United States Patent [19]

Schwarz

[11] **3,806,289**

[45] **Apr. 23, 1974**

[54] **APPARATUS FOR PRODUCING STRONG AND HIGHLY OPAQUE RANDOM FIBROUS WEBS**

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[22] Filed: **Apr. 5, 1972**

[21] Appl. No.: **241,373**

[52] **U.S. Cl.** **425/72**, 264/115, 425/461

[51] **Int. Cl.** **B29f 3/08**

[58] **Field of Search** ..... 425/72, 83, 461; 264/115, 264/121, 210 R

[56] **References Cited**

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2,662,576	12/1953	Pukacz	264/121 X
3,070,420	12/1962	White et al.	264/121 X
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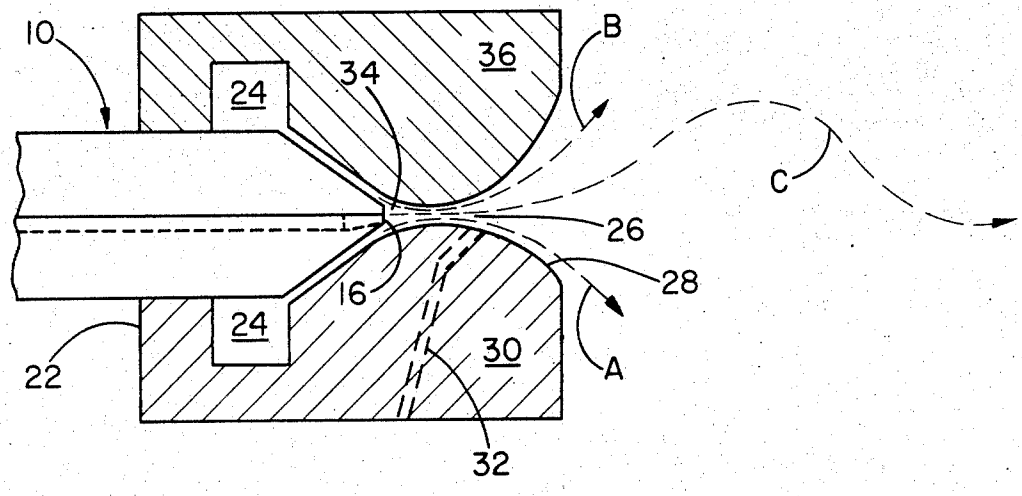
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[57] **ABSTRACT**

Apparatus for producing a randomly mixed fibrous web of high strength and opacity. A thermoplastic polymer is extruded through a die having slots of varying length and cross-sectional area. Air at about the polymer melt temperature is impinged angularly on the fibers and allowed to expand thus cooling the fibers and breaking them up into varying dimensions as they are deposited on a carrier. In a preferred embodiment a controlled Coanda effect is applied so as to provide an overall wavy pattern of randomly mixed fibers.

7 Claims, 8 Drawing Figures



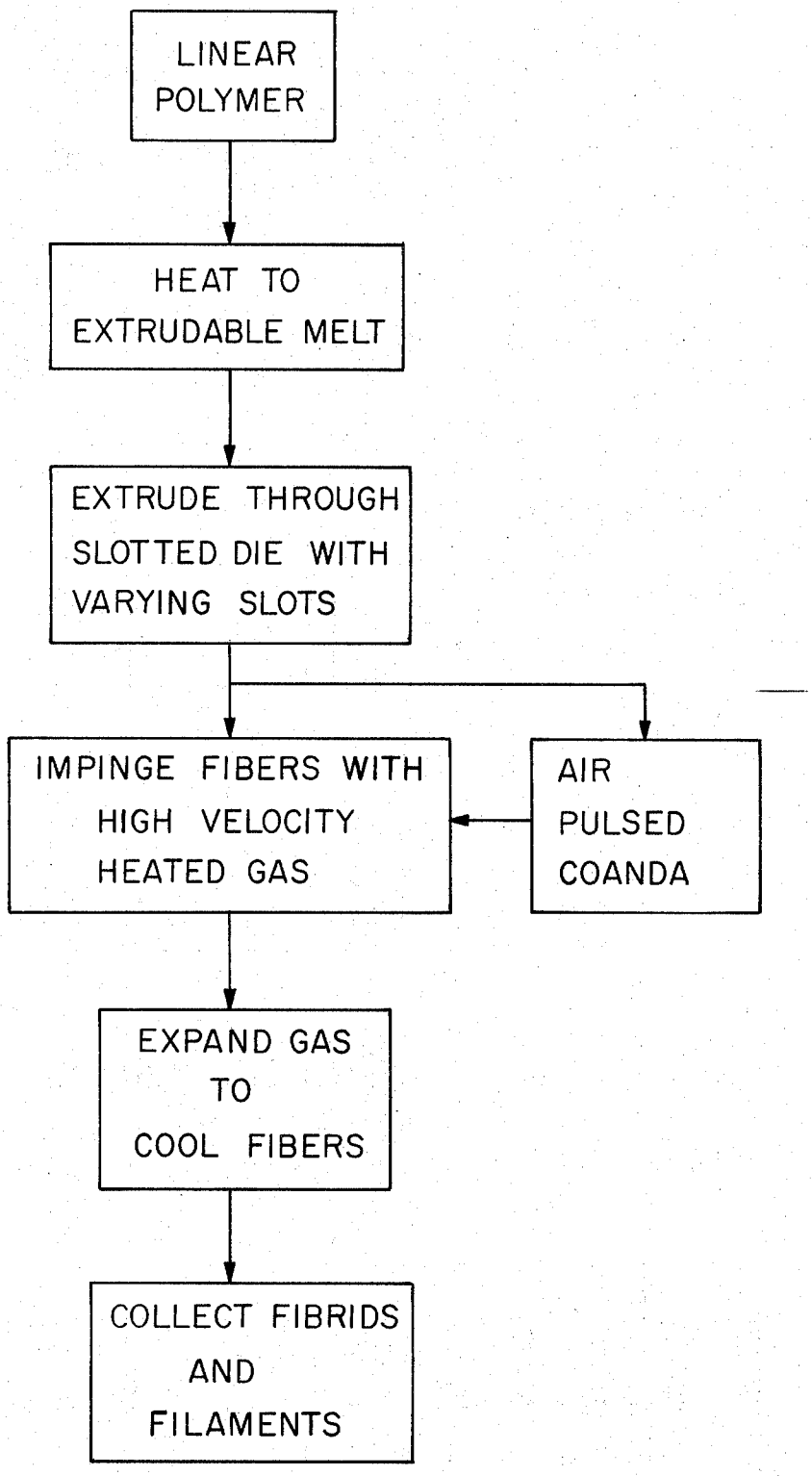

LINEAR POLYMER
HEAT TO EXTRUDABLE MELT
EXTRUDE THROUGH SLOTTED DIE WITH VARYING SLOTS
IMPINGE FIBERS WITH HIGH VELOCITY HEATED GAS
AIR PULSED COANDA
EXPAND GAS TO COOL FIBERS
COLLECT FIBRIDS AND FILAMENTS

FIG. 1

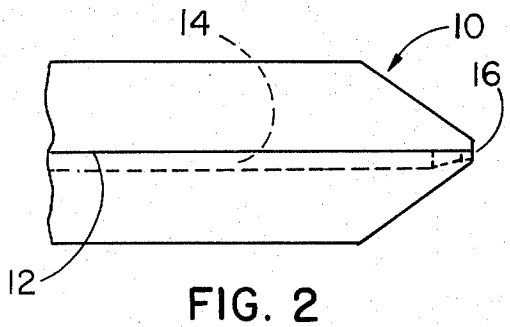


FIG. 2

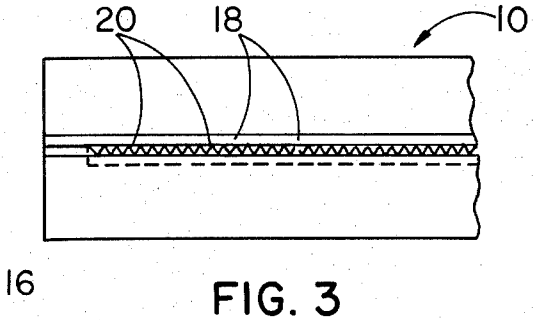


FIG. 3

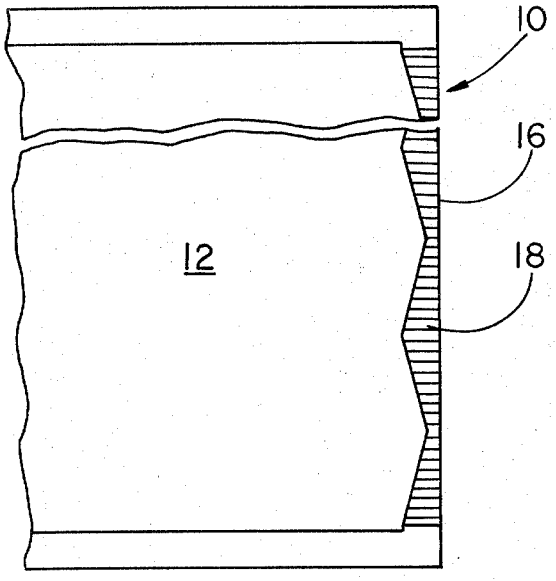


FIG. 4

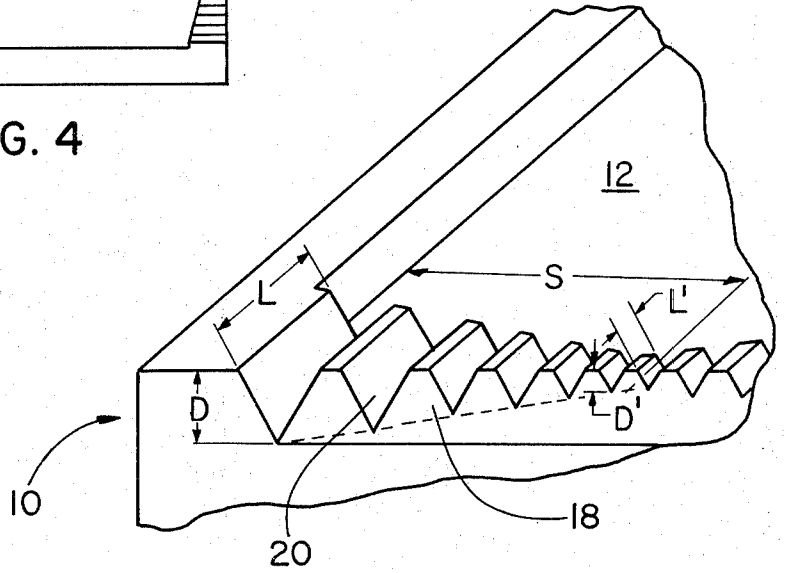


FIG. 5

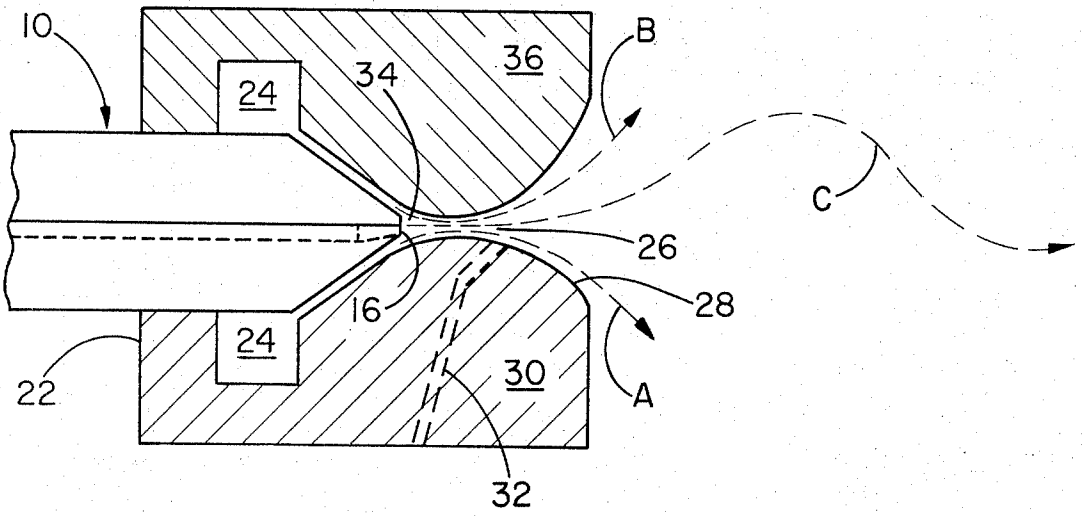


FIG. 6

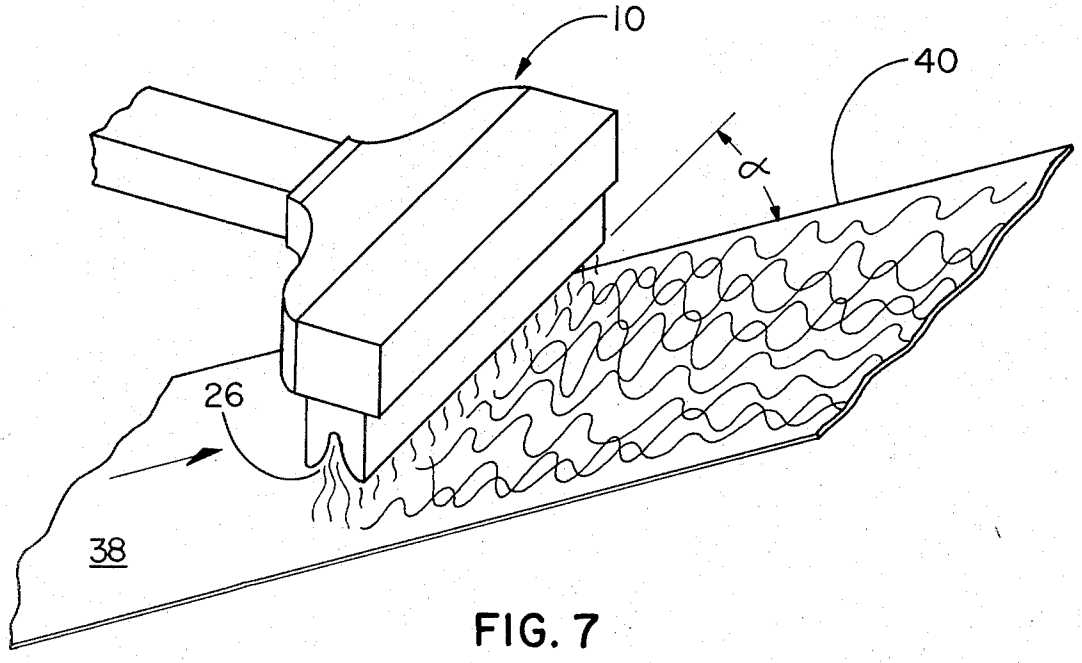


FIG. 7

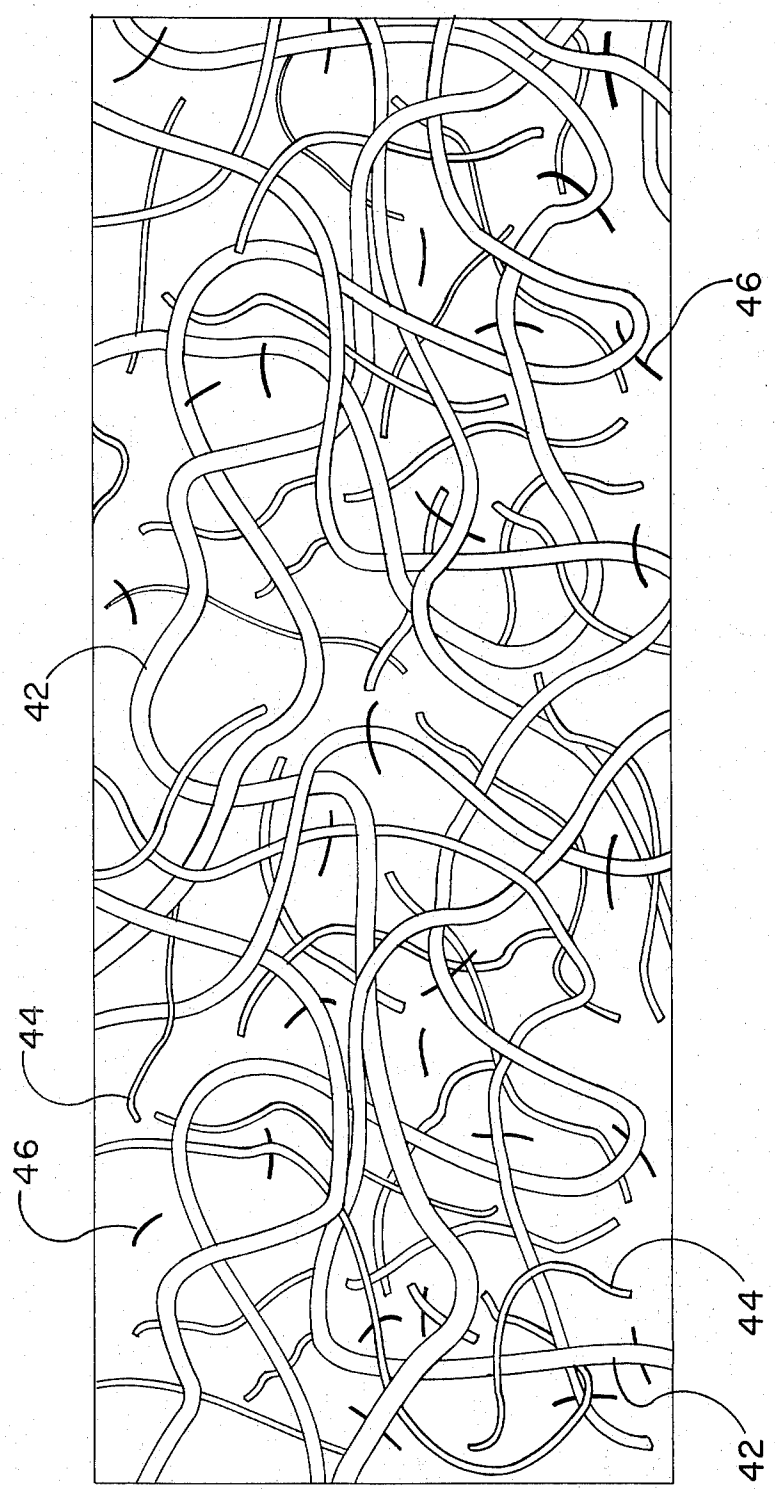


FIG. 8

APPARATUS FOR PRODUCING STRONG AND HIGHLY OPAQUE RANDOM FIBROUS WEBS

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates generally to nonwoven fibrous webs. More particularly, the invention relates to extrusion apparatus that produce webs characterized by high strength and opacity.

2. Description of the Prior Art

It is known to form fibrous webs by drawing fibers from an extruder and depositing them on a moving carrier such as a rotating screen or moving wire. It is further known to perform the drawing step by impinging a current of air against the fibers. U. S. Pat. No. 3,509,009 to Hartmann, for example, discusses such methods and apparatus for carrying them out including extruder dies formed by grooves in wedges which are placed together so that the grooves are juxtaposed. As the polymer is extruded, the mass is blown into fine fibers through the use of air currents and forms a web on a moving carrier. This patent teaches, however, that it is preferred to draw continuous filaments by entraining them in a gas stream directed into the filament path and depositing them on a foraminous support.

It is also known and disclosed in U. S. Pat. No. 3,488,819 to Jackson, for example, that the Coanda effect of a divergent nozzle may be utilized to oscillate an airjet causing an entrained yarn to be deposited on a carrier in continuous crosswise movement. In addition, the prior art contains teachings of the use of dies for extrusion having various shapes and configurations of spinneret holes; such are disclosed, for example, in U. S. Pat. Nos. 3,249,669 and 3,528,129.

SUMMARY OF THE INVENTION

The present invention has as a primary object to provide improvements in apparatus for producing nonwoven fibrous webs of exceptional strength and opacity for a given weight. Other objects and advantages will be apparent upon reference to the drawings and to the detailed description below.

In accordance with the invention the improved webs are formed by heating a thermoplastic polymer to produce an extrudable melt, extruding the melt through a slotted film die having slots of correspondingly varying length and cross section, drawing the melt into fibers by impinging a gas at the melt temperature at an angle to the extruding polymer, cooling the gas and fibers by allowing the gas to expand thereby causing the fibers to break up in varying lengths, and collecting the broken fibers into a web. In a preferred embodiment the apparatus includes means for providing a Coanda effect and angular deposition in an interlocking crosswise wave pattern.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a flow diagram illustrating the steps of the preferred method,

FIGS. 2 to 5 are views of a preferred die construction,

FIG. 6 is a sectional view showing means for providing the Coanda effect,

FIG. 7 illustrates a preferred deposition system whereby the Coanda and angular die placement provide desired sheet properties, and

FIG. 8 schematically illustrates a formed web portion.

DETAILED DESCRIPTION OF THE INVENTION

The apparatus of the invention will now be described in detail with particular reference to the preferred embodiments illustrated in the drawings.

Turning to FIG. 1, the process involves first the selection of a suitable thermoplastic polymer. Many such polymers capable of extrusion in fiber form are available, and the particular one to be utilized is a matter of choice based usually on considerations such as cost, melt temperature, fiber properties, and extrusion properties, as well as desired web characteristics. Examples of polymers contemplated for use in the invention include the following: polyolefins, nylons, polyesters, and polyacetals. However, it will be recognized that other extrudable polymers are available, and the invention is not to be limited to those specifically mentioned.

The selected polymer is then made extrudable by heating to some temperature above its melting point. Preferably the heating is only sufficient to result in an extrudable melt as additional heat will be generated by extrusion, and overheating or excessive degrading of the polymer is to be avoided. Generally, temperatures of from about 10° to about 50°C above the polymer melting point are sufficient for the contemplated polymers. This melt is extruded through a slotted die having slots with correspondingly varying slot length and cross sectional area dimensions. The phrase "correspondingly varying" is used to indicate that the length and cross section area dimensions must vary in the same manner. That is, the larger the slot length, the larger will be its cross sectional area. In general, each slot is preferably of uniform dimensions which are different from those of adjacent slots. The fibers emerging from the die are impinged by high velocity air at about the melt temperature directed at an angle of from about 10° to 45° to the fiber orientation direction. The gas is thereafter allowed to expand rapidly causing cooling and fracturing of many of the fibers into a mixture of fibrids, short fibers and filaments of widely varying dimensions. In the terms of this invention the words "fibrids", "short fibers" and "filaments" are defined as follows: filaments are substantially continous strands generally of 1 to 20 denier, short fibers are discontinuous strands ¼ inch to 3 inches in length and generally of ½ to 3 denier, and fibrids are short strands of less than ¼ inch in length and generally less than ½ denier. This mixture is collected on a moving carrier such as a screen or the like and forms a strong, opaque web which may be removed and wound into rolls with apparatus conventionally used for such purposes. By "opaque" it is meant that the web has high opacity for its thickness, normally in the range of from 60 to 95 percent as measured by TAPPI Standard Method No. 175P.

As indicated by the flow diagram, FIG. 1, an alternative embodiment includes the step of using a Coanda arrangement to direct the fibers across the receiving carrier. Pulsed air may be used to cause the fibers to deposit in wavy patterns across the carrier surface. This manner of deposition increases the interlocking nature of the random pattern of the fiber-filament-fibrid mixture thus augmenting strength and opacity.

Turning now to FIGS. 2 to 5, the invention will be described in terms of the embodiment illustrated therein.

In these views a die, generally indicated as **10**, is shown schematically. In accordance with the invention it includes a smooth top surface **12** and bottom surface formed by cavity **14** and lip **16** having grooves or slots of regularly varying dimensions. As an example, the slots may vary in length, L,L', from 0.080 inch to 0.015 inch and in depth D,D', from 0.050 inch to 0.010 inch in a spacing, S, of about 0.250 inch with five teeth **18.** This pattern is preferably repeated in a cylical manner across the lip **16** as illustrated. These dimensions are particularly suitable for use with polyolefins, e.g., polypropylene, and results in a web having the previously mentioned advantages of strength, opacity, and gross uniformity of formation. Of course, the particular dimensions selected involve largely a matter of choice depending upon the desired fiber characteristics in the web and will, in some cases, differ widely from the example recited. In particular, the specific slot cross-section shape need not be as shown since it is recognized that the filaments, fibers, and fibrids will tend to become round in cross-section as cooling takes place. It is only critical that the slots **20** exhibit significant variation in both length and cross-sectional area across the lip **16** of die **10.** The ratio of length to cross section is preferably selected for each polymer to result in generally equal shear stresses for each slot. Thus, the conditions are such that in all cases,

$$Pa = s\ CL$$

where

P = die pressure, psi;
C = slot cross sectional circumference, in.
s = shear stress, lbs./in.
a = slot cross section, in.^{2}
L = slot length, in.

thus, s/P = constant = a/CL for each slot. While the circumference of the slots depends on the cross sectional shape, where the same shape is selected for all slots, it will vary in proportion to $\sqrt{a}$. Hence, it is preferred that the individual slot lengths be proportioned according to $\sqrt{a}$ to maintain a constant value of a/CL. By keeping the shear stress generally equal in all slots, flow through each one is assured. The particular slot cross section shape depends upon the desired properties and end use. It may be round, rectangular, or triangular, for example. A "dog-bone" shape may be used to produce an effect of high luster.

The number of teeth 18 per inch of width will similarly be dependent upon desired fiber properties such as denier as well as web properties such as basis weight. However, it is contemplated that the typical ranges for these dimensions for producing a web with paper-like strength and opacity will be as follows: length of groove (L,L') 0.008 to 0.5 inch; cross sectional area of groove 0.0001 in.^{2} to 0.0025 in.^{2}, preferably 0.0002 in.^{2} to 0.0015 in.^{2}; and number of grooves from about 5 to 100 and preferably from 10 to 30 grooves per inch. The larger dimensions will, of course, result in fiber mixtures wherein the fibers are correspondingly larger. In all cases, though, the resulting web will be characterized by a mixture of fibers of differing length and denier.

Turning now to FIG. **6,** a preferred embodiment will be described. Die **10** as previously described is housed within chamber **22.** As shown in cross-section the housing includes dual air manifolds **24** which direct air flow from a source at elevated temperature (not shown) down the beveled edges of die **10** to lip **16** and out through nozzle **26.** In accordance with the invention in a preferred embodiment, nozzle **26** includes an outlet **28** having a nearly symmetrical Coanda configuration which has been exaggerated in the drawing for illustrative purposes. By avoiding complete symmetry it is possible to produce higher stability on one side of nozzle **26** to which the fibers will naturally be drawn as they are formed; in the illustrated case the preferred side will be side **30** which has a slightly smaller, by about 1 to 10 per cent, for example, radius of curvature when compared to the radius of side **36.** Channel **32** is provided in side **30** and connected to a source (not shown) of pulsed air. Such sources are well known and, in themselves, form no part of the invention. For example, such pulsing mechanisms may include a fan that alternately blocks and opens channel **32** to the passage of air at a pressure somewhat greater than that supplied by manifolds **24.**

In operation, the polymer is extruded through die **10** and lip **16** as various sized fibers, indicated generally as **34.** Air from any suitable source (not shown) under a pressure of about 10 to 150 psig resulting in a jet speed in nozzle **26** of from 1000 to 21,600 yards per minute, preferably from 10,000 to 21,600 yards per minute and heated to about the temperature of the melt is supplied to manifolds **24** which direct it at opposing angles against the fibers **34** as they emerge from die lip **16** causing some drawing and orientation, especially of the longer fibers. The upper limit of 21,600 yards per minute has been selected as representing sonic velocity. It is recognized, however, that with special orifice designs, higher rates are obtainable; when available, these higher air rates may also be utilized with the present invention.

The path that the fibers would naturally tend to take due to the slight dissymetry of the Coanda configuration is illustrated by arrow A of FIG. **6.** As the air expands, rapid cooling of the polymer filaments **34** takes place causing them to separate into the various lengths for filaments, short fibers, and fibrids. Air under pressure of about 0.1 to **1** psig, for example, is pulsed through channel **32** and, when air is flowing in the channel, causes displacement of the fiber flow towards side **36.** Channel **32** is preferably positioned so that the excited pulsed air moves generally at a tangent to the outlet curve of side **36** on nozzle **26,** thus tending to urge the fibers in that direction as well, as indicated by arrow B. When air is not flowing in channel **32,** the fibers will tend to resume the original flow direction A. The result, indicated by arrow C, is a generally sine wave deposition path in the direction of travel of carrier **38** with a frequency that depends upon the pulsing frequency. This frequency may be, for example, in the range of 2 to 600 cycles per second. In a critically designed system, for example, an oscillating diaphragm of an earphone placed in channel **32** could be used to replace the air pulses and induce vibrations and fiber deposition at a desired frequency.

FIG. **7** is a perspective view of the preferred web-forming operation. Belt or other receiving surface or carrier **38** moves in the direction indicated as by means of rollers or the like and collects fibers **34** as they are deposited by nozzle **26.** As shown, it is preferred that die **10** be disposed angularly with respect to the lateral direction of movement of surface **38.** The angle, α, selected is not critical and preferably may vary, for exam-

ple, between 30° and 60°. It has been found that this angular deposition in combination with the controlled Coanda effect results in wavy motion of the fibers in the direction of movement of surface **38**. The fibers are caught in this interlocking pattern as a random mixture of oriented filaments, short fibers and fibrids. The rapid cooling caused by the nozzle expansion prevents deorientation of the fiber molecules and shrinking of the fiber ends which has previously resulted in balling and lumping producing poor formation characteristics.

FIG. **8** schematically illustrates the web **40** formed on surface **38** which may be subsequently treated by methods and for purposes that are well known. For example calendaring may be used, and the resulting sheet will display increased stength and density due to the fibrids intermixed between the fibers. These fibrids also increase the total inner surface area thus providing increased fiber-to-fiber and fiber-to-air interface area and higher opacity. The filaments **42** are longer, thicker, and issue from the larger slots. Fibers **44** are medium sized and issue from the average sized slots, while the remaining short, thin fibrids **46** issue from the small slots.

The webs produced in accordance with the invention have wide utility. For example, depending upon the polymer and fiber size ranges, they may be used as synthetic papers, base materials for garments, and reinforcing material for tapes. Other uses for specific combinations will be apparent to those skilled in this art.

In summary, the invention comprises an improved apparatus for use in a method for producing strong, opaque fibrous webs including the steps of extruding a polymer through a die having slots of corresponding varying dimensions and impinging the fibers at an angle with heated, high velocity air. The fibers are cooled by rapid air expansion and collected on a carrier to form a web. A controlled Coanda may be used and the fibers deposited at an angle with respect to the carrier in preferred arangements. The apparatus of the invention includes a die having a lip with slots of correspondingly varying dimensions as well as means for applying a controlled Coanda effect and angular deposition in the preferred embodiments.

I claim:

1. Apparatus for producing a high strength opaque web of random filaments, fibers and fibrids, from a thermoplastic polymer comprising, in combination,

a. means for providing the polymer in extrudable form;

b. an extruder adapted to receive said polymer and having a slotted die with slots of correspondingly varying length and cross sectional area dimensions selected to result in generally equal shear stresses for each slot;

c. means for providing high velocity air at about the extrusion temperature of said polymer;

d. conduits for said air causing impingement with the extruding polymer as it emerges from the extruder, said impingement being from opposing sides at an angle of from about 10° to 45° to the fiber direction and tending to draw and orient said emerging fibers;

e. a diverging nozzle configuration for rapidly expanding and cooling said air and extruding polymers; and

f. means for collecting said extruding polymer as it is formed into filaments and fibrids.

2. Apparatus of claim **1** wherein said extruder and die are disposed angularly with respect to the collecting means.

3. Apparatus of claim **1** further including means for providing a Coanda effect wherein said diverging nozzle has a nearly symmetrical Coanda configuration and pulsing means are provided to disturb the Coanda effect with the result that said extruding polymer is deposited on said collecting means in an interlocking wave pattern.

4. Apparatus of claim **1** wherein said die slots vary regularly in length in the range of from about 0.008 inch to 0.500 inch and in cross sectional area in the range of from 0.0001 $in.^2$ to about 0.0025 $in.^2$ with from five to 100 slots per inch providing generally equal shear stresses in each slot.

5. The apparatus of claim **3** wherein said pulsing means is a conduit for pulsed air at a pressure slightly higher than said heated air.

6. The apparatus of claim **5** wherein said conduit provides air pulsed at a frequency of from 2 to about 600 cycles per second which is directed at an angle tangent to the outlet curve side of said diverging nozzle.

7. The apparatus of claim **5** wherein said pulsing means includes an oscillating diaphragm.

* * * * *