

[54] MELT-BLOWING DIE USING CAPILLARY TUBES

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[52] U.S. Cl. 425/72, 425/464

[51] Int. Cl. D01d 3/00, D01d 7/00

[58] Field of Search 425/464, 72; 264/176 F, 264/178 F

[56] References Cited

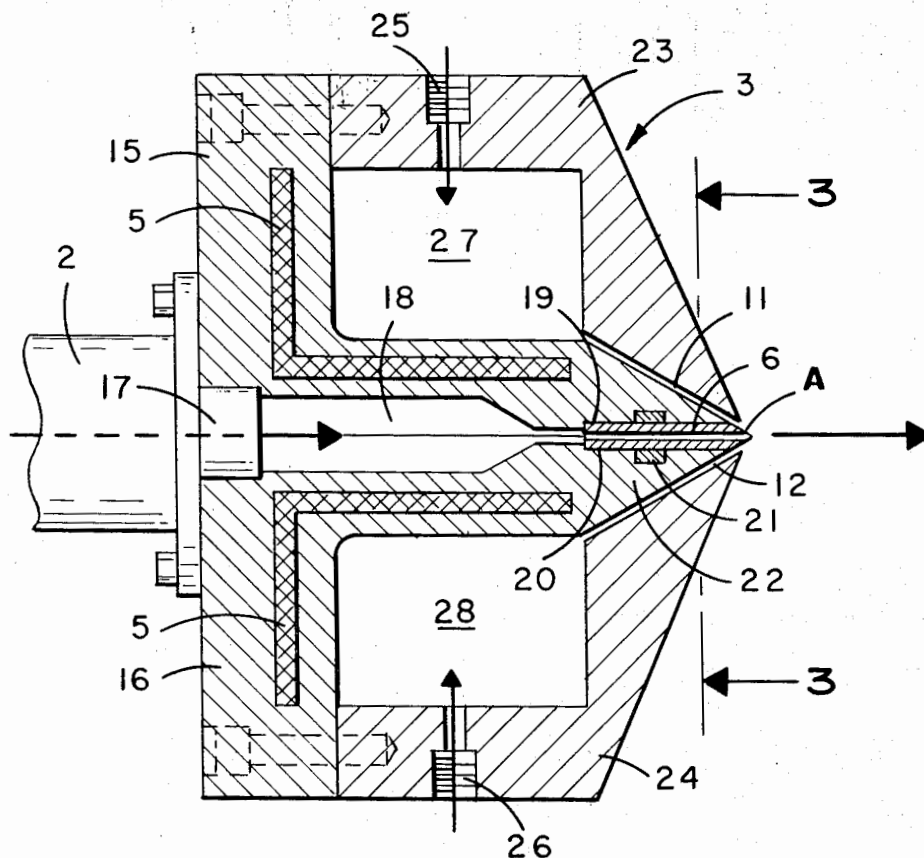
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[57] ABSTRACT

A melt-blowing die which has capillary tubes rather than drilled orifices is more easily fabricated and operates more effectually. Preferably, one end of each capillary tube is machined so as to terminate in an apex having an included angle within the range of 30° to 90°. Or the tubes can have conical ends with the same angle. The inside diameter of these tubes range from 0.010 to 0.025 inch and they connect with a chamber in the die. Preferably the die is a two-piece assembly and is fabricated by bolting the two pieces and including the capillary tubes in a solder layer.

16 Claims, 11 Drawing Figures



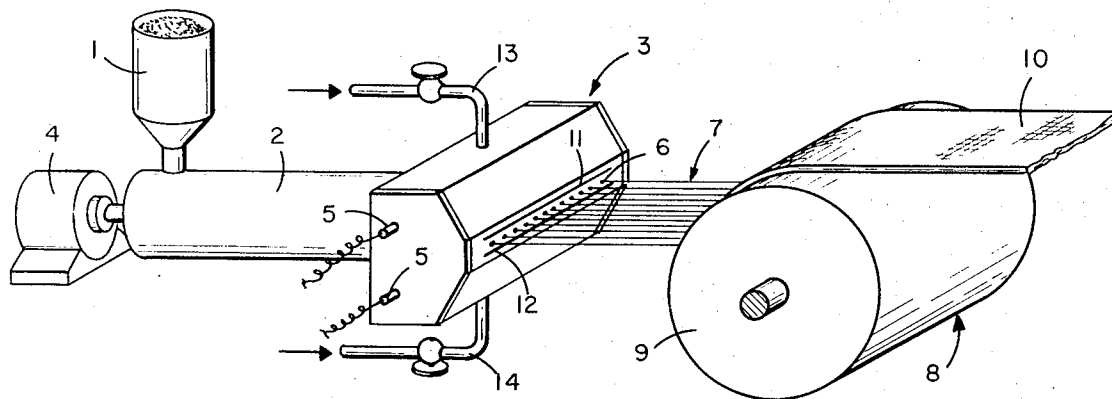


FIG. 1.

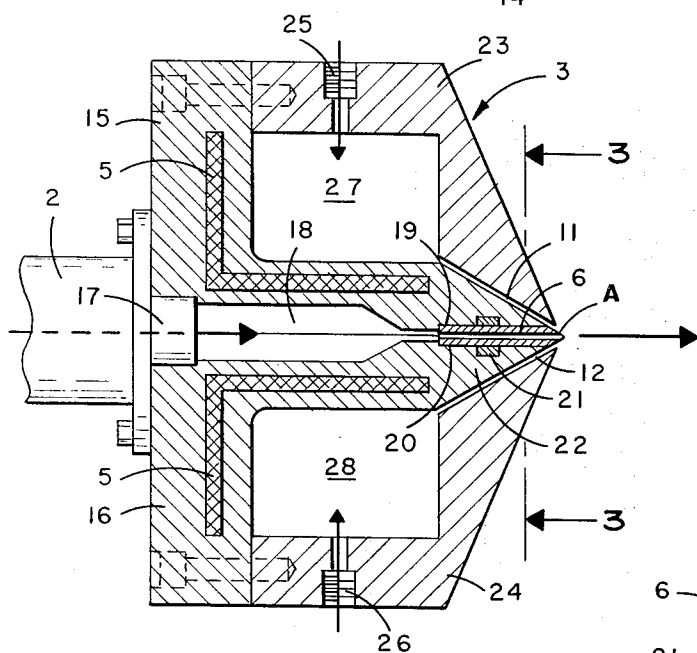


FIG. 2.

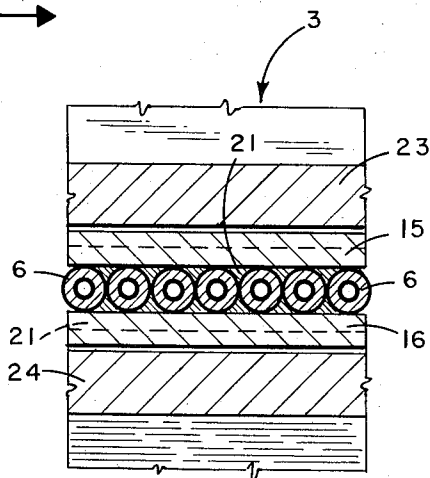


FIG. 3

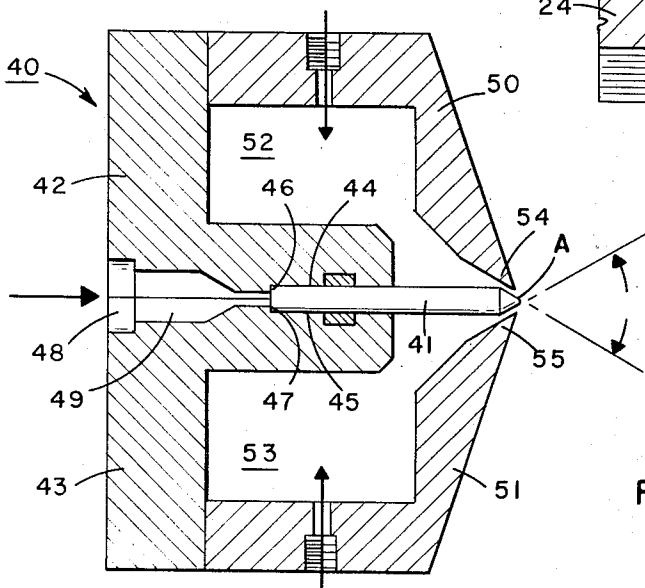


FIG. II.

FIG. 4.

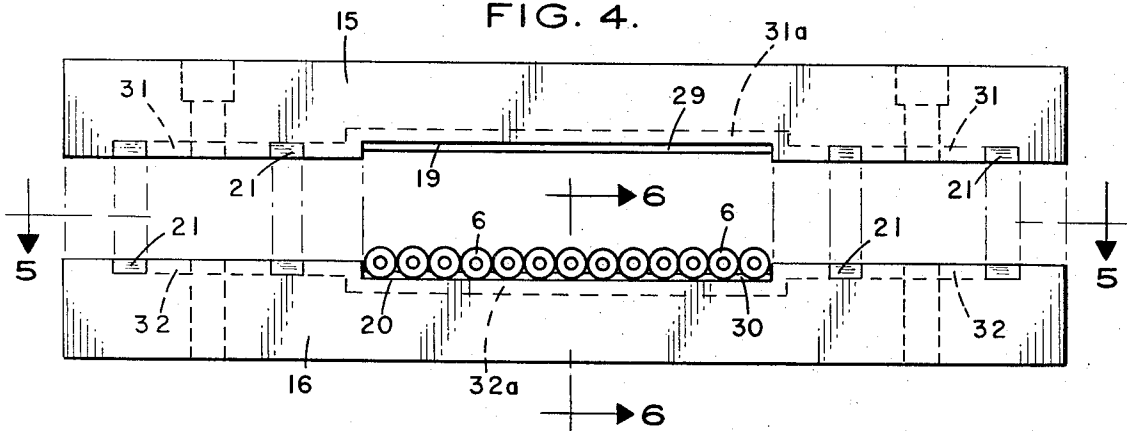


FIG. 5.

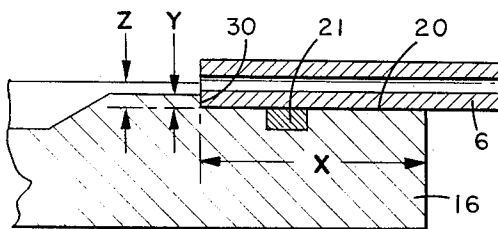
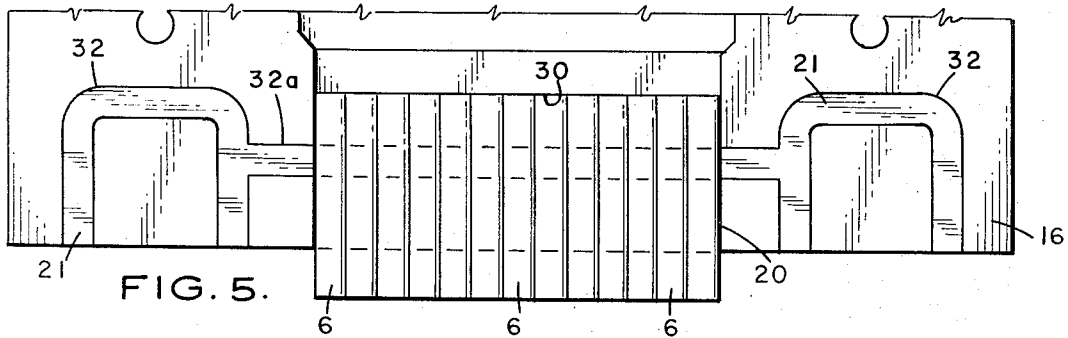


FIG. 6.

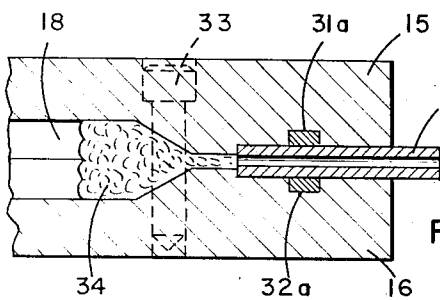


FIG. 7.

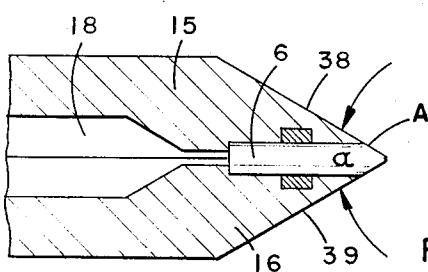


FIG. 10.

FIG. 8.

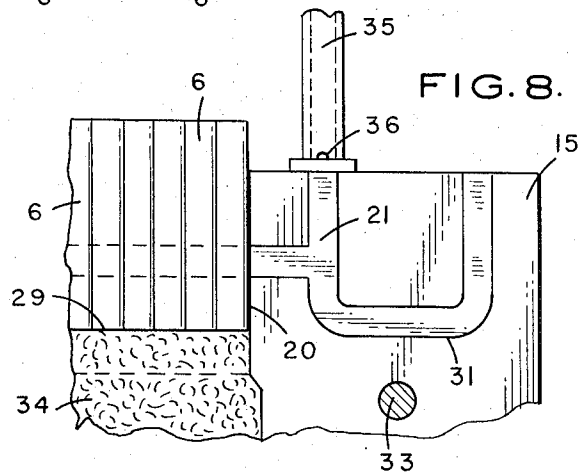
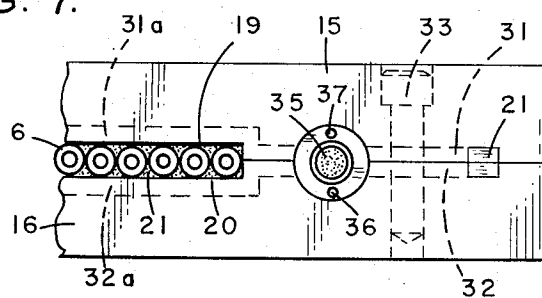


FIG. 9.



MELT-BLOWING DIE USING CAPILLARY TUBES

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention is directed to a die for the melt-blowing of thermoplastic resins which uses capillary tubes for die openings. More particularly, the present invention relates to a die having a plurality of capillary tubes to produce a line of die openings having internal diameters which are uniform and are precisely aligned as required for the melt-blowing process.

2. Prior Art

Melt-blowing and suitable dies therefor are disclosed in the following publications and patents:

1. Naval Research Laboratory Report 4364, "Manufacture of Superfine Organic Fibers", Apr. 15, 1954.
2. Wentz, Van A., *Industrial and Engineering Chemistry*, 48, No. 8 (1956, pp. 1342-1346).
3. Naval Research Laboratory Report 5265, "An Improved Device for the Formation of Superfine, Thermoplastic Fibers", Feb. 11, 1959.
4. British Pat. No. 1,055,187.
5. U.S. Pat. No. 3,379,811.
6. Japanese Pat. 25871/69, published Oct. 30, 1969.

SUMMARY OF THE INVENTION

A die apparatus for melt-blowing thermoplastic materials having a plurality of capillary tubes as the die openings. The die is a two piece assembly and the capillary tubes are included in the solder layer between the two pieces to form the die apparatus.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic view of the overall melt-blowing process;

FIG. 2 is a cross sectional view of one embodiment of the present invention;

FIG. 3 is a cross sectional view taken across 3—3 of FIGS. 1 and 2;

FIG. 4 is a front view of the melt-blowing die with the capillary tubes in place on the lower portion of the die;

FIG. 5 is a sectional view taken across 5—5 of FIG. 4 showing a top view of one portion of the die with the capillary tubes in position before soldering;

FIG. 6 is a cross sectional view taken across 6—6 of FIG. 4 showing one capillary tube in position before soldering on one piece of the die;

FIG. 7 is a view in cross section similar to FIG. 6 wherein the two pieces making up the die are bolted together and packed in preparation for heating the solder;

FIG. 8 is a view in cross section of the die as the die would be positioned in the oven or being heated, with a reservoir for the solder attached;

FIG. 9 is a top view of the die with the reservoir for the solder attached before machining;

FIG. 10 is a cross sectional view of the die after machining whereby a preferred embodiment of the present invention is produced; and

FIG. 11 is a cross sectional view of another embodiment of a die of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

During the course of the research project leading to this invention, it was found that dies for use in a melt-blowing process require very close tolerances. This has made their fabrication very difficult and costly. One requirement which is responsible for the high cost is the large number of very small holes which must be drilled. A second requirement which was found, that fabricators have difficulty adhering to, is that all holes must emerge on a sharp (chisel) edge and that this line of holes must be accurately in line over long distances. The center of each tube must not be offset from a straight line by more than 3 mils.

A method has been found of fabricating this type of die which overcomes some of the above difficulties and reduces the cost of the die. This method uses capillary tubes to replace drilled holes in the die. By using capillary tubes, the problems associated with precise drilling or electrical discharge machining of very small holes are avoided. Of greater importance, it is possible to align the row of capillary tubes very precisely so that the holes follow a straight line accurately.

In general the method used to demonstrate the principles of using capillary tubes follows. Two metal blocks which will each form one-half of the die are machined with the desired melt cavity. The melt cavity distributes the flow of thermoplastic fluid to the inlets of the orifices. Slots are then milled accurately in the areas where the capillaries are to be packaged. Each block has an identical slot with a depth equal to or slightly less than the radius of a capillary tube. Channels are then milled in the end blocks (outside of the area which will contain holes) and along the slots at the mid-point of the tube location. These channels are filled with solder and then the solder is machined smooth. The capillary tubes are then packed into one slot and the two halves are matched and carefully aligned. The clamped halves are placed in a nitrogen oven where the soldering is completed. The soldered die is then finally machined.

Other methods of soldering can also be used. The advantages of using a capillary die include the following:

1. Holes can be longer since they do not have to be drilled.
2. Hole diameters are very uniform.
3. Holes do not have burrs or jagged interiors.
4. It is easier to achieve the precise alignment required to make superior webs by the melt-blowing process.

5. Machining of a melt channel is easier since this can be done on split halves, as compared to a single piece assembly.

6. Fabrication costs are greatly reduced.

A 2-inch die has been made using the capillary tube method. This die has performed satisfactorily on the melt-blowing process.

Since melt-blowing in general and dies therefore have been described as indicated above this specification will be devoted to the details of the novel die apparatus of the invention.

This can be best accomplished with the aid of the drawings.

Referring to FIG. 1 of the drawings, a melt-blowing process is carried out by introducing into hopper 1 pel-

lets of one or more thermoplastic materials, i.e. resins, and which may include dyes, additives or other modifiers with the thermoplastic resins. These are conveyed into extruder 2.

With some thermoplastic resins it is necessary to degrade them to a considerably lower viscosity by either thermally treating the resin before introducing the resin into the extruder 2, or thermally treating the resin in the extruder 2 and/or die assembly 3.

For example, if polypropylene is to be melt-blown, the polypropylene is added into hopper 1 and heated in extruder 2 at temperatures in excess of 550° F., and preferably within the range of 620° to 800° F. The degree of thermal treatment necessary varies with the molecular weight of the polypropylene.

Resin is forced through extruder 2 into die head 3 by drive 4 which turns the extruder screw (not shown). Die head 3 usually contains heating plate 5 which may also be used in the thermal treatment of the thermoplastic resin before it is melt-blown.

The fluid resin is then forced out of a row of capillary tubes 6 rigidly mounted within die assembly 3, where it is impinged by a gas stream which attenuates the resin into continuous fibers 7 which are collected on a moving collecting device 8 such as drum 9 to form a continuous mat 10.

The hot gas stream, preferably air, which attenuates the thermoplastic resin is supplied through gas jets or slots 11 and 12, respectively, which are adjacent to and on either side (above and below) of the die openings. Slots 11 and 12 are supplied with hot gas by gas lines 13 and 14, respectively.

Referring now to FIG. 2, thermoplastic resin through inlet 17 is introduced into the back of die head 3 which comprises upper die block 15 and lower die block 16.

The resin is forced into chamber 18 between the upper and lower die blocks 15 and 16, respectively.

According to the present invention, upper and lower die blocks 15 and 16 have been milled beyond chamber 18 to form troughs 19 and 20 to provide a seating cavity for capillary tubes 6. Capillary tubes are rigidly positioned in troughs 19 and 20 between die blocks 15 and 16 by solder 21.

In this embodiment, the tubes 6 terminate exterior to chamber 18 in a sharp-angled point indicated as A. Die nose 22 is of generally triangular cross section and can be formed by machining the exterior surfaces of die blocks 15 and 16 as will be described in more detail hereinafter. The point A of the tubes 6 are formed in the machining operation. The angle of the point is within the range of 30° to 90°, preferably 55° to 65°, most preferably 60°.

An upper gas cover plate 23 and a lower gas cover plate 24 are connected to upper and lower die blocks 15 and 16. Hot gas is supplied by inlet 25 in gas plate 23 and inlet 26 in gas plate 24. Suitable baffling means (not shown) can be provided in both upper gas chamber 27 and lower gas chamber 28 to provide a uniform flow of gas through the gas slot 11 and 12.

FIG. 3 shows the relationship of the tubes 6 to each other after having been aligned and soldered into a preferred configuration.

Referring to FIGS. 4-10, inclusive, there is illustrated a technique for making the inventive die. An identical groove or trough 19 is machined in die blocks 15 and 16 and a groove or trough 20 is machined in lower die

block 16. The dimensions of troughs 19 and 20 are selected so that when in operating position they just hold the desired number of capillary tubes 6 as determined by the outer diameter (O.D.) of capillary tubes 6.

Troughs 19 and 20 extend into the upper and lower die blocks 15 and 16 ending near shoulder 29 in upper die block 15 and near shoulder 30 in lower die block 16. The height of shoulders 29 and 30 should preferably not exceed the outer diameter tubes 6.

FIG. 4 illustrates the relationship of the various parts prior to final assembly and prior to the actual soldering operation. Solder reservoirs 31 and 32 are seen in cross sectional view. A solder reservoir 31 is in the upper block plate 15 and a solder reservoir 32 is in the lower block plate 16.

In FIG. 5 in lower die block 16, solder reservoir 32 comprises two U-shaped portions on either side of trough 20 with a single slot 32a extending across the lower portion of trough 20.

An identical arrangement is milled into upper die block 15 where die reservoir 31 and slot 31a are milled.

For assembly, solder reservoirs 31 and 32 are filled with solder 21. After it has hardened the solder is machined flat so that it does not extend out of the reservoirs. The desired number of capillary tubes are then placed in trough 20 of lower die block 16. Upper die block 15 and lower die block 16 are then bolted together.

As shown in FIG. 7, the two are bolted together by bolts 33 so as to hold capillary tubes 6 firmly within troughs 19 and 20 with the inner ends of capillary tubes 6 abutting shoulders 29 and 30 of the upper die block 15 and lower die block 16. Die blocks 15 and 16 are usually machined to provide the chamber 18 necessary for the introduction of thermoplastic resin to the capillary tubes 6.

Prior to the heating operation for heating the solder 21 and introducing more solder 21 to securely hold the capillary tube 6, insulating packing 34 (shown in FIG. 7) is packed in the chamber 18 so that solder 21 will not flow into chamber 18 while the die is heated for soldering.

In FIGS. 8 and 9, external solder reservoir 35 is shown attached to die blocks 15 and 16 which is bolted to said blocks with screws 36 and 37. The solder reservoir 35 serves to provide a pressure head of solder to replenish solder.

After die blocks 15 and 16 are securely clamped with bolts 33 and tubes 6 are firmly in troughs 19 and 20 and one end of each tube abuts shoulders 29 and 30, die assembly 3 is placed in an oven to heat the solder 21.

When die assembly 3 is placed in the oven, solder 21 melts and flows through solder reservoirs 31 and 32 completely contacting the capillary tubes 6 and filling the space between the capillary tubes 6 in the trough 19 and 20, as shown in FIG. 3. Upon cooling, tubes 6 are rigidly placed between die blocks 15 and 16. It is preferred that the position of the die blocks 15 and 16 be that as shown in FIG. 8 while in the oven or while being heated. Insulating packing 34 prevents flow of solder 21 into the capillary tubes 6 or chamber 18.

It is apparent that the heating must allow solder 21 to completely fill the space around the capillary tubes 6 and provide a complete barricade in troughs 19 and 20 to any possible flow of thermoplastic resin.

Preferably tubes 6 have a length that permits one end of each tube to extend exteriorly past the ends of the die blocks 15 and 16 and lower die block 16 before they are machined.

In the final machining operation, die blocks 15 and 16 are machined to provide a die nose 22 of a triangular cross section which terminates in an angular cross sectional tip A. The angle α as shown in FIG. 10 is between 30° and 90°, preferably between 55° and 65°, and most preferably about 60°.

In one embodiment, die blocks 15 and 16, and tubes 6 are machined so that tubes 6 have surfaces which are integral with surface 38 of upper die block 15 and 39 of lower die block 16, to form the included angle α . See FIG. 10.

Some even more specific details of preferred embodiments follow. In FIG. 6, trough 20 extends into the lower die block 16 for about ¼ inch to about 1 inch, preferably about ½ inch (as indicated by the dimension x).

The capillary tubes 6 have internal diameters of between about 0.010 to about 0.025 inch, and may have outside diameters of between 0.025 and 0.050 inch, preferably 0.03 to 0.04 inch.

Capillary tubes 6 actually used to construct an embodiment of the invention were 316 stainless steel seamless tubes. This type of steel has the ability to resist the temperatures used in the soldering operation. The tubes were 0.015 ± 0.0005 inside diameter x .031 inch outside diameter by 1.0 inch long.

Although capillary tubes having circular cross sections are illustrated, the cross section may be square or rectangular, or any other shape.

It is to be understood that the outside diameter (O.D.) of the capillary tubes controls the spacing of the die openings. This distance is preferably within the range of 30 to 40 mil from center to center.

The dimensions of the shoulder 30 and depth of the trough 20 in the lower die block 16 will vary depending on the size and shape of the capillary tubes 6 used.

Usually, the dimensions are such that die block 15 and die block 16 when in operating position will snugly hold the capillary tubes in the troughs 19 and 20. Hence, if the dimensions of troughs 19 and 20 are identical, depth Z will be one-half the O.D. of the capillary tube used, and the height Y of the shoulder will be equal to or less than the wall thickness of the capillary tube used.

A suitable solder when capillary tubes of 316 stainless steel are used is Eutectic 1801 silver solder having a composition of 51 percent silver, 22 percent copper, 19 percent zinc, 7 percent cadmium, and 1 percent tin. The flux used with such a solder is Eutectic 1801-B flux. This particular solder melts at 1,100° F. and bonds at 1,135° F., according to the manufacturer. While other solder and fluxes may be utilized, if such a solder is used, the clamped upper die block 15 and lower die block 16 would be placed in an oven or otherwise suitably heated to temperatures in excess of the bonding temperature of the solder used. Accordingly, a temperature of at least 1,135° F. is used when Eutectic 1801 solder is employed.

FIG. 11 illustrated a die head embodiment which does not require machining of the die block or capillaries to obtain the desired angular cross sectional tip of each of the capillaries. In contrast it utilizes capillary tubes with conical shaped tips.

Thus, die head 40 is made up of an upper die block 42 and a lower die block 43. Upper die block 42 has a groove or trough 44 and die block 43 also has a groove or trough 45 machined therein for receiving capillary tubes 41. Troughs 44 and 45 end in shoulders 46 and 47. Capillary tubes 41 abut these shoulders.

In operation thermoplastic resin is introduced into the back of the die head 40 through an inlet 48 which enters into a chamber 49 which supplies the resin to the capillaries of the capillary tubes 41.

In this embodiment, capillary tubes 41 project outwardly from the die blocks 42 and 43 at a distance up to about half the length of the tube without requiring any external support other than said die blocks. Upper gas cover plate 50 and a lower gas cover plate 51 forms an upper air or gas chamber 52 and a lower gas chamber 53.

The capillary tubes 41 have a conically formed apex A having an included angle within the range of 30° to 90°, and preferably within the range of 55° to 65°.

Tips 54 and 55 of the upper air plate 50 and lower air plate 51, respectively, have an angle which is the same as that of the apex A of the capillary tubes 41. Furthermore, tips 54 and 55 of the air plate can be positioned so that they are positioned essentially opposite the taper of capillary tubes 41 within the range of 1 to 5 mils.

The die of the present invention has several fabrication and operational advantages over other dies which are in the art or have been developed for the melt-blowing process. Since the tolerances in dimensions are critical in a melt-blowing die, the dies of the present invention allow melt-blowing dies to be made having the uniform small die openings which extend for large widths (40 inches to 60 inches or more, i.e., requiring 500 to 2,000 or more capillary tubes) without the high fabrication cost of the methods before suggested.

Furthermore, as has been discovered by another in the research project the die openings must be in line over a long distance.

Accordingly, by the fabricating method of the present invention, a novel die apparatus is produced wherein the machining operations are all relatively simple, can be carried out to very close tolerances, and still provide a die having the tolerances necessary for use in the melt-blowing process. Still further, the dies of the present invention are more readily cleaned and can be used to produce larger outputs of melt-blown materials.

It is also an advantage of the apparatus of the present invention that the hole length can be much longer than those obtained by the drilling approach.

What is claimed is:

1. A melt-blowing die having a generally triangular cross-section which comprises in combination:
 - a die block having a chamber for thermoplastic material, and
 - a plurality of discrete smooth bore, uniform diameter, capillary tube means, having an internal diameter of from 0.010 to 0.025 inches and an external diameter of 0.025 to 0.050 inches each having one end and another end, rigidly held within said die block, and each of said tube means in a touching essentially planar relationship with each of said another ends in a precise alignment defining a sharp edge,

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- said one end of said tube means in fluid connection with said chamber and said another end of said tube means having a shaped tip with a cross sectional angle within the range of 30° to 90° in fluid communication with the exterior of said die, and upper and lower gas slots defined by gas plates with tip means adjacent to said shaped tip in a spaced, parallel planar relationship to said shaped tip whereby said air plates form the same angle as said shaped tip.
2. A die according to claim 1 wherein said tip is triangular in cross section.
 3. A die according to claim 1 wherein said tip is conical.
 4. A die according to claim 1 wherein the centers of said tube means are aligned in substantially a single plane.
 5. A die according to claim 1 wherein said angle is within the range of 55° to 65°.
 6. A die according to claim 1 wherein said die block comprises an upper die block and a lower die block.
 7. The die of claim 1 wherein said tube means are of circular cross section.
 8. The die of claim 4 wherein the center of each tube means is offset from a straight line no more than 3 mils.
 9. The die of claim 1 wherein said tube means are stainless steel capillary tubes aligned in a bed of solder.
 10. The die of claim 9 wherein said die block has two discrete components and said tubes are rigidly mounted between said components.
 11. The die of claim 1 wherein said gas plate tips are positioned essentially opposite said shaped tips.
 12. The die of claim 1 which is at least 40 inches long and has at least 500 tube means.
 13. In a melt-blowing apparatus comprising:

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- extruder means in combination with die means, said die means having gas attenuating means and fiber collecting means
- the improvement which comprises said die means having a generally triangular cross-section which comprises in combination:
- a die block having a chamber for thermoplastic material, and
- a plurality of discrete smooth bore, uniform diameter, capillary tube means, having an internal diameter of from 0.010 to 0.025 inches and an external diameter of 0.025 to 0.050 inches each having a one end and another end, rigidly held within said die block, and each of said tube means in a touching essentially planar relationship with each of said another ends in a precise alignment defining a sharp edge.
- said one end of said tube means in fluid connection with said chamber and said another end of said tube means having a shaped tip with a cross sectional angle within the range of 30° to 90° in fluid communication with the exterior of said die, and upper and lower gas slots defined by gas plates with tip means adjacent to said shaped tip in a spaced, parallel planar relationship to said shaped tip whereby said air plates form the same angle as said shaped tip.
14. The melt-blowing apparatus of claim 13 wherein the die has an angle within the range of 55° to 65°.
 15. The melt-blowing apparatus of claim 13 wherein the tube means in said die are of circular cross-section.
 16. The apparatus according to claim 13 wherein the die contains stainless steel capillary tubes aligned in a bed of solder.

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