

Polyhexamethylene adipamide melt of 1175 poises melt viscosity and a relative viscosity of 32 containing 0.3% TiO_2 is spun at 13.7 grams per minute through a pack with 1.58 sq. in. area. The pressure at the inlet of the test pack is 7400 pounds per square inch. The test spinneret pack is as in Example I except that the granular bed comprises 6 ml. of 60-80 mesh sand, next 7.2 ml. of 100-150 mesh sand, next 7.2 ml. of 150-200 mesh sand, and except that the sintered metal disc has a mean pore diameter of 35 microns. The L/NR^4 value of the test pack is 19.5. In the control spinneret pack all conditions are identical except that the $\frac{1}{4}$ inch thick, sintered metal disc is not present and that sufficient additional sand is added to have substantially the same spinning production at substantially the same inlet pressure. The filaments produced with the test spinneret pack are acceptable but not as superior as those of Example I because of the high pressure used, which is closed to the critical. The cross-sectional area of the pack is the same as Example I. The results are shown in Table II.

Example V

Polyhexamethylene adipamide melt of 1175 poises melt viscosity and a relative viscosity of 32, containing 0.3% TiO_2 is spun at 13.7 grams per minute through a pack with 1.58 sq. in. area. The pressure at the inlet of the test pack is 3200 pounds per sq. inch. The test spinneret pack comprises, in fixed adjacent relationship, and in the direction of molten polymer flow, a $\frac{1}{4}$ inch thick sintered metal disc of 65 microns mean pore diameter, next 7.2 ml. of 150-200 mesh sand, next a $\frac{1}{4}$ inch thick sintered metal disc of 65 micron mean pore diameter, next a coarse wire screen as a lateral distribution means, and finally a spinneret plate containing extrusion orifices. The L/NR^4 value of the test filtering media is 7.9. The cross-sectional area of the pack is the same as Example I. In the control spinneret pack all conditions are identical except that the $\frac{1}{4}$ inch thick sintered metal discs are not present and that sufficient additional sand is added to have substantially the same spinning production at substantially the same inlet pressure. The filaments produced with the test spinneret pack are not acceptable and neither are those of the control because of the quality defects, non-homogeneous filaments, and other imperfections. There is a lack of shear due to the insufficient relative amount of inert material, and the low pressure used. The results are shown in Table II.

Example VI

Polyhexamethylene adipamide melt containing 0.3% TiO_2 is spun at 12.5 grams per minute, through a pack with 2.30 sq. in. area. The melt viscosity is 1175 poises, and the relative viscosity is 32.5. The pressure at the

inlet of the test pack is 4200 pounds per square inch. The test spinneret pack is as in Example I except that the granular bed comprises 9.6 ml. of 80-100 mesh sand, next 11.2 ml. of 100-150 mesh sand, and finally 11.2 ml. of 150-200 mesh sand. The L/NR^4 value of the test pack is 11.5. In the control spinneret pack all conditions are identical except that the $\frac{1}{4}$ inch thick sintered metal disc is not present and that sufficient additional sand is added to have substantially the same spinning production at substantially the same inlet pressure. The filaments produced with the test spinneret pack are acceptable, but both these filaments and those of the control are of a lower grade than those of Example I because of the lower pressure used, close to the critical lower limit. The results are shown in Table II. The cross-sectional area of the pack is 2.30 square inches, non-circular, per col. 2 of Table I.

Example VII

Polyhexamethylene adipamide melt containing 0.3% TiO_2 is spun at 11.7 grams per minute, through a pack with 1.48 sq. in. area. The melt viscosity is 1175 poises and the relative viscosity is 32.5. The pressure at the inlet of the test pack is 7900 pounds per square inch. The test spinneret pack is as in Example I except that the granular bed comprises 8.0 ml. of 80-100 mesh sand, next 9.6 ml. of 100-150 mesh sand, and finally 8.0 ml. of 150-200 mesh sand and except that the sintered metal disc is $\frac{1}{8}$ inch thick and has a mean pore diameter of 20 microns. The L/NR^4 of the test pack is 24.2. In the control spinneret pack all conditions are identical except that the $\frac{1}{8}$ inch thick sintered metal disc is not present and that sufficient additional sand is added to have substantially the same spinning production at substantially the same inlet pressure. The filaments produced with this test spinneret pack are not acceptable because of the high off-deniers (6.5, vs. 0.2 for the control). Furthermore, the pack leaks at the high pressure used. The results of this example are shown in Table II. The cross-sectional area of the pack is 1.48 square inches, circular, per col. 1 of Table I.

TABLE II

Example	Draw-Twist Breaks, Pound	Percent Draw Roll Wraps	Percent Broken Filament Rejects
I. Test.....	0.019	5.4	0.46
I. Control.....	0.023	7.7	0.49
I. Test (b).....	0.50	72	-----
II. Test.....	0.024	5.5	1.3
II. Control.....	0.030	8.9	0.9
III. Test.....	0.018	3.6	-----
III. Control.....	0.030	8.9	0.9
IV. Test.....	0.029	5.8	1.0
IV. Control.....	0.025	6.0	1.0
V. Test.....	0.03	11	1.2
V. Control.....	0.02	6	0.8
VI. Test.....	0.05	6.7	1.1
VI. Control.....	0.08	8.5	1.1
VII. Test.....	0.046	1.6	0.54
VII. Control.....	0.044	1.8	0.95

Examples V and VII show that, although the shearing factor L/NR^4 is in the acceptable range, unacceptable filaments are produced because the inlet pressure is first too low and then too high to perform satisfactorily. Example V shows the unacceptable results from depending primarily on sintered discs and using insufficient granular material. All controls have substantially shorter pack life. They show the need to have porous metal with immobile voids in addition to a bed of finely divided inert granular material combined in accordance with this invention.

It will be apparent that for actual manufacturing purposes microscopic examination of the spinneret pack for purposes of determining L/NR^4 would be undesirable. Utilization of the following procedure permits the de-

termination of this factor knowing certain values and constants for a given system. Thus the factors to be considered in spinning through a pack of this invention are the pressure developed and the shearing of the polymer to either break or disperse non-homogeneities. An empirical equation is developed from the Hagen-Poiseuille law (ref. Heat Transmission, W. H. McAdams, McGraw Hill Pub., 1954, pages 148-149) to describe these two factors:

$$\frac{dP}{dL} = \frac{40.75nW}{GD^4p} = \frac{8nW}{N\pi GpR^4}$$

where $G=32.2$ ft./sec.² and p =density of polymer in lbs./cu. ft., D is the diameter of the capillary and for a specific filter bed this equation is resolved to:

$$P = KnW \left(\frac{L}{NR^4} \right)$$

where P is the inlet pressure in pounds per square inch within the range of 3300 to 7700 and

$$\frac{L}{NR^4}$$

is the shear factor (L is the mean length of the capillary, N is the number of capillaries, and R is the mean radius of the capillary openings). The symbol K represents a constant for the polymer and is equal to

$$\frac{8}{\pi Gp}$$

For polyhexamethylene adipamide $K=0.0228$. W (for any polymer) is the throughput within the range of 10 to 75 grams per minute, and n (for any polymer) is the melt viscosity in poises within the range 1000 to 2000.

Therefore, the operable shear factor

$$\frac{L}{NR^4}$$

may be determined within the operable range of pressures for any combination of polymer viscosity, throughput, and spinneret pack of this invention.

This application is a continuation-in-part of U.S. application, Serial No. 669,050, filed July 1, 1957, and now abandoned.

Many other equivalent modifications will be apparent to those skilled in the art from a reading of the foregoing without a departure from the inventive concept, and therefore this invention is not intended to be limited except as indicated in the appended claims.

What is claimed is:

1. A spinneret pack for a melt-spinning assembly comprising in fixed adjacent relation, in the order of polymer flow, a granular bed of finely divided inert material, a porous metal plate having a thickness of about $\frac{1}{16}$ to $\frac{1}{2}$ inch and containing immobile voids having a mean pore diameter of from about 5 to about 200 microns, lateral distribution means, and a spinneret plate containing extrusion orifices, said granular bed and said metal plate together providing a total shear factor, L/NR^4 , within the range of from 1 to 30 for a pack inlet pressure within the range of from 3300 to 7700 pounds per square inch, wherein L is the mean length of capillaries, N is the number of capillaries and R is the mean radius of the capillaries.

2. The pack of claim 1 wherein the porous metal plate is a sintered metal plate.

3. The pack of claim 1 wherein the finely divided inert material is sand.

4. The pack of claim 1 wherein the distribution means is a coarse screen.

5. The pack of claim 1 wherein the individual shear factors for said granular bed and said metal plate are 40 to 95% and 5 to 60% respectively of the said total shear factor.

6. A spinneret pack for a melt-spinning assembly comprising in fixed adjacent relation, in the order of polymer flow, a coarsely porous metal plate with immobile voids, a granular bed of finely divided inert material, a finely porous metal plate having a thickness of about $\frac{1}{16}$ to $\frac{1}{2}$ inch and containing immobile voids having a mean pore diameter of from about 5 to about 200 microns, lateral distribution means, and a spinneret plate containing extrusion orifices, said granular bed and said metal plates together providing a total shear factor, L/NR^4 , within the range of from 1 to 30 for a pack inlet pressure within the range of from 3300 to 7700 pounds per square inch, wherein L is the mean length of capillaries, N is the number of capillaries and R is the mean radius of the capillaries.

7. The pack of claim 6 wherein the finely porous metal plate is a sintered metal plate.

8. The pack of claim 6 wherein the finely divided inert material is sand.

9. The pack of claim 6 wherein the distribution means is a coarse screen.

10. The pack of claim 6 wherein the individual shear factors for said granular bed and for the sum of said coarsely porous metal plate with said finely porous metal plate are 40 to 95% and 5 to 60% respectively of the said total shear factor, the shear factor of said finely porous metal plate being greater than that of said coarsely porous metal plate.

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