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(54) Die for extrusion of blown plastic film

(57) The invention relates to the kind of die which has many helical grooves (40) spiralling around a mandrel to the grooves (40). Instead of the usual one-groove (40) to one conduit (47) relationship, in the invention the grooves (40) and conduits (47) are intercalated, and each groove (40) is fed from two conduits (47), and each conduit feeds two grooves. The result is that the cooler liquid resin from the walls of the main duct (48) is constrained to move to the centre of the stream in the groove (40). The arrangement leads to an improvement in the homogeneity of the resulting film.

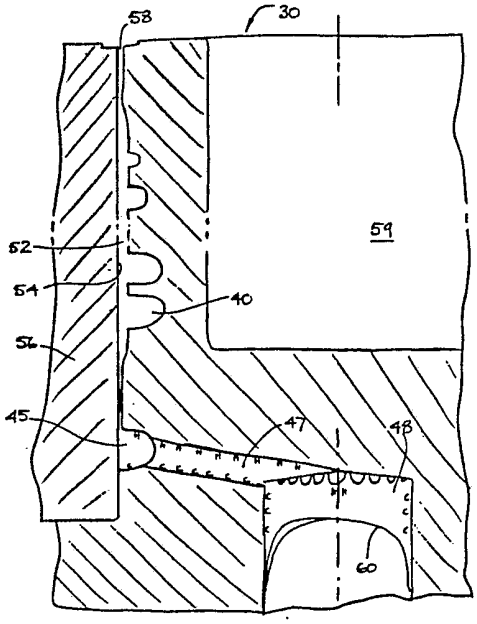

FIG 3

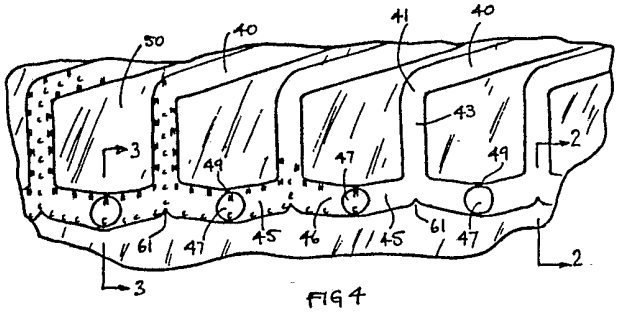

FIG 4

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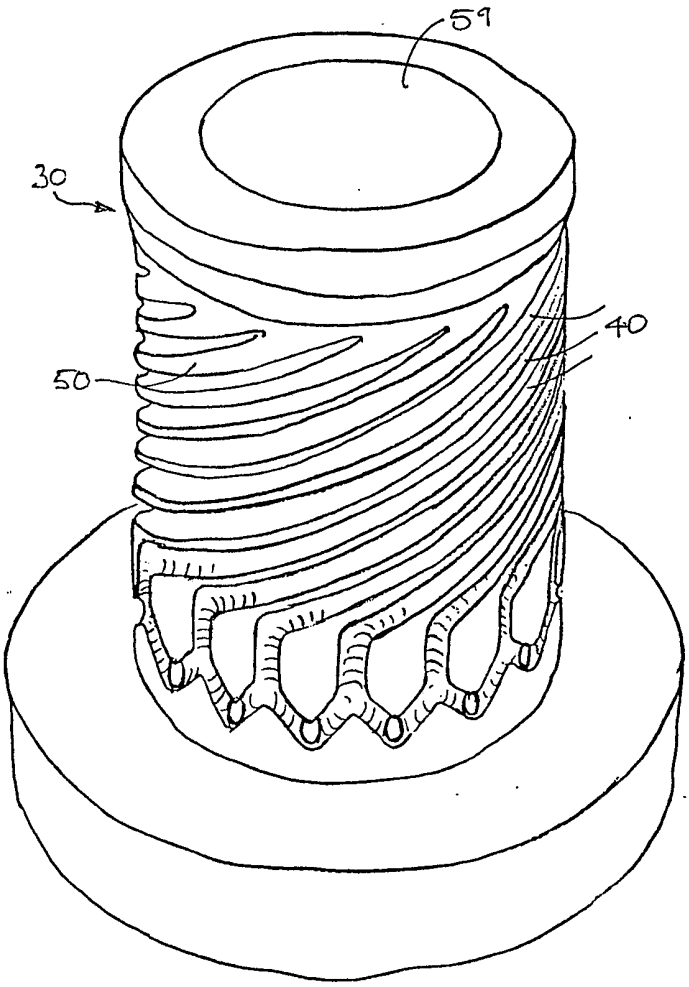

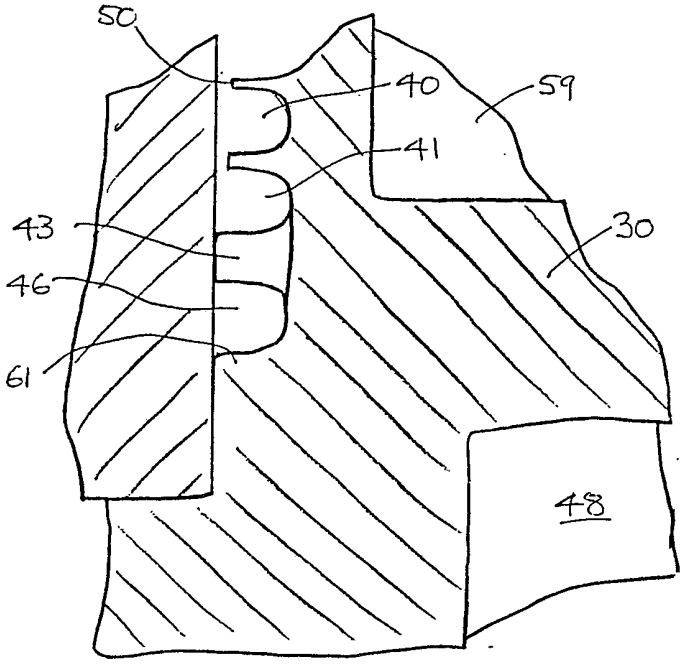

FIG 2

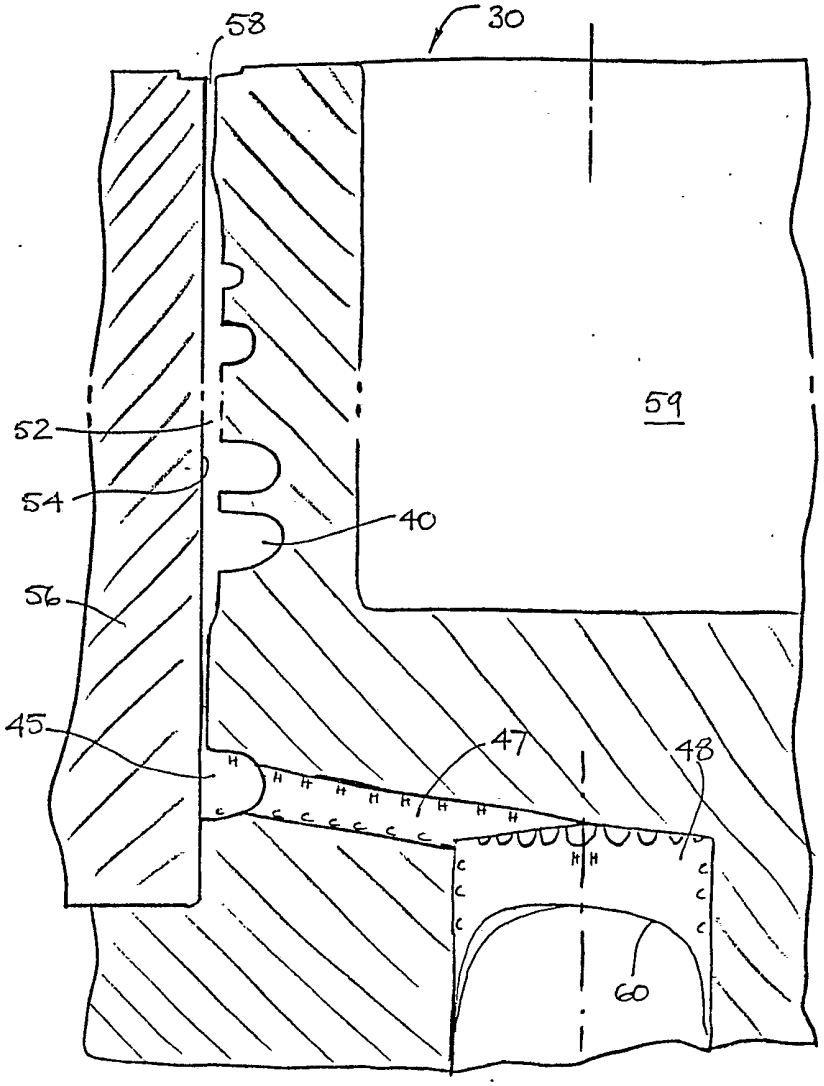
58
30
59
52
54
40
56
45
47
48
60

FIG 3

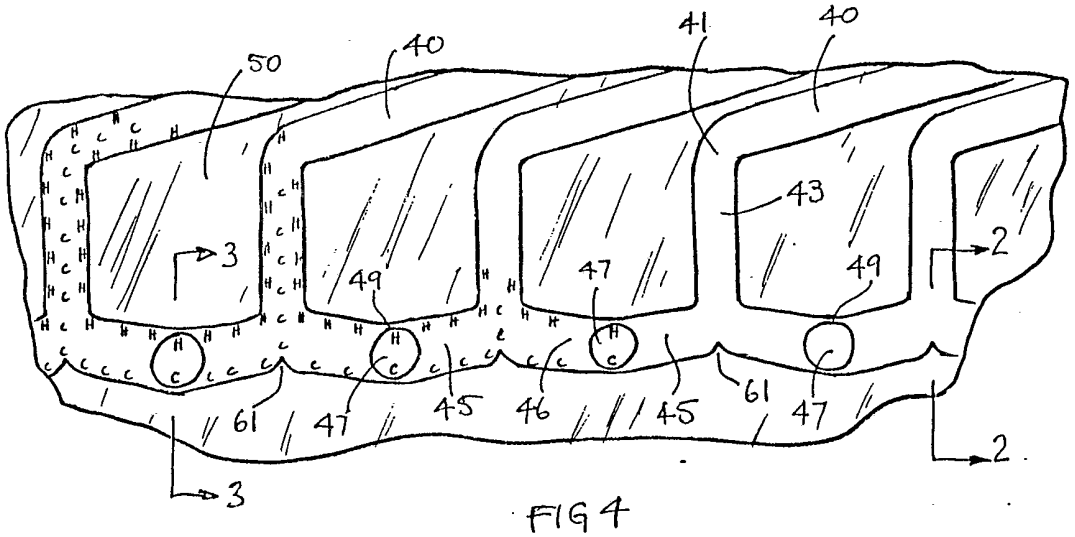
50
40
41
40
43
3
49
47
49
2
61
47
45
46
45
61
47
2
3

FIG 4

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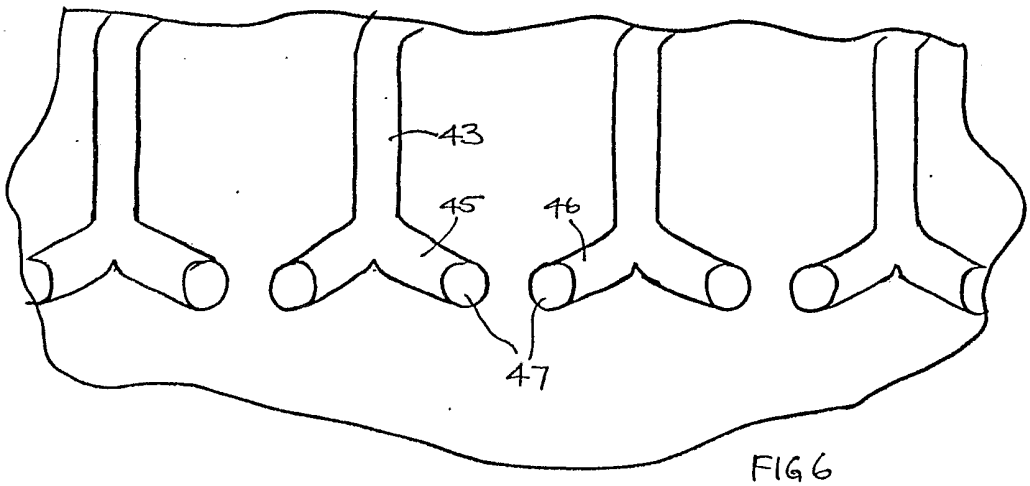
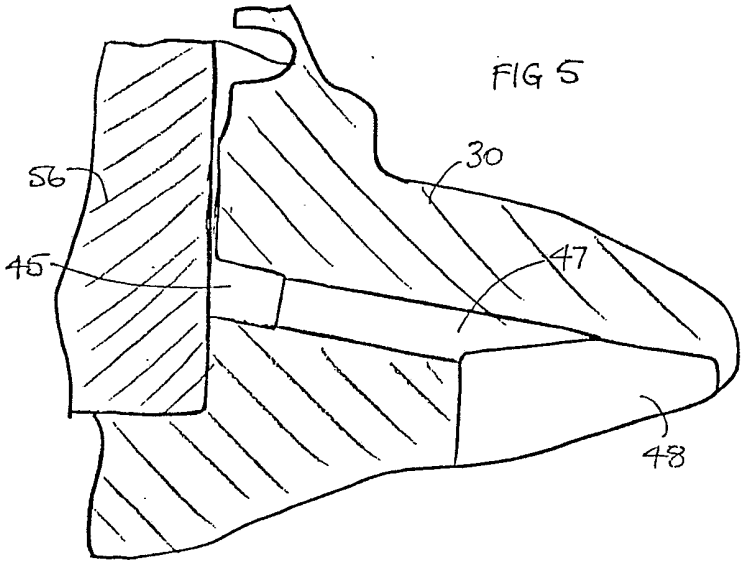


FIG 6

FIG 5



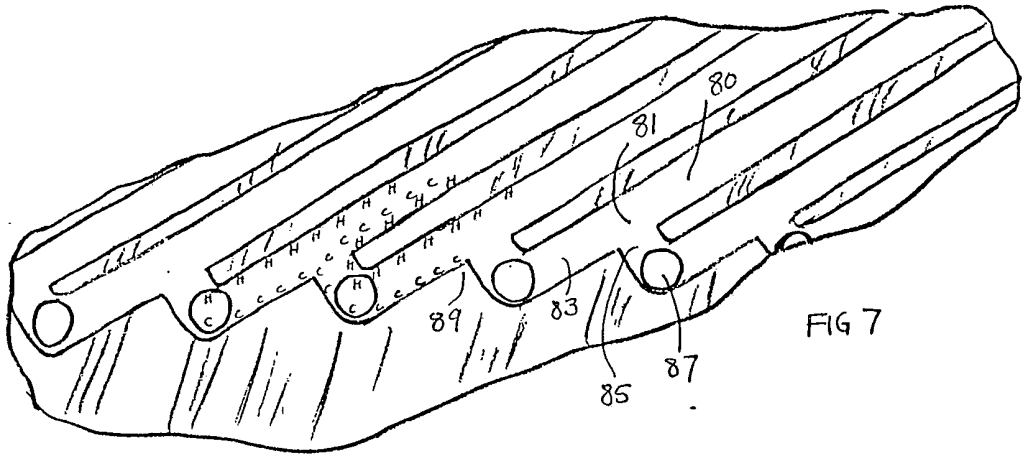


FIG 7

SPECIFICATION

Extrusion die for blown plastic film

This invention relates to the manufacture of plastic film.

BACKGROUND TO THE INVENTION

Patent publications US 4201532 (COLE, 06 May 1980) and US 4298325 (COLE, 03 November 1982) illustrate the conventional spiral-mandrel extrusion dies used for manufacturing blown plastic film.

In this kind of die, a basically cylindrical mandrel is formed with many individual helical grooves, which spiral around the circumference of the mandrel. Liquid resin is fed to the start-channel of each groove through a respective conduit, which receives the liquid resin from a main supply duct. The main supply duct is common to all the conduits.

The invention is concerned with the manner in which the liquid resin travels from the main supply duct to the start-channels of the helical grooves.

THE PRIOR ART

In the extrusion dies shown in the above prior patent publications, a problem arises, which will now be described with reference to Fig 1 of US 4201532, referred to above.

Molten polymer, or liquid resin in more general terms, enters the die through the main supply duct 24. As a general rule, a liquid flowing along a duct generally has a velocity profile over the cross-section of the duct such that the liquid in the centre of the duct flows more quickly than the liquid on the walls of the duct. It is recognised in the invention that one result of this velocity profile is that the liquid at the centre of the duct is not only moving faster, but is also hotter than the liquid in contact with the walls of the duct.

The cooler the liquid resin, the heavier its viscosity, so that the liquid at and near the walls of the duct 24 tends to travel somewhat sluggishly along the duct as compared with the hotter liquid in the centre of the duct. The material travelling very slowly along the walls can start to degrade, and to affect the properties of the blown plastic film, particularly its homogeneity.

The effect, if not checked, would tend to snowball, and therefore in dies of this kind the walls of the main duct must be kept well-heated, to make sure the temperature differences and gradients in the liquid resin are kept small. Even so, a significant temperature difference over the cross-section of the duct 24 is, in practice, unavoidable.

The individual conduits 30 branch out from the main duct 24, and we now consider the disposition of the liquid that flows in the conduits 30. We note that the liquid that enters the bottom sector of the conduit tends to be liquid that has travelled along the walls of the main duct 24, whereas the liquid that enters the top sector of the conduit tends to be liquid more from the centre of the main duct 24.

In each of the conduits 30, therefore, the liquid resin at the top of the conduit is hotter than the liquid resin at the bottom of the conduit. This temperature difference again tends not to be self-correcting, since the hotter liquid, being less viscous, passes quickly through the die, leaving the cooler liquid behind.

It has been found to be generally the case that a significant temperature difference is still present as the liquid resin leaves the conduits 30 and enters the spiral grooves.

This temperature difference—between the top sector and the bottom sector of the conduit—leads to a significant non-homogeneity in the plastic film produced by the die.

GENERAL DESCRIPTION OF THE INVENTION

In the invention, the start-channel of the helical groove is fed not from a single conduit but from two feed-channels interposed between the conduits and the start-channels. In the invention the two streams of liquid resin from the two feed-channels are arranged to converge before entering the start-channel. In the invention, the conduits and the start-channel are so arranged that the respective cool sectors at the bottoms of the two conduits are brought together before the stream enter the start-channel.

In this way, the distribution of liquid over the start-channel is such that the cooler liquid is surrounded by hot liquid. The result is that in the invention the liquid resin passing up through the grooves is subject to more gentle temperature gradients than has been the case when the start-channels are fed in the conventional way, ie when each start-channel is fed directly from only one respective conduit. In the invention, the homogeneity of the resulting plastic film is much improved.

It is recognised in the invention that the evenness of the properties of the resulting film is such that blown film can be manufactured economically even in such difficult-to-blow materials as high-density polyethylene.

DETAILED DESCRIPTION OF EXAMPLES OF THE INVENTION

Embodiments of the invention are shown in the accompanying drawings, in which:–

Figure 1 is a pictorial view of a mandrel of an extrusion die;

Figures 2 and 3 are cross-sections of part of the mandrel and associated components of the extrusion die, drawn on lines 2–2 and 3–3 of Fig. 1;

Figure 4 is a side elevation of part of the mandrel of Fig 1;

Figure 5 is a cross-section, corresponding to

Fig. 2, of a another mandrel;

Figures 6 and 7 are elevations, corresponding to Fig 4, of further mandrels.

The mandrel 30 shown in Figs 1 to 4 is provided with many helical grooves 40 which spiral around the outer cylindrical surface 50 of the mandrel. Liquid resin oozes from these grooves into the annular chamber 52 formed between the surface 50 and the inner surface 54 of the outer die member 56.

The top of the annular chamber 52 narrows to form an annular nozzle 58, through which the liquid resin is extruded. The plastic resin emerges from the annular nozzle 58 in the form of a tube, and the tube is inflated by means of air blown into the hollow interior 59 of the mandrel 30.

Each one of the helical grooves 40 is provided with a start-channel 41, and the resin enters the start-channel 41 via a lead-in-channel 43. The resin enters the lead-in-channel 43 from both a left feed-channel 45 and a right feed-channel 46 simultaneously, in accordance with the invention.

The feed-channels 45,46 are fed via conduits 47 from the main resin-supply-duct 48. The conduits are intercalated with the start-channels around the circumference of the mandrel, and are interconnected as shown by the feed-channels.

The line 60 in Fig 3 is a graph of the temperature distribution of the liquid resin flowing upwards in the main duct 48. We refer to the "hot" liquid and the "cool" liquid for the sake of convenience—in fact of course the transition between the different temperatures is gradual, and not stepped.

The hot liquid from the centre of the main duct 48 enters the top sector of the conduit 47, and the cool liquid from the walls of the main duct 48 occupies the bottom sector of the conduit 47. The letters H and C on the Figures denote the sectors and zones occupied by the appropriate temperature liquids.

The stream of liquid flowing along the conduit 47 splits into two sub-streams upon reaching the flow-dividing-means 49. The sub-streams divide and separate, one to each of the feed-channels 45,46.

From Fig. 4 in particular it can be seen that the respective cool sectors from the two sub-streams in the two feed-channels 45,46 meet and converge at the spit 61 between the two feed-channels. The resin flowing upwards in the lead-in-channel 43 therefore has cool liquid towards the centre and hot liquid towards the outside. This temperature distribution extends into the groove 40 itself.

The result is that the liquid in the groove is much more even as to its temperature than has been the case in conventional designs of extrusion die.

In some previous dies, it has been possible for the cool liquid to travel only very slowly through the die, due to the internal shape and structure of the die. This cool liquid might remain in the die for several minutes, as compared with the normal residence time of a few seconds that the liquid spends in the die.

If it is permitted to have a long residence period, the liquid starts to cure to some extent, and to change its properties, so that when it finally does emerge from the nozzle, there is a flaw, or at least a non-homogeneity, in the manufactured plastic film.

In the invention, because there is less variation in temperature, there also is less variation in the velocity of the liquid, a feature which leads to the film being highly homogeneous. In the invention, the cold material does not tend to remain upon the inside surfaces of the die, but instead the colder material is gathered up and carried along with the flow of liquid. All the portions of the liquid therefore tend to be at a more uniform temperature, and to have a more uniform residence time within the die.

In the invention, it is recognised that precautions should be taken to ensure there are no pockets in which the liquid might collect, and start to cure. Thus, the conduits 47 should communicate with the duct 48 in a way that does not lead to the formation of pockets. For example, the holes that comprise the conduits 47 are so formed as to have the relationship as illustrated in Fig 4 with the main-duct 48.

For the same reason, the feed-channels 45,46 may be formed with sloping upper and lower surfaces, as shown in Fig 5, to make the flow of resin into the lead-in-channel 43 as smooth and obstructionless as possible.

In the die of Figs 1 to 4, there are as many conduits 47 as grooves 40, and twice as many feed-channels 45,46. Each groove is fed from two conduits 47, and each conduit feeds two grooves.

In the die of Fig 6, there are twice as many conduits as grooves. This is generally not preferred however, because the designer of the die is generally concerned to provide as many grooves as possible (to ensure that the manufactured plastic film consists of many "layers" or plies); and too large a multiplicity of conduit holes into the main duct would make the die have the aspect of being riddled with holes.

It is not essential, in the invention, that the start-channel (including the lead-in-channel) and the feed-channels should be as clearly-defined and separate from each other as they are in the Figs 1 to 4 embodiment. In the die of Fig 7, the start-channel of the helical groove is identified by the reference numeral 80, the lead-in-channel by 81, the left feed-channel by 83, the right feed-channel by 85, the conduit by 87, and the spit, where the cool sectors of the liquid converge, by 89.

In the invention it is essential that the respective streams from the two feed-channels converge before entering the groove, but it is

not essential that the spit that defines the point of convergence should be geometrically at the centre of the lead-in-channel.

CLAIMS

1. Extrusion die for the manufacture of blown plastic film, characterised;
in that the die includes an annular nozzle, through which liquid resin is extruded;
in that the die includes an annular chamber from which the liquid resin enters the nozzle;
in that the annular chamber is provided with many grooves which encircle the annular chamber in respective helical spirals;
in that the die includes a main supply-duct, through which liquid resin enters the die;
in that the die includes many conduits in liquid-stream-conveying communication with the main supply-duct;
in that the die includes feed-channels, and start-channels;
in that each start-channel is in liquid-stream-conveying communication with a respective one, and only one, of the grooves;
in that each feed-channel is in liquid-stream-conveying communication with at least one of the conduits;
in that each start-channel is in liquid-stream-conveying communication with a respective pair of feed-channels;
in that a respective junction is formed between each start-channel and its respective pair of feed-channels;
and in that the arrangement of the die is such that, at the junction, the two streams from the feed-channels converge into a combined stream in the start-channel.

2. Die of claim 1, further characterised in that the arrangement of the die is such:
that a first or hot sector of the stream of liquid resin entering one of the conduits mainly comprises liquid from a hot zone of the main supply-duct, being a zone where the liquid is predominantly relatively hot;
that a second or cool sector of the stream of liquid resin entering that same conduit mainly comprises liquid from a cool zone of the main supply-duct, being a zone where the liquid is predominantly relatively cool;
that the said hot and cool sectors of the stream remain separate and distinct in the stream of liquid passing through the conduit;
that the said hot and cool sectors of the stream remain separate and distinct as the stream passes from the conduit into the respective feed-channel;
and that the said hot and cool sectors of the stream remain separate and distinct as the streams from the two feed-channels pass into, and combine in, the respective start-channel.

3. Die of claim 2, further characterised in that the arrangement of the die is such that, at the junction:
the two cool sectors of the respective streams of liquid from the two feed-channels become contiguous upon entering the start-channel;
and the two hot-sectors of the respective streams of liquid from the two feed-channels lie one to each side of the said contiguous cool-sectors in the combined stream in the start-channel.

4. Die of claim 3, further characterised:
in that each of the conduits is in liquid-stream-conveying communication with a respective pair of the feed-channels.

5. Die of claim 4, further characterised:
in that the die includes a flow-divider means for dividing and separating the flow from the conduit into two sub-streams;
in that the said means is effective to communicate the said two separate sub-streams one into each of the two feed-channels comprising the said pair.
and in that the arrangement of the die is such that each of the sub-streams retains, in the respective feed-channel, a respective hot-sector and a cool-sector.

6. Die of claim 5, further characterised:
in that the die includes the same number of conduits as start-channels;
in that the start-channels are intercalated circumferentially with the conduits, around the annular chamber;
in that the die includes twice as many feed-channels as conduits;
in that the feed-channels are so arranged as to:
(a) communicate each start-channel to the two nearest conduits, one to either side of that start-channel; and
(b) communicate each conduit to the two nearest start-channels, one to either side of that conduit.

7. Die of claim 1, further characterised in that the junction is symmetrical about the start-channel.

8. Die of claim 3, further characterised:
in that the junction is so shaped as to include a spit between the two feed-channels;
and in that the arrangement of the die is such that the said cool-sector of the stream from each feed-channel is the sector of the stream that lies closest to the spit.

9. Die of claim 8, further characterised in that the spit is so shaped that the liquid passes the spit in a smooth and obstruction-less manner.

10. Die of claim 1, further characterised in that the start-channel of the groove includes a lead-in-channel, which lies at a substantial angle to the line of the groove.

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