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Restrictor bar and sealing arrangement for a melt blown die apparatus.

Melt-blown die apparatus are provided for producing a fibrous web from a polymer material. The apparatus includes die means for extruding a molten stream of the polymer which includes heated cavity means therein for containing a molten quantity of this polymer. The apparatus also includes primary gas means for providing a pressurized gas at an exit end of the die means and restrictor bar means for selectively restricting a flow of the molten quantity of the polymer within the heated cavity means. This invention permits greater operational control of the polymer flow for accounting for different polymer selections and melt temperatures.

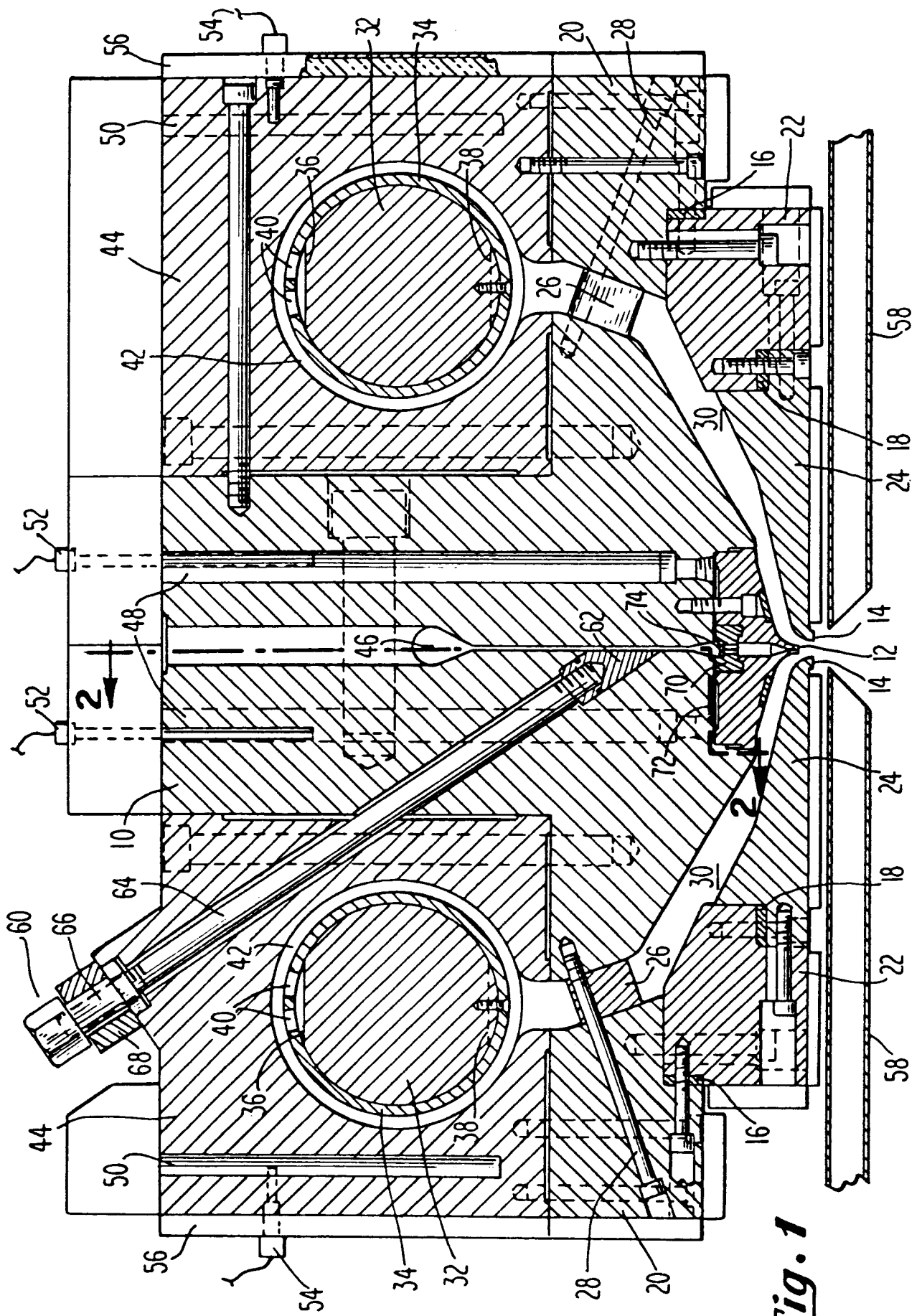


Fig. 1

Field of the Invention

This invention relates to melt blown processes for the production of micro-denier fibrous webs from polymer stock, and more particularly, to means for providing for a uniform and restricted flow of polymer during extrusions and means for assuring proper sealing of the polymer flow channel (without stress in key components) during high polymer pressure operation.

Background of the Invention

Current melt-blown technology produces microfibers of plastic in which a plurality of laterally spaced, aligned hot melt strands of polymeric material are extruded downwardly and are immediately engaged by a pair of heated and pressurized, angularly colliding gas streams. The gas streams function to break up the strands into fine filamentous structures which are attenuated and thermally set for strength.

The feed stock used for melt blown procedures is typically a thermoplastic resin in the form of pellets or granules which are fed into the hopper of an extruder. The pellets are then introduced into a heated chamber of the extruder in which multiple heating zones raise the temperature of the resin above its melting point.

The screw of the extruder is usually driven by a motor which moves the resin through the heating zones and into and through a die. The die, which is also heated, raises the temperature of the resin and the chamber to a desired level, at which point, the resin is forced through a plurality of minute orifices in the face of the die. As the resin exits these minute orifices, it is contacted by a pressurized hot gas, usually air, which is forced into the apparatus through air discharge channels located on either side of the resin orifices. The hot gas attenuates the molten resin streams into fibers as the resin passes out of the orifices.

Many of today's melt-blown dies include coat hanger cavities for receiving and uniformly distributing a pressure of molten polymer prior to extruding the polymer at the nosepiece. See Matsubara, U.S. 4,285,655, August 25, 1981. With the advent of wider and wider dies, the height of the coat hanger type die increases to the point where it becomes impractical. One attempt around this art-recognized problem is to incorporate a distribution system within the heated polymer cavity for providing constant pressure loss and resident time of the molten polymer flowing through the die without the need for a massive die body. See Appel, U.S. 4,043,739, August 23, 1977.

Although in the main, such prior art die constructions have provided suitable polymer flows in melt-blown processes, a need exists for a die mechanism which can account for resin flow inconsistencies and flow anomalies in the coat hanger, breaker plate or nosepiece. There is also a need for a mechanism

which can account for various resins melt temperatures and pressures without the need for replacing the die assembly.

Summary of the Invention

Melt-blown die apparatus are provided for providing a fibrous web from a polymer material. In a preferred configuration, the apparatus includes die means for extruding a molten stream of a polymer which includes heated cavity means therein for containing a molten quantity of the polymer. The apparatus also includes primary gas means for providing a pressurized gas at an exit end of the die means. In an important aspect of this invention, restrictor bar means are provided for selectively restricting a flow of the molten quantity of the polymer within the heated cavity means.

Accordingly, selective restriction of the polymer flow can be obtained by this invention. A number of resins, melt temperatures and flow rates are possible, without ever changing the die assembly. By merely adjusting the restrictor bar means, a range of flow rates for the molten polymer can be directed to the exit end of the die. This invention accounts for a myriad of flow inconsistencies and imperfections in the coat hanger, breaker plate and nosepiece.

In further preferred embodiments of this invention reliable sealing means are provided for preventing leakage around the breaker plate and nosepiece as well as minimizing stress in the nosepiece area of the die. Preferred gaskets and machining techniques are disclosed for maintaining the critical spacing between the air lip and the nosepiece.

Brief Description of the Drawings

The accompanying drawings illustrate preferred embodiments of the invention according to a practical application of the principles thereof and in which:

FIG. 1 is a front elevation, cross-sectional view of a preferred melt blown die apparatus of this invention illustrating preferred spacer bar means, air lip means and other novel features of the apparatus;

FIG. 2 is a cross-sectional side view of the coat hanger section of the melt-blown die of FIG. 1, taken through line 2-2; and

FIG. 3 is an enlarged view of the preferred spool means described in FIG. 1.

Detailed Description of the Invention

This invention provides a melt-blown die apparatus for producing fibrous webs from a polymer. The apparatus includes die means for extruding a molten stream of the polymer and primary gas means for providing a pressurized gas at an exit end of the

die means. The die means further includes heated cavity means therein for containing a molten quantity of the polymer and restrictor bar means for selectively restricting a flow of the molten quantity of the polymer within the heated cavity means.

In a more detailed embodiment of this invention, a melt-blown die apparatus is provided which includes die means for extruding a molten stream of a polymer. The die means includes heated cavity means having a coat hanger chamber and a polymer flow channel for directing a molten quantity of the polymer. The polymer flow channel is disposed between the exit end of the die means and the coat hanger chamber and includes a restrictor bar means disposed therein for selectively restricting a flow of the molten polymer. The restrictor bar means of this embodiment includes a restrictor bar disposed along a first side of the polymer flow channel, a stud having a first end connected to the restrictor bar and disposed through a portion of the die means, and spool means disposed on a second end of the stud opposite from the restrictor bar for providing a rotational and axial displacement of the stud through the die means and an attendant displacement of the restrictor bar within the polymer flow channel. The spool means further includes a spool releasably threaded to the stud. This spool has a pair of ends and a central cylindrical portion having a diameter less than a cross-sectional dimension of the ends. The spool means further includes clamping member means having an aperture therein for receiving the central cylindrical portion of the spool and for permitting substantially free rotation of the spool. This embodiment also includes primary gas means for providing pressurized gas at an exit end of the die means.

The invention also provides a method forming a fibrous polymer web which includes providing a melt-blown die apparatus having restrictor bar means for selectively restricting a flow of a molten quantity of polymer within a heated cavity of a die means and adjusting the restrictor bar means to restrict a flow of the molten polymer for a given polymer selection and flow rate.

Finally, this invention provides a melt-blown die apparatus which includes die means for extruding a molten stream of polymer, primary gas means for providing a pressurized gas at an exit end of the die means and heated cavity means disposed within said die means for containing a molten quantity of polymer. In this embodiment, a nosepiece means is provided in the die means which includes a plurality of extrusion orifices. The die means also includes a pair of die halves each forming a portion of the heated cavity means and gasket means disposed between the nosepiece and the die halves for minimizing leakage without stress on key areas of the molten polymer during the extrusion process.

The invention will be further understood within the

context of the following more detailed discussion. The melt blown process is a manufacturing method for producing a fibrous web using a single process which converts polymer pellets directly into micro-denier fibers. The key elements are the polymer feed system, air supply system, die and web collection system. Preferred embodiments for these systems will now be described.

The polymer feed system preferably involves resin handling, extrusion, extrudate filtration and metering or pumping. The resin pellets or granules are loaded into a hopper that supplies a feed throat portion of the extruder. The hopper may have drying and oxygen elimination equipment depending on the resin employed. The most common resin chosen is polypropylene which sometimes requires a nitrogen purge for minimizing oxidation. Preferably, the resins of this invention are fiber grades with melt flow indexes (MFI) of about 35-1200. The most preferred resin is a 35 MFI polypropylene.

The preferred extruder for the melt blown operation of this invention is a single screw device with a length to diameter ratio (L/D) range of about 24-32, preferably about 30. Twin screw units, melter pot systems and other variations are also acceptable. The single screw extrusion feed ports are preferably jacketed for cooling. The extruder screw design is resin dependent, although general application screws for polyolefins, such as polypropylene, or polyamides, such as nylon, are preferred. The extruder also can include barrel temperature controls, such as Proportional-Differential-Integral (PID) (heat and cooling - on/off) controllers which employ discrete units, PLC or microprocessor configurations. A preferred extruder barrel temperature profile for a four zone unit is 400-500-525-525°F for the 35 MFI polypropylene resin. Screw rotation can be provided by a motor through a gear box to the screw. DC motor systems and belt drive units are preferably used for this purpose. The speed of the extruder screw is used to maintain a set pressure at the metering pump inlet. The inlet pressures for melt blowing polypropylene are preferably about 500 to 2000 psig, more preferably about 900 psig. A melt temperature of about 550°F is ideal for operability. A pressure feedback loop sensor is preferably placed directly into the flow stream for better control.

Melt blown processes, as with other extrusion processes, require filtration of the polymer melt. Cartridge filters, screen packs, and other means can be employed, although this invention preferably uses a 150 micron cartridge filter system, for polypropylene. The filter as well as all interconnecting piping for the polymer stream is heated with electrically heated bands, or a hot fluid system, and controlled by a PID (heat only on/off) system. Typical temperatures employed by this invention are 550°F for the filter and 550°F for the piping.

Following filtration, the melt is metered into the die with a melt pump, preferably a positive displacement gear-type pump. This pump provides the pressure and flow control necessary for quality die operation. The inlet pressure to the pump is controlled by extruder speed pressure feedback. The speed of the pump is controlled by a DC motor system through a gear box and linkage, such as a universal shaft, to the pump. The pump temperature is preferably controlled with electrical power PID (heat only on/off) control to obtain a melt temperature of about 550°F for polypropylene extrusion. Die inlet pressures of about 300 to 1000 psig result with a flow rate of about 4.0 pounds per linear inch of die per minute.

The preferred operating and construction parameters for the novel primary air equipment of this invention will now be described. The primary air supply system involves the compression of a gas, preferably plant air or external air, with minimal filtration. The pressurized air is preferably electrically heated directly, or indirectly, with a gas or oil fired furnace, to a controlled temperature. The now heated and pressurized air is metered to the die. Metering is done through pressure regulating valves, although true flow control units could also be used. Preferred air temperatures at the die inlet are about 500 to 650°F, more preferably about 550°F. The temperature and pressure at the die inlet are strong functions of the pressure drop through the die and the resultant temperature drop through the system. Typically, artisans have employed 35 to 75 pounds of air per pound of polymer with air pressures ranging from 10 to 60 psig with commercially available dies. Since this invention has been designed to produce high strength fibers, air flow rates of about 100 to 150 pounds of air per pound of polymer were selected. Commercially available dies could not handle this air flow rate reliably or at pressures that were economical. In the preferred die design of this invention air pressures of about 15 psig inlet at about 135 pounds of air per pound of polymer at a polymer flow rate of about 4.0 pounds per linear die inch per minute are employed.

Referring now to FIG. 1, the preferred air flow path chosen for the primary air supply system of this invention is an open design with no substantial obstructions or balancing members. Preferably, the only interruption in the path are air foils 26 surrounding each of the supporting bolts 28 for the preferred primary air discharge channel 30. This unique aerodynamic design and proven method of fabrication has resulted in very low inlet air pressures of up to about 20 psig, and preferably about 10-15 psig, for producing very high air flows, e.g., about 90-200 pounds of air per pound of polymer at about 4.0 pounds/linear inch/minute. These parameters permit product and process extensions where prior art equipment was limited. Moreover, the air flow temperature drop due to aerodynamic losses is minimized to less

than about 50°F, preferably about 25°F as opposed to greater than about a 100°F drop in commercially available units. The lower temperature and pressure requirements of this invention produce significant energy savings for the operating plant and thus allow for economical operation for otherwise questionable process.

In the preferred primary air system embodiment of this invention, the air enters the die 10 via four inlets into a pair of cylindrical tubular chambers 34. Each cylindrical chamber 34 is fitted with a pressure control diverter member 32 which assures even pressure distribution and mass uniformity across the die width. The diverter member 32 has a minimum gap 36 at about the die center and a maximum gap 38 (shown in phantom) at the ends or "entrances" of each chamber 34. The air passes through a series of holes 40 at the top of the chambers 34 above the diverter member 32 to fill toroidal sections 42 along the die width. The flow then fills two elongated angular discharge channels 30 that approach both sides of the nosepiece 12. The air meets the polymer strands and then exits the die 10 via a rectangular channel or sharp edge. As the die design is tailored for a given resin or range of products, the air flow channel member surfaces are aerodynamically tuned for a given set of set back and slot width dimensions. The air flow path width is preferably wider than the nosepiece 12 active width. This design also minimizes the negative edge or end effects.

The air box 44, or air manifold support member, is typically supported outboard of the main die body halves in the prior art. This mounting technique can cause bending moments in the air discharge channel and irregular slot width and set back spacing. The unique design of one embodiment of this invention uses the mass and stability of the main die body halves to support the air box 44 for minimizing bending moments. This integral design allows for heat transfer between these members and enables facilitated insulating of both the air box 44 and the main die body halves of the die 10. The integral design also provides thermal and structural integrity to the die assembly, thus allowing both dimensional and thermal stability.

Primary air temperature control has typically been left to natural processes in the prior art. The preferred design of this invention employs two sets of heat zones. The first set, preferably comprising electrical resistance heaters 48 and thermocouples 52, provides heat close to the coat hanger section 46 of the main die body halves. The second set of heat zones, preferably comprising electrical resistance heaters 50 and thermocouples 54, provides heat outboard of the air boxes which surround each cylindrical chamber 34. The second set of heat zones will temper and/or stabilize the air passing through the air box 44 and cylindrical chambers 34.

The use of the outboard temperature zones also

provides a thermal base for the die structure. This will help to prevent warping, dimensional variations of slot width, or other thermal distortions. Thermal stability and dimensional control is also aided by preferred outboard insulation 56 over the external die surfaces which accounts for less thermal disruption of the air stream and better cross direction mass flow control of the air.

Preferred dimensional and operational characteristics of the exit end of the die of this invention will not be described. The melt blown die 10 of this invention is the critical element in combining the air and polymer. Cross web uniformity is the key to fabric quality. Web strength, weight distribution, bulk and other parameters are the typical criteria used to quantify die operation. The polymer path through a die 10 is preferably a coat hanger design with a linear spinnerette type nosepiece as the exiting port of the exit end. The exit capillaries are preferably about 0.010 to 0.020 inches in diameter (L/D range of 8 to 12) with spacing of about 20 to 40 holes per inch, more preferably about 0.0145 inch diameter holes (L/D = 10) with a spacing of about 30 holes per inch. Electrical heat and PID (heat only on/off) controls are preferably used for die temperature maintenance. Polymer filtration within the die 10 using 150 micron filters is preferred. The dimensional control of the air lip 14 or air knives allow air to exit with the polymer at high speed, above about 0.5 Mach, preferably up to about 0.8 Mach. An included angle of about 60° was employed for the nosepiece 12 and air lip 14 geometry.

The polymer yarns produced by the dies of this invention can be drawn to micro-denier size of about 1 to 5 microns. In order to produce high strength fibers, the use of secondary air was employed for quenching and/or insulating from surrounding temperatures. The secondary air manifold 58 utilizes room temperature air supplied by a blower system and injects the cool air just below the primary air/polymer exit end of the die 10. The fibers are then projected horizontally or vertically, to a moving porous belt (not illustrated), preferably made from woven stainless steel. A vacuum chamber is preferably created under the belt to exhaust the primary air, secondary air, and other entrained air. Further, the vacuum retains the fibers on the belt until a stable web has been collected. At this point the fibers of the web are lightly bonded together by residual polymeric melt heat in the fibers and the primary air. Further bonding may be required to satisfy product needs.

The dimensional control of the air lip - nosepiece relationship will now be discussed. The slot width, the distance from internal edges of the air lips 14 and set back, the distance between edge of the nosepiece 12 to edge of the air lips 14 are critical dimensional characteristics for product manufacture using a melt blown die. Typical dimensions for these parameters on prior art devices are 0.045 to 0.090 inches for set

back and 0.030 to 0.120 inches for slot width. Due to the greatly increased air required by this invention, slot widths of about 0.35 inches and corresponding set backs of about 0.20 were preferred to assure economical air flow and exit flows of up to about Mach 0.8.

The typical method disclosed by the prior art for setting these parameters is by adjusting screws accessed from the die exterior for both the horizontal slot width and vertical set back. This causes centering offsets and dimensional instability during heat-up and operation. The preferred design of this invention utilizes spacer bars 16 and 18 in the vertical and horizontal directions to set the slot width and set back assemblies. The component members of the elongated discharge channels 30 are then torqued and held into a fixed position. As die widths are increased from about 20 inches to greater than about 60 inches this becomes increasingly important for product uniformity and set-up. The wide dies of this invention preferably employ spacer bars, of at least about .25 inches or greater, preferably greater than about .50, and not shims, i.e., bars of significantly less thickness which are used singularly or in multiples. The shim system cannot be easily controlled during assembly and usually requires external adjustments which are inherently unstable. It has been determined that a spacer bar of at least about .25 inches in transverse, or separating, thickness permits substantially flat machining and does not exhibit a prohibitive amount of thermal distortion. The spacer bar system and final hot torquing of the discharge blocks and air lip members locks in predetermined dimensions selected for product or process needs, such as operational temperatures and air flow rates, and allows for reliable quality control. Within a wide range, the set back and slot width parameters can be changed at assembly by using specific bars, for examples, having thickness of about .25, .5, 1.0, 1.5 and 2.0 inches, to fit these needs.

With reference to FIGS. 2 and 3 the construction and application of the preferred restrictor bar assembly 60 will now be discussed. The polymer flow path of commercial melt blown dies is typically a simple coat hanger design leading to a filter supported by a breaker plate and then to the nosepiece. This gives little versatility, or flexibility. The preferred polymer flow path of this invention incorporates a restrictor bar 62 along one side of the main die body with studs 64 to the outer surface of the die. The cross directional shape of the restrictor bar 62 causes the polymer flow to be adjusted for better uniformity or for countering edge effects within the coat hanger 46 prior to engaging filter 74. The restrictor bar shape is determined by the tension or compression on the restrictor bar studs 64. This force is applied by the use of the internal threads in the restrictor bar spools 66 on the outside of the die. If a compressive force is applied to the stud

64 the spool 66 will push against the upper surface of the die clamp 68 forcing the restrictor bar 62 to retract and allowing more flow through the die. Conversely, if tension is applied to the stud 64 the spool 66 will push against the lower surface of the clamping member 68 and extend the restrictor bar 62 into the flow stream causing less mass flow in the polymer flow channel, i.e., the lower thin passageway of the coat hanger section 46. The position of the restrictor bar 62 can be determined quantitatively by measuring the extension of a micro-adjusting pin beyond the surface the clamping member 68. The number of studs 64 and micro-adjusting pins is a function of die width and are preferably spaced on 3 inch and 6 inch centers. The studs 64 are pinned to the restrictor bar 62 to avoid rotation with the spool after setting. The restrictor bar 62 can account for resin flow inconsistencies and flow anomalies in the coat hanger 46, breaker plate and/or nosepiece 12. Further, extrusion of varied resins, varied melt temperatures and/or varied flow rates is possible with one die assembly.

The preferred nosepiece 12 sealing arrangement will now be discussed with reference to FIG. 1. The assembly of the nosepiece 12 to the main die body halves of the die 10 has in the prior art caused equipment damage and/or premature failure of the nosepiece in commercial designs. This design creates a flat surface, within about 0.002 inches, across the nosepiece upper surface inboard and outboard sections. This increases the sealing area, but more importantly, does not introduce any stress on the capillary area of the nosepiece at assembly or during operation. In addition, the spider 70, also referred to as a breaker plate, and nosepiece, are considered a set and are match machined as an assembly to within about .005 inches. Assembly stress has been the root cause of many nosepiece 12 failures. In order to enhance sealing, the use of a soft-copper gasket 72 was employed. This gasket 72 enhances sealing and limits stress. Further, the assembly scheme described is not sensitive to bolt torque and other assembly techniques employed to protect the nosepiece.

From the foregoing, it can be understood that the present invention provides improved melt-blown die apparatus which include restrictor bar means for selectively restricting a flow of molten polymer for compensating for various resins and melt temperatures as well as inconsistencies in the machined nosepiece sections of the die. This invention also provides sealing means for minimizing leakage around the nosepiece and breaker plate. Although various embodiments have been illustrated, this was for the purpose of describing, but not limiting the invention. Various modifications, which will become apparent to one skilled in the art, are within the scope of this invention described in the attached claims.

LIST OF REFERENCE NUMERALS

	10	die
5	12	nosepiece
	14	air lip
	16	spacer bars (slot width)
	18	spacer bars (set-back)
	20	first discharge block
10	22	second discharge block
	24	air lip block
	26	air foil
	28	supporting bolts
	30	discharge channel
15	32	control diverter member
	34	cylindrical tubular chambers
	36	minimum gap
	38	maximum gap
	40	holes
20	42	torroidal sections
	44	air box
	46	coat hanger section
	48	resistance heaters
	50	resistance heaters
25	52	thermocouples
	54	thermocouples
	56	outboard insulation
	58	secondary air manifold
	60	restrictor bar assembly
30	62	restrictor bar
	64	restrictor bar stud
	66	spool
	68	die clamp
	70	spider
35	72	copper gasket
	74	filter

Claims

1. A melt-blown die apparatus for producing a fibrous web from a polymer, said apparatus having die means for extruding a molten stream of said polymer, said die means comprising heated cavity means therein for containing a molten quantity of said polymer, said apparatus further comprising primary gas means for providing a pressurized gas at an exit end of said die means, wherein said apparatus comprises:
 - restrictor bar means for selectively restricting a flow of said molten quantity of said polymer within said heated cavity means.
2. The apparatus of Claim 1 wherein said heated cavity means comprises a coat hanger chamber and a polymer flow channel disposed between said coat hanger chamber and said exit end of said die means.

3. The apparatus of Claim 1 wherein said restrictor bar means comprises a restrictor bar disposed along a first side of said polymer flow channel.
4. The apparatus of Claim 2 wherein said restrictor bar means comprises a stud having a first end connected to said restrictor bar, said stud disposed through a portion of said die means. 5
5. The apparatus of Claim 4 wherein said restrictor bar means comprises spool means disposed on a second end of said stud opposite from said restrictor bar for providing a rotational and thus axial displacement of said stud through said die means and an attendant displacement of said restrictor bar within said polymer flow channel. 10 15
6. The apparatus of Claim 5 wherein said spool means comprises a spool releasably threaded to said stud, said spool having a pair of ends and a central cylindrical portion having a diameter less than a cross-sectional dimension of said ends. 20
7. The apparatus of Claim 6 wherein said spool means comprises clamping member means for clamping said spool to said primary gas means, said clamping member means having an aperture therein for receiving said central cylindrical portion of said spool. 25 30
8. The apparatus of Claim 4 wherein said restrictor bar means comprises a pin for retaining said restrictor bar in fixed position against said stud. 35
9. The apparatus of Claim 6 wherein said spool means comprises a pin disposed through said spool and contacting said stud for selectively eliminating relative rotation between said spool and said stud. 40
10. A melt-blown die apparatus for producing a fibrous web from a polymer, said apparatus comprising:
 - (a) die means for extruding a molten stream of said polymer, said die means comprising heated cavity means for containing a molten quantity of said polymer, said heated cavity means comprising a coat hanger chamber and a polymer flow channel disposed between an exit end of said die means and said coat hanger chamber; 45 50
 - (b) primary gas means for providing a pressurized gas at said exit end of said die means; and
 - (c) restrictor bar means for selectively restricting a flow of said molten quantity of said polymer within said polymer flow channel, said restrictor bar means comprising: 55

a restrictor bar disposed along a first side of said polymer flow channel,

a stud having a first end connected to said restrictor bar and disposed through a portion of said die means,

spool means disposed on a second end of said stud opposite from said restrictor bar for providing a rotational and axial displacement of said stud through said die means and an attendant displacement of said restrictor bar within said polymer flow channel, said spool means comprising a spool releasably threaded to said stud, said spool having a pair of ends and a central cylindrical portion having a diameter of less than a cross-sectional dimension of said ends, said spool means further comprising clamping member means having an aperture therein for receiving said central cylindrical portion of said spool, for permitting substantially free rotation of said spool, and for retaining said spool on said primary gas means.

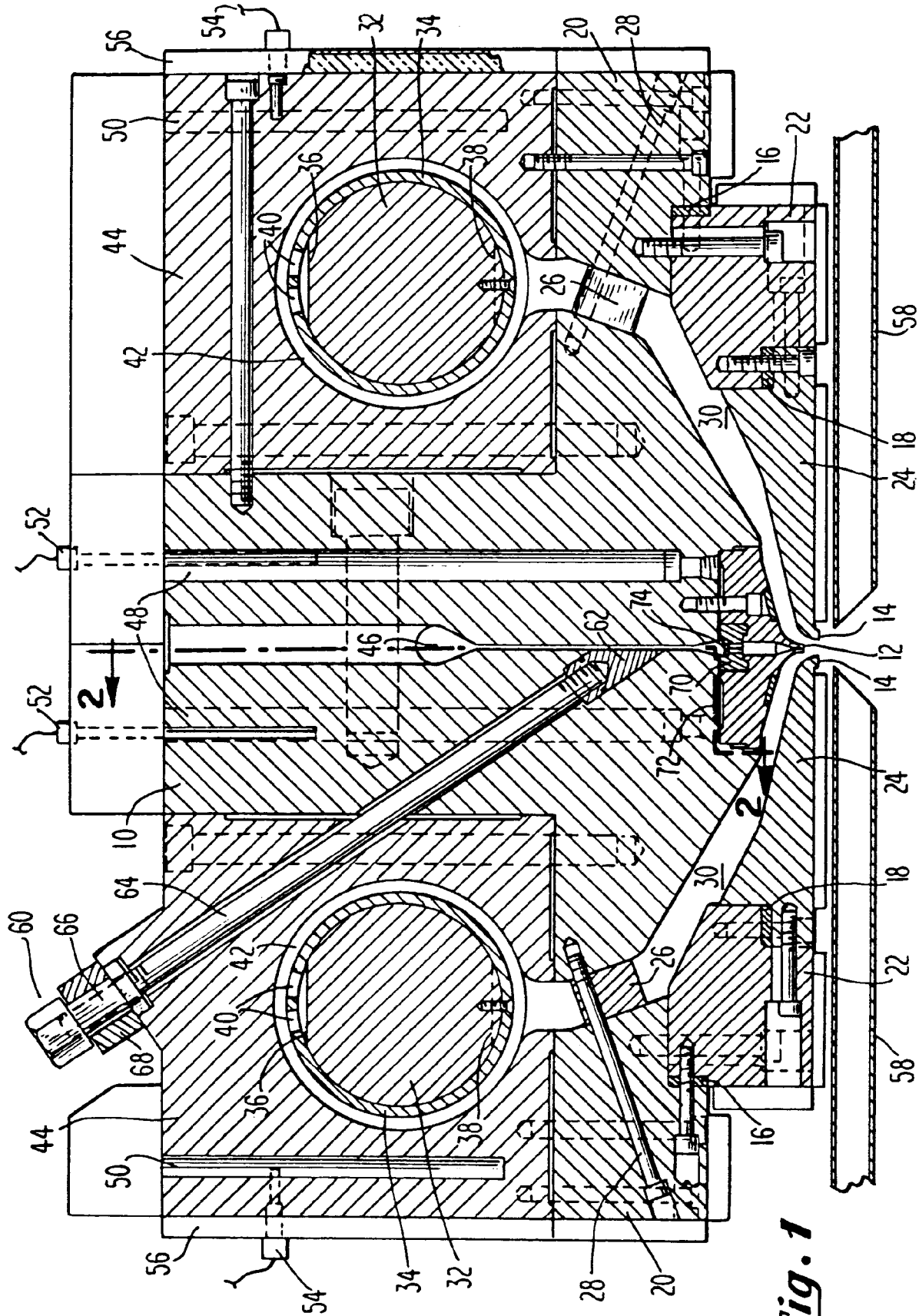


Fig. 1

