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APPARATUS AND METHOD FOR QUENCHING AND STABILIZING
EXTRUDED MOLTEN FILAMENTS
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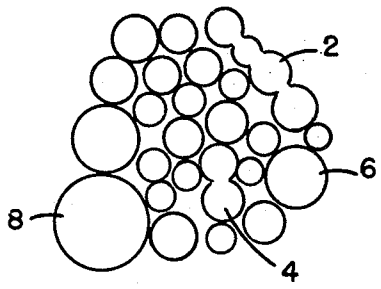


Fig. 1

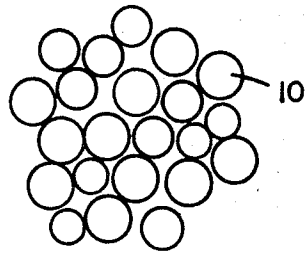


Fig. 2

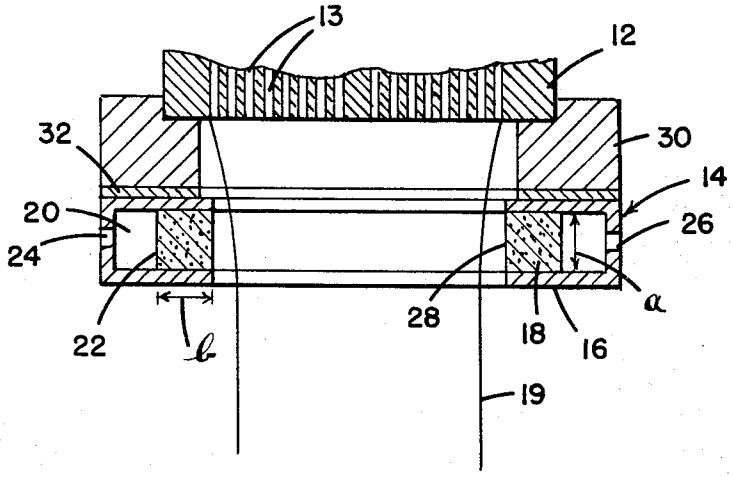


Fig. 3

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APPARATUS AND METHOD FOR QUENCHING AND STABILIZING EXTRUDED MOLTEN FILAMENTS

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U.S. Cl. 264—176 F 4 Claims

ABSTRACT OF THE DISCLOSURE

A method and apparatus for increasing the production capability of an existing spinneret in the preparation of fibers from molten filaments with reduced cementation of said molten filaments wherein an annular porous member is positioned below the spinneret to impinge a uniform and specific rate of diffused cooling gas onto the filaments, is disclosed herein.

In the manufacture of thermoplastic resin fibers, particularly of low denier filaments, at a high production rate wherein a high extrusion rate and high density of spinneret holes are employed in an attempt to obtain the highest economic efficiency in the spinning operation, a problem arises of the formation of filaments of non-uniform cross-section. For example, with conventional quenching of the filaments either two or more freshly extruded molten filaments fuse together to form a much larger denier filament or two or more filaments form "dumb-bell" like cross-sectional shapes. These defects occur to a greater extent when three factors are present in the spinning process: (1) The undrawn filament denier is 5 denier and under, (2) the extrusion rate is at least 0.06 lb. per spinneret hole per hour, and (3) the density of extrusion holes per square inch of spinneret surface within the perforated area is at least about 30 holes per square inch.

To overcome the above problem, thereby permitting a higher production rate of good quality low denier filament fibers, it has been found that a controlled annular flow and uniformly distributed diffused cooling gas directed toward the freshly extruded molten filaments is necessary.

Various annular quenching apparatus and methods for molten synthetic thermoplastic resin filaments are known in the art. U.S. Pats. 2,821,744 to Spohn et al., and 2,832,642 to Lennox disclose annular devices designed to fit directly below the spinneret and impinge a circular flow of a gas inwardly toward the molten filaments emanating from the spinneret. The former patent is directed to preventing "die-facing" and teaches that the gas flow from a nozzle or diverging slit in the annular device must direct a flow of gas at rather low pressure over the entire face of the spinneret or die. The latter patent is directed to a device for producing crinkled filaments by directing a controlled annular flow of a sheet-like stream of gas inwardly toward the molten filaments emanating from the spinneret. It has been found that these devices, in a spinning operation as previously described are much too difficult to control with respect to obtaining a critical rate of flow with an even or uniform peripheral distribution of cooling gas to obtain the result desired herein.

U.S. Pat. 3,061,874 to Lees discloses a device for symmetrically quenching molten filaments emanating from a spinneret having no orifices or holes near the center of the plate. The quenching device must be within 3/16 inch of the spinneret, the flow of quench gas must be parallel to the face of the spinneret and the velocity of the quench gas is maintained at a high level to obtain a spontaneously crimpable fiber. This high velocity gas flow requires an interior space in the filament bundle to permit the downward exhaust of quench gas after contacting the filaments.

It is an object of the present invention to provide an apparatus which permits the manufacture of good quality fibers from an existing spinneret at an increased production rate.

It is another object to provide an apparatus for the manufacture of good quality low denier filament fibers at an increased production rate.

It is still another object of this invention to provide a method of preparing good quality, thermoplastic fibers at an increased production rate.

These and other objects are accomplished in accordance with this invention in an apparatus for the melt extrusion of a stream of filaments of synthetic thermoplastic resin under pressure through a spinneret assembly, the improvement which comprises an annular quenching means including an annular porous structure having multi-directional orifices, means to supply a cooling gas to said porous structure whereby said cooling gas emerges at a uniform rate from the periphery of the interior wall surface thereof in a diffused manner toward the freshly extruded filament stream, said annular quenching means positioned concentrically and parallel to said spinneret and at a distance therefrom and from the filament stream sufficient to stabilize and prevent fusing of the individual filaments.

A more specific embodiment of this invention is an apparatus for extruding molten synthetic thermoplastic resin filaments of a size no greater than 5 denier from a spinneret having a plurality of substantially evenly spaced holes of which the outer course has a diameter ranging from about 3 to about 7 inches, a hole density of at least about 30 holes per square inch, and pumping means to extrude molten resin through the holes of said spinneret at a rate of at least 0.06 lbs. of resin per hole, wherein the improvement comprises an annular solid porous structure having multidirectional orifices and being positioned parallel to and concentric with the spinneret face at a distance ranging from about ½ to about 6 inches from said face, the interior wall surface of said porous structure being of a dimension such that the flow of diffused cooling gas therefrom will reduce fusing of the filaments, preferably about ⅛ to about 1 inch away from the outer course of filaments which emanate from said spinneret, said porous structure having an average pore size range of from about 100 to about 180 microns, and means to cause a cooling gas to flow through the porous structure and emerge from its interior wall surface at a rate of from about 0.4 to about 1.0, preferably about 0.5 to about 0.7 cubic foot per minute per square inch of said interior wall surface.

This invention also includes a method of preparing undrawn synthetic thermoplastic resin fibers having filaments of a size no greater than 5 denier by extrusion of molten resin at a rate of at least 0.06 lb. of resin per hole through a spinneret having a plurality of substantially evenly spaced concentric rings of holes of which the outer ring has a diameter ranging from about 3 to about 7 inches and a hole density of at least about 30 holes per square inch, the improvement which comprises impinging a substantially uniform annular flow of a diffused cooling gas from multi-directional orifices having an average cross-sectional size in their largest dimension between about 100 and 180 microns at an initial flow rate of from about 0.4 to about 1.0, preferably about 0.5 to about 0.7 cubic foot per minute per square inch inwardly against the freshly extruded molten filaments.

The invention will be more readily understood on viewing the accompanying drawing of which

FIG. 1 is a representation of an enlarged cross-sectional view of a portion of low denier filaments of a melt spun fiber prepared with conventional quenching means at a high production rate;

FIG. 2 is a representation of an enlarged cross-sectional view of a portion of low denier filaments of a melt spun fiber prepared from the quenching means of this invention at a high production rate; and

FIG. 3 is a front partial cross-sectional view of a portion of a melt spinning apparatus showing a form of the quenching means of this invention.

In FIG. 1 "dumb-bell" shapes **2** and **4** are representative of filaments which become cemented together when freshly extruded in an operation wherein quench air flows across the filaments in a uni-directional and horizontal manner and the low denier filaments are extruded from a spinneret having a hole density of at least 30 holes per square inch at a rate of at least 0.06 lb. of resin per hour per hole.

Varied size cross-sectional shapes **6** and **8** caused by fusion of multiple filaments are also found in the above type of extrusion operation. Where larger denier filaments, lower hole densities or lower extrusion pressures are used, the tendency for the above undesirable cross-sections to form is substantially reduced.

FIG. 2 depicts the cross-sectional shapes of low denier filaments **10** spun in a manner similar to those of FIG. 1 except that the quenching apparatus and method of this invention were used in their preparation. No "dumb-bell" shaped cross-sections are formed and the filaments are of more uniform cross-sectional size.

FIG. 3 shows the quenching means of this invention positioned parallel to and concentric with the face of the spinneret assembly **12** having representative extrusion holes **13** therein. The quenching assembly broadly designated as **14** consists of an annular housing **16** having an internally positioned annular porous structure **18** and forming a suitably wide enclosed space **20** surrounding the exterior wall **22** of the porous structure. The housing **16** abuts the top and bottom walls of the porous structure **18** so that a cooling gas introduced through opposite ports **24** and **26** by means of connecting pipes or tubes (not shown) will first surround the porous structure **18** and then penetrate it with a uniform flow of gas which emerges from the interior wall surface thereof.

The height of the porous structure **18** shown at *a* can range from about ¼ inch up to about 5 inches. From a practical standpoint the height will range from ¼ and about 1 inch.

The thickness of the porous structure **18** shown at *b* is also dictated by expedience. It must be thick enough to provide suitable strength and diffusion of the gas flowing therethrough, and thin enough to be of a practical size. A thickness of from about ¼ to ½ inch is advantageously employed.

The quenching means **14** is spaced from the spinneret assembly **12** by means of flange **30** with intermediate insulating ring **32**. Means for attaching these members is not shown. Preferably, a distance from about ½ to about 2 inches from the spinneret face is used, however, the quenching means **14** is effective at a distance as far as 5 to 6 inches from the spinneret face although the farther away the quenching means is from the spinneret face, the greater the flow of cooling gas required within the given limits.

The solid annular porous structure **18** can be made of material including, for example, carbon and sintered metal. The porous structure is conventional and can be described as a solid material through which a multiplicity of circuitous channels pass and diffuse gas flowing therethrough and emerging therefrom in multi-directional paths. The pore size should be substantially uniform and have an average size ranging from about 100 to about

180 microns. This pore size has been found necessary in combination with the given cooling gas flow rate to stabilize and quench the low denier molten filaments without damaging or degrading the filament structure. If the pore size is smaller, the cooling gas flowing through the pores emerges as a high velocity jet of air which damages the surface of the outer courses of filaments **19** emanating from the spinneret. If the pore size is larger the velocity of diffused cooling gas is too weak to be totally effective for the purpose of this invention.

It has been found that the cooling gas must be delivered to the quenching means **14** through at least two substantially equidistant ports as **24** and **26** in the housing **16** to provide an even distribution of gas around and through the porous structure **18**. The gas must be delivered through the ports at a pressure sufficient to produce a flow rate from the interior wall surface **28** of the porous member **18** of from about 0.4 to about 1.0 cubic foot per minute per square inch of said interior wall surface. The particular pressure employed will depend to a great degree on the size of the porous structure, the pore size thereof and the size of the spinneret. If the porous structure is only ¼ inch in height, considerably less pressure will be required to produce the desired flow rate per square inch of interior wall surface. If the porous member is up to 5 inches in height, a considerably higher delivery pressure will be required to produce the desired flow rate of diffused gas from the interior wall surface of the porous structure. The size of the spinneret, that is the distance across the spinneret to its center, will also dictate a variation in the pressure and flow rate.

The spinneret used with the apparatus and method of this invention is conventional and can be described in its preferred form as having a multiplicity of concentric rings of substantially evenly spaced holes starting near the center of the spinneret and extending outwardly toward the periphery thereof. The outer course of holes will generally have a diameter of from about 3 to about 7 inches depending on the size of the spinneret assembly. While the spinneret holes have been described as concentric rings, similar arrangements of evenly spaced holes producing a generally annular outer course of holes including spiral and straight line arrangements are considered substantially equivalent. Where the spinneret is larger and contains an outer course approaching 7 inches or so in diameter, the flow rate of cooling gas must be increased to the upper limit and, preferably, the average orifice size of the porous structure will be greater in order to efficiently stabilize all the filaments. When the outer course of filaments is about 4 inches in diameter, a lower flow rate and pore size will be effective. Care must be taken under the conditions set forth herein to use the proper flow rate of cooling gas for stabilizing and quenching the filaments since too low a flow rate will not be totally effective while too high a flow rate may degrade the filaments and adversely effect their drawability.

The fibers or yarns formed with the apparatus and method of this invention are advantageously employed in the manufacture of mechanically crimped high quality staple fiber.

An example of the working of the apparatus and method of this invention follows:

EXAMPLE

Polyethylene terephthalate resin having an intrinsic viscosity of about 0.6 was melt extruded under pressure through a 600 hole spinneret wherein the outer annular course of holes had a diameter of about 4 inches at a rate of 40 pounds of resin per hour (0.067 lb. per hour per hole). The spinning apparatus was such as to produce undrawn filaments of 5 denier.

Initially the filaments were conventionally quenched by cooling air flowing unidirectionally and perpendicularly thereto at a velocity of 120 cubic feet per minute from a straight foraminous quench opening of about 6 by 12

inches (0.83 c.f.m./sq. in.) beginning about 4 inches from the spinneret face. The filaments produced were completely unsatisfactory because of cemented or "dumb-bell" cross-sectional shapes and variable size cross-sectional shapes as shown in FIG. 1 of the drawing. Varying the velocity of the quench air emanating from a fine mesh screen did not improve the cementing problem but did adversely effect the drawability of the yarn.

Conventional quenching was discontinued and the quenching assembly including the porous structure as shown in FIG. 3 of the drawing was positioned about 1½ inches under the spinneret face. The porous structure was ½ inch thick carbon having an average pore size of about 100 microns. Air was pumped into ports **24** and **26** of the quenching assembly **14** at 5 p.s.i.g. which provided a diffused uniform flow of air emerging from the interior wall surface of the porous carbon at a rate of about 0.5 cubic foot per minute per square inch. The filaments now produced under the same spinning conditions had a substantially uniform cross-section with no "dumb-bell" formations.

High quality staple fibers were produced from a tow of the fibers produced in this manner by a wet orientation process, mechanical crimping and heat setting.

I claim:

1. In an apparatus for extruding molten synthetic thermoplastic resin filaments of a size no greater than 5 denier from a spinneret having a plurality of substantially evenly spaced holes the outer course of which has a diameter ranging from about 3 to about 7 inches, a hole density of at least 30 holes per square inch of spinneret surface within its perforated area, and pumping means to extrude said molten synthetic resin through said spinneret holes at a rate of at least 0.06 lb. of resin per hour per hole, the improvement which comprises an annular solid porous structure having multi-directional orifices positioned parallel to and concentric with the spinneret face at a distance ranging from about ½ to about 6 inches from said face, said porous structure having an interior wall surface of a dimension such that the flow of cooling gas therefrom will reduce fusing of the molten filaments which emanate from said spinneret, said porous structure having an average pore size ranging from about 100 to about 180 microns, and means to cause a cooling gas to flow through the porous member and uniformly emerge from said interior wall surface at a rate of from about 0.4 to about 1.0 cubic foot per minute per square inch.

2. The apparatus of claim **1** wherein the solid porous structure is from about ¼ to about 1 inch high, from about ½ to about 2 inches from the spinneret face and has an interior wall surface of a dimension such that it is from about ⅛ to about 1 inch away from the outer course of filaments.

3. The apparatus of claim **2** wherein the cooling gas is caused to flow through said interior wall surface at a rate of from about 0.5 to about 0.7 cubic foot per minute per square inch.

4. In a method of preparing undrawn thermoplastic resin fibers having filaments of a size no greater than 5 denier by extrusion of molten resin at a rate of at least 0.06 lb. of resin per hour per hole through a spinneret having a plurality of substantially evenly spaced holes the outer course of which has a diameter ranging from about 3 to about 7 inches, said spinneret having a hole density of at least 30 holes per square inch of spinneret surface within its perforated area, the improvement which comprises impinging a substantially uniform annular flow of a diffused cooling gas from multi-directional orifices having an average cross-sectional size in their largest dimension from between about 100 and 180 microns at an initial flow rate of from about 0.4 to about 1.0 cubic foot per minute per square inch against the freshly extruded molten filaments, said orifices being within a distance from the outer course of molten filament sufficient to reduce the fusing of the filaments emanating from the spinneret.

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JAY H. WOOD, Primary Examiner

U.S. Cl. X.R.

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