METHODS AND APPARATUS FOR EXTRUDING A TUBULAR FILM

Processes and apparatus for extruding a tubular film of polymer material. The apparatus comprises a circular coextrusion die having an inlet (10) for the or each component and having an exit channel (18) ending in a circular exit orifice (21) which is located radially outwardly from the die axis compared to the inlet (10). The die comprises several planar or conical die parts (5, 6, 7, 28, 29) clamped together, with surfaces supplied with grooves (14) shaped to form channels (11, 12, 13) for the flow polymer material. The shape of the channels is adapted to equalize the flow over the circumference of the exit orifice (21), and the flow of material is divided between the inlet (10) and the exit (21) into a number of part flows (13) of generally helical form with space (15) provided for overflow of material between said part flows, whereby the part are adapted so that they join to one common, circular flow.
METHODS AND APPARATUS FOR EXTRUDING A TUBULAR FILM

The present invention relates to methods and apparatus for extruding a tubular film of polymer material with provision for the circumferential equalisation of the material in helical grooves, extending generally in a plane or conically, formed in one or more generally planar or conical diepart surfaces, and guiding the flow of material outward. The invention aims at better utilisation of the special possibilities which this particular arrangement of the grooves offers.

The patent literature relating to such methods and apparatus for extrusion, especially for coextrusion, comprises the following:


Figure 1 of the accompanying drawings is based on the last mentioned reference. This drawing shows that the circular extrusion - be it monoextrusion or coextrusion - which uses which extend in a plane or conically grooves for the circumferential equalisation of the flow or flows, offers several advantages over the more common system, in which the circumferential equalisation is established by use of cylindrically extending grooves, i.e. grooves formed in one or more cylindrical diepart surfaces.

Thus, when the polymer material is extruded outward at the same time as it is circumferentially equalised by means of the grooves, the space in the die can be very well utilized. This means that the die can be made very compact, which has importance not only for saving of steel and easier assemblage and disassemblage, but also for quickly and safely achieving even temperatures. Furthermore it is an advantage for cleaning work that most channels are formed between the clamped together dieparts and therefore easily accessible after a simple disassembling.

The circumferential distribution by use of helical grooves with space provided for overflow between the grooves - originally grooves formed in cylindrical surfaces - was first described about 30 years ago. In this system of distribution the cross-sections of each helical groove and of the space between adjacent grooves which allow overflow, is adapted so that gradually less and less material flows through each groove, and more and more passes over to the neighbour groove, while gradually the depth of the grooves reaches zero.

It has been claimed that a single helical groove, extending over several revolutions around the circular die can make a perfect circumferential distribution,
provided the design of the groove and intervening spaces for overflow is exactly adapted to the rheological properties of the molten polymer material under the prevailing conditions. However, this is theory, and in practice the polymer flow must first in one or another way be divided into several part flows, each of these proceeding into a helical groove with space provided for overflow between the different grooves. The higher the number of part flows and thereby the number of grooves, the shorter the helical portion of each groove can be, but in any case the design of the grooves and of the spaces for overflow is essentially dependent on the rheological properties of the molten polymer material.

Like most of the technology described in the documents listed above, the present invention is primarily related to coextrusion, although two aspects of the invention are also applicable to monoextrusion. A first aspect of the invention concerns provision a middle film with surface layers, which have significantly higher melt flow index (and therefore significantly lower melt viscosity) than the middle film. This is a very important use of coextrusion, but as it shall be explained below the prior art dies of the described type are unsuitable for such applications.

A second aspect of the invention concerns a concept, which to the knowledge of the inventor is entirely new, namely to extrude thermoplastic polymer film out through an exit orifice located in the circumference of the die, a system which is found to give interesting new possibilities for film production. Peripheral extrusion from a circular die is used for manufacture of food structures, and in the above mentioned WO-A-00/07801 (Neubauer) for manufacture of a tube by use of a dieplate inside the cross-section of a mold cavity, e.g. between moved corrugator belts. However, it has not been used for manufacture of blown tubular film.

A third aspect of the invention concerns a practical adjustment of the overflow between the spiral grooves. With the technology which is known today large and expensive dieparts have to be exchanged to make one and same die applicable to different polymers which exhibit significantly different rheologies, or alternatively there is used expensive feed-back systems to compensate for insufficient function of the helical groove equalisation. These feed-back systems either apply different amounts of cooling air over the circumference of the film while the latter is blown or set different temperatures at different circumferential locations at the exit part of the die, all automatically controlled from inline automatic readings of the thicknesses.
Compared to the expensive prior art system, the third aspect of the invention aims at a relatively cheap solution, by utilizing the geometrical arrangement of the helical grooves formed in planar or conical surfaces to allow insertion of devices which allow a relatively simple adjustment of overflow. This shall be explained later.

Reverting to the aim of the first aspect of the invention, i.e. producing of a film with surface layers of significantly higher melt flow index, a very important example is the coating on both sides of high molecular weight high-density polyethylene, (HMWHDPE) having a melt-flow index (m.f.i.) of about 0.1 or lower according to ASTM D1238 Condition E, with linear low-density polyethylene (LLDPE) or another ethylene copolymer having m.f.i. 0.5-1 or even higher. The HMWHDPE provides strength to the film, especially when it becomes oriented, while the surface layers provide improved bonding properties and/or improved gloss and/or increased coefficient of friction. The reason why the surface films in practice consist of copolymers which have higher m.f.i. is that such copolymers are more readily available in the market, give higher gloss and provide easier welding.

Tubular coextrusion of HMWHDPE with surface layers of copolymers of a much higher m.f.i. is commonly carried out in circular coextrusion dies in which the circumferential equalisation is established by a system of helical grooves (with overflow) which extend in a geometrical arrangement as along a cylindrical surface. However, the prior art dies use the planar or conical arrangements of the helical grooves, which as mentioned as several advantages are very unsuited e.g. for the coextrusion of HMWHDPE having m.f.i. 0.1 or lower, with ethylene copolymers, having m.f.i. 0.5 or higher (reference to ASTM D1238 condition E). The same is true for the coextrusion of polypropylenes of similar high melt viscosities as HMWHDPE with copolymers which in practice are applicable as surface layers on such polypropylene film.

These known coextrusion dies consist of disc formed or shell ("bowl")-formed elements nested in a "bowl" or shell (which may consist of several parts screwed together) with the flow of two or more joined components taking place between a cylindrical or conical internal surface of this "bowl" and the outward surfaces of the nested elements. (For easy understanding see fig. 1). The joining of material takes place successively (sequentially). One surface component first joins with the component which shall become its neighbour, then the two
components proceed together over a relatively long distance along the outward surface of a nested element before they meet the third component of the coextrusion. If more than three components are wanted in the final film these steps are repeated, always with a relatively long distance between the locations where joining takes place. This is required for constructional reasons. If there are extruded three or more components and at least two of these components exhibit very different melt viscosities, as in the example with HMWHDPE, this means that, over 5-10 cm or an even longer channel through the die, the viscosity of the component which contacts one surface of the channel will be very different from the viscosity of the component which contacts the opposite surface of the channel. Such combination produces a disturbed layer distribution which, example, can show as transverse striations.

The field of technology to which the present invention belongs has in the foregoing been described as methods and apparatus for extruding a tubular film of polymer material under use for the circumferential equalisation of helical grooves extending in a plane or conically and formed in one or more planar or conical diepart surfaces. More specifically the invention concerns processes and extrusion dies for forming a tubular film by extruding at least one thermoplastic polymer material A by means of a circular extrusion die having at least one inlet for A and having an exit passageway ending in a circular exit orifice whereby the or each inlet is located closer to the axis of the circular die than the exit orifice and A in a molten state flows outwards towards the exit orifice, and in which process the shaping of the flow of A is established by an arrangement of dieparts having planar or conical surfaces, which dieparts are clamped together whereby said surfaces are supplied with grooves shaped to form channels in manner to equalise the flow over the circumference of the exit orifice, the flow between each inlet and the exit being hereby divided into a number of part flows of generally helical form at least through a portion of each channel with space provided for overflow between said portions.

The first aspect of the invention is limited, as far as the method is concerned, to coextrusion of at least one thermoplastic polymer material A with at least two thermoplastic polymer materials B and C of a melt flow index (the test conditions are specified below) which is at least double that of A, B being applied on one and C on the other side of A. Hereby at least the coextrusion of A follows
the process defined above, and the coextrusion is characterised in that the joining of A with B is established at the same location as its joining with C or in the immediate vicinity thereof, and that A flows outward at least immediately before it joins with B and C, while B and C flow towards each other immediately before the joining.

The coextrusion die for carrying out this process if similarly characterised, but its use is of course not limited to coextrusion of components with the defined relation between their rheologies.

The circumferential equalisation of polymer materials B and C should normally but not necessarily take place in similar way as the circumferential equalisation of A. However a good equalisation of these surface components is not always required since each may occupy less than 15% or even less than 10% of the structure, and therefore simplified and less efficient, known means of circumferential equalisation may be applied.

The indication of melt flow indices refers to the ASTM standard D 1238-90b. If the full melting range for each of the polymer materials is lower than 140°C condition E should be used (i.e. temperature of 190°C and load 2,16 kg). If the highest limit of the melting range of any of the polymer materials is from 140°C up to but less than 180°C condition L should be used (i.e. temperature 230°C and load 2,16 kg). If the highest limit of the melting range of any of the polymer materials is from 180°C up to 235°C condition W should be used (i.e. temperature 285°C and load 2,16 kg). It is not considered a practical possibility that the higher limit of any of the polymer materials will exceed 235°C.

This first aspect of the invention is useful in particular for coextrusion of at least one middle layer consisting of polyethylene based material having melt flow index 1 or lower according to the mentioned condition E, said middle layer or layers constituting at least 50% of the coextruded film, and surface layers of higher m.f.i. as defined above.

The first aspect of the invention is also useful in particular for coextrusion of at least one middle layer consisting of polypropylene based material having melt flow index 0,6 or lower according to the mentioned condition L, said middle layer or layers constituting at least 50% of the coextruded film, and surface layers of higher m.f.i. as defined above.
The condition that the part flows or channels must be of a generally helical form does not limit the invention to the regular helical form, e.g. the form following a two- or three dimensional curve defined by a point which moves at a constant angular velocity around another point in a plane or around an axis in the space, at the same time moving at a constant linear velocity and - if 3-dimensionally - with its projection on the axis also moving constantly. Although such a particularly regular form usually is very suitable for the shaping of the channels it is not needed for proper equalisation. Thus as an example, if there are many part flows, e.g. 16 or more, the "generally helical" portion of each can be very short and can then be of linear shape under small angle to the tangent of a circle defined as crossing this short linear portion and formed by rotation of a point around the die axis. Another example of an irregular but generally helical form which can be suited for the shaping of the channels, is a staggered form in which a first segment of a generally helical partflow follows a channel which is circular around the die axis, then just before this partflow would meet the adjacent partflow the channel bends to project the first mentioned partflow out into an "orbit" further apart from the die axis. Here a second segment of the channel continues circularly, later again before the two part flows would meet each other, the channel bends out to a third "orbit", and so on. As it shall be explained later such a staggered form can be advantageous, e.g. in connection with the special means for adjustment of overflow.

The first aspect of the invention is not limited to coextrusion of three polymer materials. There can be further component as stated in claims 17 and 18, and therefore the coextrusion die can have more than three sets of channels as stated in claims 52 and 53.

The part flows may extend in a generally planar manner - this applies to all three aspects of the invention - or they may extend in a geometrical arrangement as along a circular conical surface. For constructional reasons this should preferably be a right conical surface, i.e. its generatrix is a straight line, but the generatrix can also be curved, e.g. like a parabola with its axis parallel to the axis of the die but displaced from that axis. In any case the tangent planes of the conical surface should preferably form an angle of at least 20° and more preferably 45° to the axis of the die at least over the most downstream part of said surface. In the case of a right conical surface these angles are the angles between the straight generatrix and the axis.
As mentioned above the flow of A is divided into several part flows before the circumferential equalisation. It is noted that in the case of coextrusion according to the first aspect of the invention, the designated A is reserved for the polymer material of the lower melt flow index, while in the case of extrusion according to the second and third aspects of the invention the claims deal with one component only (although they are not limited to monoextrusion but also comprise coextrusion) and this component is called A. The following description relates to all three aspects of the invention.

The dividing into part flows should preferably take place by the system which in US-A-4,403,934 (Rasmussen et al) is referred to as labyrinthine dividing, although there may be some dividing carried out by other systems prior to the labyrinthine dividing. Labyrinthine dividing is easiest understood by a reference to figs 3 and 9, the latter representing the unfolding of a circular section through three flat disc formed dieparts. Labyrinthine dividing means that a main flow branches out to two generally circularly arched equally long and mutually symmetrical first branch-flows, which together occupy essentially 50% of the circumference of the corresponding circle, whereafter each of the first branch-flows branch out to two, in similar way generally circularly arched second branch flows, these in total four second branch flows also occupying together essentially 50% of the circumference of the corresponding circle. The dividing may continue in similar manner to form 8 or 16 or 32 or even 64 part flows. There may be small modifications of the circular arrangement, e.g. the four second branch-flows may form four of the sides in a regular octagon, the eight third branch-flows may form eight of the sides in a 16-sided regular polygon, etc.

The labyrinthine dividing has first been described in US-A-2,820,249 (Colombo) in connection with extrusion coating of cylindrical items. The first description of labyrinthine dividing for extrusion of blown film and in connection with a subsequent equalisation by means of helical channels with overflow is found in the above-mentioned US-A-4,403,934 (Rasmussen et al).

At least a part of the channels for the labyrinthine dividing may be formed integrally with the channels for the generally helical flow between the planar or conical surfaces of said first dieparts by grooves in at least one surface of a pair of contacting surfaces.
This is illustrated in fig. 3. Alternatively or additionally at least the beginning of said labyrinthine dividing is established by use of second dieparts having generally planar or conical surfaces, the second dieparts being clamped together with the first dieparts, the arrangement of channels for said beginning of the labyrinthine dividing being established partly by grooves in contacting surfaces between said second parts or between one second part and one first part and partly by interconnecting channels through said second and/or first parts. This is illustrated in fgs. 7, 8 and 9.

In any case there is preferably formed a relatively wide continuous cavity around the axis of the die. This is useful for efficient application of internal cooling air, for electrical connections, etc.

The choice between the two above mentioned types of labyrinthine dividing, or a compromise between the two, depends mainly on the diameter of the die and preferable size of the continuous cavity around the axis.

When any of the three aspects of the invention is used for coextrusion, and one of the coextruded polymer materials is susceptible to thermal degradation at a temperature which is in practice required for extrusion of one of the other coextruded materials it may be preferable or necessary to provide for thermal insulation between the dieparts which form the channel systems for the two polymer materials. One example of this is the coating on both sides of HMWHDPE of m.f.i. lower than 0,1 according to the above mentioned ASTM test with an ethylene/vinylacetate copolymer. This can conveniently be carried out with a coextrusion die like the die shown in fig. 2a and fig. 3, but since a conveniently fast extrusion of the HMWHDPE requires an extrusion temperature of about 200°C or higher and the copolymer tends to degrade during passage through the die if its temperature exceeds about 180°C, it is necessary to make a suitable thermal insulation within the die between the two polymer materials. Thus with reference to fig. 2a, the disc formed diepart 7a should be divided into two disc formed half parts with thermal insulation between the two, and similarly the disc formed diepart 7b should be divided into two disc formed half parts thermally insulated from each other. The thermal insulation is preferably established by means of airspaces, i.e. one or both half parts which together form 7a or 7b are supplied with ribs, recesses, knobs or the like, exactly machined so that the parts can be firmly and exactly clamped together. At the boundary adjacent to a polymer flow there must
be an efficient seal to avoid material leaking in between the two half parts and destroys the thermal insulation. This seal can e.g. be a ring of Teflon (trade mark) or bronze. When the heat transfer between the half parts is minimized, the flow of middle component A will practically maintain its temperature from its inlet up to the location where it joins with the other component or components.

A similar thermal insulation can be arranged when the dieparts 7a and 7b are conically shaped as in fig. 5. When carrying out the first aspect of the invention, the exit passageway may guide the common flow of the joined B, A and C further outward and then turn it in an axial direction, or the common passageway may without further outward passage immediately guide the common flow in a generally axial direction, in each case so that the joined materials flow generally axially when they meet the exit orifice. The first mentioned possibility is illustrated in figs 2a, 2b and 6, the last mentioned in fig. 12.

A third possibility is that the exit passageway guides the common flow of B, A and C to the peripheral surface of the die, as shown in figs. 4a, 4b, 6 and 7, but this possibility is described more detailed below under the third aspect of the invention.

The embodiment shown in fig. 12 - which belongs to the first aspect of the invention - is further characterised in that the helical grooves for circumferential equalisation of one surface component is formed in a cylindrical diepart surface. It could also be in two cylindrical surfaces facing each other or these surfaces could be conical but rather close to the cylindrical shape, e.g. their generatrix could form an angle of no more than 30° to the axis. In this way it becomes practically possible to make the common exit passageway cylindrical right from its start and therefore minimize its length and the pressure drop in the material from the time of joining to the exit orifice. This pressure drop has importance for the circumferential equalisation of the surface components when their melt viscosities are significantly lower than that of the middle component, a low pressure drop being preferable.

The second aspect of the invention which is illustrated in figs. 4a, 4b and 5, is characterised in that the exit passageway conducts the molten material right to the peripheral surface of the die, where the exit orifice is located, and the tubular film leaves the exit orifice under an angle of at least 20° to the axis of the die, and an adjusted overpressure is applied inside the tubular film to establish the desired diameter of the tube while it is drawn down and solidified. Expressly disclaimed is
therefore the application of a similar assembly of dieparts to make a tube, which immediately upon leaving said parts is delivered to the to the inside of a conveying mold as in WO-A-00/07801 (Neubauer). According to this third aspect of the invention the tubular film leaving the die from its periphery may directly be blown as it is normal in the extrusion of a tubular film by the inside air which is kept under an overpressure, feedback controlled from an automatic registration of the diameter, while the film is drawn down in thickness and drawn away in the axial direction by conventional means (driven rollers, collapsing frame etc). However, most preferably the tubular film which in molten state has left the peripheral surface of the die, should meet a ring which is concentric with the die and in fixed relation to the latter, so that the angle between the axis of the die and the direction of movement of the film is reduced and a frictional force is set up between the ring and the film to assist in a molecular orientation of the film, while the latter is drawn over the ring. This feature makes it possible to achieve a higher longitudinal orientation than achievable by conventional extrusion of blown film, and is in particular useful when the polymer material contains high amounts of a high molecular weight material, e.g. contains at least 25% HMWHDPE of m.f.i. = 0.1 or lower (the above mentioned ASTM test, condition E) or at least 25% polypropylene of m.f.i. - 0.6 or lower (the above mentioned ASTM test, condition L).

The achievement of a higher degree of longitudinal orientation in connection with the extrusion ("moltorientation") is important e.g. when the film is used for manufacture of cross-laminates. For this application the tubular film can be cut in a helical manner prior to lamination, in well-known manner, and can be further oriented at different stages of the manufacturing process, as it also is well-known, see e.g. EP-A-0624126 (Rasmussen).

The second aspect of the invention is applicable to monoextrusion as well as coextrusion. In addition to the advantage that the melt orientation is improved due to the arrangement of the ring, the second aspect of the invention has the advantage that the channels from termination of the circumferential equalisation to the exit orifice, and in case of coextrusion from the location of joining of the different polymer materials to the exit orifice, can be reduced to a minimum.

The above mentioned ring is preferably round at least on the part of the surface which contacts the film, and is preferably mounted in the immediate vicinity of the exit orifice. It should preferably be thermally insulated from the hot dieparts
either by being mounted through a thermally insulating material or by support
means which pass through the hollow space around the centre of the die.

The ring should preferably be cooled in order to avoid the tubular film
adhering too strongly to it, but in the case of particularly thick film this is not always
necessary. The cooling can be by means of circulating water or oil of a suitable
temperature. If the surface of the ring has a temperature below the lower limit of
the melting range of the polymer material which is contacts, a thin region of the film
will solidify and can thereby avoid or reduce the tendency to adhesion. This
solidification will normally be temporary so that the thin region of the film melts
again when the film has left the ring. A person skilled in the art may decide how
the cooling conditions best are adjusted (or if cooling is needed at all) to achieve
the optional orientation whilst minimising the risk of production stops due to
adhesion of the film to the ring. The circulation of the cooling medium can
preferably be by leading the medium in and out through a suitable number of pipes
which pass through the hollow cavity around the axis of the die.

By means of such a ring close to the die the coextrusion may conveniently
be carried out without joining the polymer materials inside the die, but letting them
fuse together while they meet on the ring.

In the case of the manufacture of a very thin film or a film which also at
room temperature has a surface having high coefficient of friction, cooling of the
ring may not be enough to avoid too much adhesion or excessive friction seen in
relation to the strength of the film while the latter passes over the outside of the
ring. In such case the ring may be adapted to carry the film on an "air pillow", i.e.
pressurized air is blown into the film from an inside space in the ring through
closely spaced find holes in one or more circular arrays around the part of the ring
which is directly adjacent to the film. The details in the construction of such a ring
adapted for carrying the film on air will be within the capability of a person familiar
with "air pillow" technology. This air is preferably cooled air so that it also acts as
an efficient medium for internal cooling.

The ring must be adapted for efficient circumferential equalisation of the
flow of compressed air before this air meets the circular array or arrays of fine
holes. It is preferably conducted from the compressor and the refrigerator through
one or preferably more pipes going through the hollow cavity around the axis of the
die, and it leaves the die through at least one other pipe connected to the inner of
the film bubble. (The cavity around the axis of the die is of course closed off from the environment so that an overpressure can be maintained inside the bubble). There is a valve at the outlet of this air to control the pressure in the bubble.

It is the opinion of the inventor that the choice of the die periphery for location of the circular exit orifice, in combination with the ring concentric with the die, over which the film is turned, in itself is inventive independently of the circumferential equalisation by use of helical grooves with overflow and the particular arrangement for these grooves are described above. Independent of the feature that the tubular film passes over the described ring - as it should normally do - an embodiment of the second aspect of the invention is characterised in that at least one side of the exit orifice is defined by a lip which is sufficiently flexible to allow adjustment of the gap of the orifice and that devices are provided for this adjustment.

It is immediately understandable that such an adjustment is possible and very practical when the exit passageway is planar nearby and up to the exit orifice, since in that case the circular die is comparable to a flat die and in flat dies the overflow from the exit orifice is almost always adjusted similarly. However, some conicity in the exit passageway is permissible even immediately before the latter meets the exit orifice. The question how much conicity is permissible depends on details in the construction but can be decided by a skilled constructor. However, in any case a conically shaped passageway can be planar out shortly before it meets the exit orifice.

The third aspect of the invention is characterised in that said overflow between the part flows is adjustable by exchangeable inserts between said dieparts or by a positionally adjustable apparatus part opposite the grooves. These features apply to monoextrusion as well as coextrusion, e.g. then can be applied as an addition to the well-known type of coextrusion dies shown in fig. 1. As it is illustrated in figs. 2a, 2b, 4a, 4b, 5 and 7 and further explained in the description to fig. 2a, the exchangeable insert can be an insert-shim (8a) by means of which the distance between the two channel forming dieparts can be regulated, shaped in such a manner that it prevents overflow between channel parts where such overflow must be prevented and allows it where it is wanted. When the flow pattern is as shown in fig. 3 (which corresponds to fig. 2a) the upstream limit of the area where overflow is desired should preferably be serrated or staggered as
illustrated by the broken lines (16) with connected broken circle segments (16b), otherwise there would be overflow areas where the flow would be stagnant. Consequently, with such a pattern of the grooves the boundary of the insert-shim (8a) preferably has such serrated or staggered form.

In the foregoing it has been mentioned that the form of the channels between which there is overflow can have a staggered form in which a first segment of a generally helical partflow follows a channel which is circular around the die axis, then just before this partflow would meet the adjacent partflow the channel bends to project the first mentioned partflow out into an "orbit" further apart from the die axis etc. etc. This is a suitable pattern of the generally helical flow for the purpose of avoiding "dead" areas, and at the same time utilizing the optimum dieparts. In this case the downstream boundary of the insert-shim can be circular.

However in the best form of such staggered helical grooves they gradually change from "orbit" to "orbit" from the circular form with generally radical connections between, to a form which is continuously helical, i.e. in one or a few "orbits" the form is circular, then it becomes regularly helical with increasing inclination relative to the circle from "orbit" to "orbit" and with reducing lengths of the generally radial connections.

Alternatively the exchangeable insert can be a cavity-filling insert. In this embodiment without the insert there is provided a space for overflow which is, but this space is partly filled by the exchangeable insert. This is illustrated by insert (8b) in figs. 2a, 2b, 4a, 4b and 5.

Instead of using exchangeable inserts, the overflow between the part flows can as mentioned be controlled by a positionally adjustable apparatus component opposite the grooves. It is preferably a continuous adjustment. Such a component can comprise a flexible flat generally annular flexible sheet which at its inward and outward boundaries is fixed to a stiff diepart forming part of the channel system, or can comprise a stiff flat generally annular plate which at its inward and outward boundaries is hinged through a flexible generally annular flexible sheet to such stiff diepart, in each case with a circular row of adjustment devices on the side of the flat generally annular sheet or plate which is opposite to the flow. The flexible sheet is preferably a metal sheet which may be integral with such stiff diepart.
This is further explained in connection with figs. 10 and 11. Instead of using tunable taps for the adjustment as shown in these drawings there can of course be used other means such as screws or wedges.

The invention shall now be described in further detail with reference to the drawings.

Fig. 1 illustrates the prior art. It shows an axial section of a coextrusion die for five components and is based on WO-A-98/00283.

Fig. 2a, which must be studied in conjunction with fig. 3 shows the axial sections indicated by c-d in fig. 3. It represents an embodiment of the present invention in which each system of helical distribution channels for three components, which become joined in the die, is integral with a preceding labyrinthine dividing system, and in which the channels of these systems are formed by grooves in clamped-together discs. It furthermore shows the exit passageway turning the common flow, so that the direction of extrusion becomes axial at the exit, and shows two different types of inserts for adjustment of the overflow between the helical grooves.

Fig. 2b, which is a similar view as fig. 2a, shows small modifications of the die illustrated in fig. 2a.

Fig. 3 shows the three sections perpendicular to the axis (1) which in figs. 2a, 2b, 4a, 4b and 6 are indicated by a-b. Fig. 3 illustrates the grooves for labyrinthine dividing, and integral herewith helical grooves for equalisation. The sections shown in fig. 3 do not extend beyond the outer limit (16c) of the spiral distribution system.

Fig. 4a, which is a similar view as fig. 2a, represents an embodiment of the invention which deviates from that shown in fig. 2a in the terminal part of the passage through the die which here takes place generally along a plane perpendicular to the axis (1) and ends at the circumference of the die. The drawing also shows the extruded film being turned over a cooled ring immediately after its exit from the die and shows one lip of the exit orifice being flexible and adjustable.

Fig. 4b is essentially similar to 4a but showing a modification in the arrangement of the flow-together of the three components.

Fig. 5 is generally similar to fig. 4a except that in fig. 5 the channels are formed in conical instead of plane surfaces.
Fig. 6 is a similar view as fig. 2a but showing coextrusion of five components.

Fig. 7 which must be studied in conjunction with figs. 8 and 9 is the axial section indicated by e-f in fig. 8. It is generally similar to fig. 4a except for the construction of the labyrinthine dividing system. In fig. 7 this dividing begins in grooves formed in the surfaces of additional discs, which are clamped to the discs carrying the grooves for the last step of labyrinthine dividing and the helical grooves.

Fig. 8 represents the axial section e-f indicated in fig. 7 and apart from the inlet region it also represents sections g-h and i-j. It shows the grooves for the last step of the labyrinthine dividing and integral herewith the helical part of the grooves.

Fig. 9 is an unfolding of the circular section formed by rotating each of the lines k-l in fig. 7 around the die axis (1). It shows the first two steps of the labyrinthine distribution.

Fig. 10 is a detail sectional drawing - a similar view as in fig. 2b but enlarged - showing devices for positional adjustment of the overflow between the helical grooves in substitute of the exchangeable insert for component A shown in fig. 2b.

Fig. 11 is an unfolding of the circular section formed by rotating the line m-n in fig. 10 around the die axis (1).

Fig. 12 which also is an axial section, but for the sake of simplification limited to the last part of the channels, represents a modification of the die of fig. 2a, showing the helical grooves for one surface component formed in a cylindrical surface, the helical grooves for the other surface component formed in a planar surface, and the helical grooves for the middle component formed in a conical surface, and further showing the common exit channel directed axially all the way from the internal orifices to the exit orifice.

The prior art die shown in fig. 1 has axis (1) and consists of clamped together discs and shell- or bowlformed parts. Thus (2a) and (2b) together form a shell or "bowl", and (3a) to (3l) are discs fitting into this "bowl". Five components are fed into the die for coextrusion, of which the inlets for two are shown. Apart from the inlet channels all channels for the five components and the common flow of two or more of these components are formed by spaces between the disc- or
shell ("bowl")-formed parts, thus the equalisation of each component over the circumference is established by helical grooves (4a) to (4e) which extend generally along a plane perpendicular to the axis (1) and here are seen almost in cross-section. These grooves are formed in the surface of one of a pair of adjacent discs or between the "bowl" and the adjacent disc. (Alternatively there might be grooves in both surfaces facing each other and this is also covered by the present invention).

This drawing shows only one helical groove for each component directly fed from the inlet for said component, but normally there would be several generally parallel grooves for each component, and there would be one or another kind of dividing channel system between these grooves and the inlet for the component. This is all prior art.

As the drawing shows there is arranged an overflow between the different parts of each groove (the parts which are adjacent when seen in axial section) or if there are several grooves for each component, (which is also prior art) between the different adjacent grooves. Each groove starts relatively deep but gradually becomes shallower to end at zero depth. The proportions between the different dimensions in such a spiral distribution system is critical for the equalisation of the flow over the circumferences and depends critically on the rheological parameters of the extruded melt under the given conditions of temperature and throughput.

As already mentioned, this construction of an extrusion die has the advantage that it allows coextrusion of many components, but has the drawback that these components must have relatively similar rheologies, otherwise the thickness of the individual layers become uneven. This is because the different components are successively joined one after the other, with a relatively long distance between the locations of joining. It should hereby be understood that the high extrusion pressure requires that each disc from which the die is constructed must be relatively thick. However, as already stated, if there is a high viscosity in one component contacting one channel surface and a much lower viscosity in a second component contacting the opposite channel surface, the common flow will soon become irregular.

In the embodiment of the invention which is shown in figs. 2a and 3, and with some small modifications in fig. 2b, the circular die having axis (1) is made from two shell (bowl) - formed parts (5) and (6), two disc-formed parts (7a) and
(7b), and in fig. 2b a further disc formed part (7c), three inserts (8a) and (8b) for adjustment of the overflow between the helical channels, and a ring (9) for adjustment of the exit orifice.

The molten thermoplastic polymer material (A) of a relatively high melt viscosity and two thermoplastic materials (B) and (C) of a lower melt viscosity are fed through separate inlets (10). They divide out in a "labyrinthine" channel system, first branching out to two part flows in channel (11), then continuing as four part flows in channels (12) and as eight part flows in channels (13). (Depending on the dimensions of the die there can of course be formed a larger or smaller number of part flows but in any case an integral power of 2).

In direct continuation of the "labyrinthine" dividing, the part flows in (13) continue in a helical distribution system, through grooves (14) whereby a proper balance is established between the flows through the spiral grooves (14) and an over-flow between the latter, which takes place in narrow gaps in the spaces (15), the beginning of which are shown in fig. 3 by broken lines (16).

The inserts for adjustment of over-flow will be described below. The broken circle (16a) in fig. 3 has relation to the devices for continuous adjustment of the overflows shown in figs. 10 and 11 and does not concern the dieparts shown in figs. 2a and b.

The broken lines (17) in figs. 2a and b indicate that the channels which are seen almost in cross-sections are connected outside the section which is represented in these drawings.

Having passed the helical equalisation system of channels, A, B and C proceed towards the common circular exit channel (18) whereby B and C pass internal orifices, (19) and (20) respectively, to join with A. The two internal orifices are immediately opposite each other at the same axial location (or there may be an insignificant axial distance between the two). The common channel ends in exit orifice (21).

In fig. 2a both B and C meet A under a pronouncedly acute angle, which in some cases has rheological advantages, while they both run perpendicularly towards A in fig. 2b. This solution can be chosen, for example if there is a need to shorten the diameter of the exit orifice. The tubular coextruded flow B/A/C passes out of the circular exit orifice (21) and having left the die it is drawn down and
blown in conventional manner. The arrangement and functions of the adjustable
lip-ring (9) will be explained below.

The shell- and disc-formed dieparts (5), (6), (7a), (7b) and in fig. 2b, (7c) are
screwed together by means of two circular rows of bolts (22a) and (22b). (In figs.
2a and b only one such bolt is shown). The exact fitting together of these parts
may be secured by means of recesses (not shown).

In fig. 2a (but not in fig. 2b) the overflow between the helical grooves for
component A is adjusted by means of the insert-shim (8a), mentioned above.
Several such insert-shims with different thicknesses should be available for the
adjustment. The thinnest could conveniently be e.g. 0.5 mm and the thickest 3
mm, while the depth of the helical grooves (14) conveniently can be e.g. between
5-20 mm at their start. The inward limitation of (8a) is circular, while its outward
limitation is serrated as defined by the broken lines (16) and broken circle
segments (16b) in fig. 3. The insert-shim (8a) is held in position by bolts (22a) and
(22b) and preferably also by recesses. Thus it makes each groove for
"labyrinthine" dividing and the beginning of each helical groove a closed channel,
while the rest of each helical groove becomes open for overflow. As it will be
understood from study of fig. 2a, the thickness of this insert-shim will also have an
influence on the thickness of flow of A where this component meets B and C, or in
other words on the gap of the "internal orifice" for A. However, when the intent is to
use the die for joining an A of higher melt viscosity with B and C of much lower melt
viscosities, and especially if the throughput of A also should be higher than the
throughputs of B and C, the gap of the internal orifice for A will in any case
conveniently be larger than the gap of the internal orifices for B and C (as it is well-
known in the art), and therefore relatively small variations in the gap of the internal
orifice for A will normally be inessential. Typically the gaps of the internal orifices
for B and C will be between 0.5-1 mm, while the gap of the internal orifice for A
typically will be between 2-4 mm.

Since variations in thickness of insert-shim (8a) cause different axial
positions of shell-part (5) relative to shell-part (6), (8a) may disturb the outflow from
the exit orifice (21) unless compensation is made for these differences. This is
done by means of exchangeable lip-rings (9) of different axial lengths
corresponding to the different thicknesses of the insert-shim (8a). The lip-ring (9) is
radially adjustable relative to the shell-part (5). It is fixed to (5) by a circular row of bolts, the bolt-holes in the lip-ring (9) being large enough to allow this adjustment.

In fig. 2b the overflows for component C are adjusted by a similar insert-shim (8a). This is possible because as shown in this figure, both walls of the internal orifice (20) for component C are cylindrical as shown, and therefore small changes in the axial position of shell-part (6) relative to disc (7b) will not have any significant influence on the joining of C with A. Contrarily to this such insert-shim (8a) normally cannot be used when the walls of the internal orifices are pronouncedly conical as the walls of the internal orifices (19) and (20) in fig. 2a.

For adjustment of the overflow, i.e. gap (15), for components B and C in fig. 2a, another type of exchangeable insert, namely the cavity-filling insert (8b) is used. This does not have any influence on the gaps of the internal orifices (19) and (20). Similar inserts are shown in fig. 2b for components A and B, but here it would have been possible to use insert-shim (8a) for all three components.

While the insert-shim (8a) adjusts the overflow by adjusting the distance between adjacent shell- or disc formed dieparts, the cavity-filling insert (8b) adjusts the overflow by filling up to a greater or lesser extent a hollowed-out space in one disc or shell located vis-a-vis the helically grooved section in the adjacent disc or shell.

The cavity-filling insert (8b) may, like the insert-shim (8a), start immediately at the inlet to the "labyrinthine" dividing system for the respective component, but can also as shown, start at a later stage. In figs. 2a and b, insert (8b) is shown screwed to parts (5), (6) or (7c).

A modification of the cavity-filling insert, constructed to allow an adjustment of the overflow, normally continuously without disassembling the die, is as mentioned above shown in figs. 10 and 11 and will be described later.

As it appears from the drawings, there is preferably provided a relatively large continuous hollow space extending from the die axis (1) to the innermost cylindrical surfaces of the clamped-together dieparts (which surfaces may e.g. be conical instead of cylindrical). This space can be very useful e.g. to establish an efficient internal cooling of the extruded tubular film.

In order not to make the study of the drawings too difficult, they are simplified on several points. Thus the dimensions of the grooves in the labyrinthine dividing and the helical overflow systems are shown identically for A, B and C,
although the die is primarily designed for coextrusion of relatively thin surface layers of B and C on a thicker middle layer of A. To avoid unnecessarily long dwell times for B and C, the channel systems for each of these components should therefore preferably each have a lower volume than the channel system for component A. Furthermore it is of course not practical that the inlets (10) for each of the three components pass along the same axial plane, they should be axially, e.g. angularly, separated from each other, and the inlets should preferably not take place through pipes which protrude into the central cavity of the die as shown in figs 2a and b but should be formed as bores through the discs or shells. Heating elements are not shown. The helical part of the grooves are shown extraordinarily short.

Finally the drawings do not show any drainage system, which is normally indispensable when channels for the extrusion are formed between clamped-together dieparts. Without a suitable drainage unavoidable leakages may build up too high pressures between the dieparts. Since such drainage is well-known in the art it is not further described here.

In fig. 4a the construction of the die is shown identical with that of fig. 2a up to the exit passageway (18), but while in fig. 2a this passageway makes a 90° bend to extrude the composite B/A/C flow axially, this flow proceeds radially out in fig. 4a, and the exit orifice (21) is located at the periphery of the die. Having left the exit orifice, the molten tubular B/A/C film is turned over the cooled ring (22) and is hauled off, blown and aircooled by conventional means (not shown). The ring (22) is directly fixed to the shell-part (6) of the die through a heat insulating material (23). The ring (22) is hollow, and the cooling takes place by circulation of water or oil, which may be temperature controlled. This cooling medium is pumped into and out of (22) through pipes, of which one (24) for the inlet is shown. These pipes are preferably passed through the cavity in the region around the axis of the die.

One of the circular lips (25) of the exit orifice (21) is preferably made flexible as indicated and is made adjustable by means of a row of screws of which one (26) is shown. Such adjustment is well-known from the construction of ordinary flat dies, and in fact the die of fig. 4a can be considered a flat die, although the exit orifice (21) is not straight but circular. Screw (26) is shown pressing on the lip of the die (25), but there can also be screws pulling the die lip, however the pressure in the melt may give a sufficient opening force to avoid any screws which pull.
Alternatively, there may be used devices which control the gap by means of thermally expanded elements. Such devices are known from other die constructions and are used especially for automatic avoidance of gauge variations by feed-back of automatic measurements of the gauge over the width of the extruded film.

It is clear that the flexibility needed for adjustment of exit orifice (21) will not cause any problem when the flow at the exit is directly radial, however it should be noted that this flow may to some extent be conical without detracting from the adjustability. In this connection it depends on details in the design how much conicity is permissible, but this can easily be decided by a constructor skilled in the art.

The purpose of fig. 4b is to show a variation of the design according to the invention, in which it is not component A but one of the surface components for the coextrusion, here component B, which flows in a planar, radial manner upstream of the internal orifices (19) and (20), while both A and C flow angularly to these orifices. Still the arrangement is such that as stated in claim 1, A flows outward relative to the axis (1) of the die (although not in planar, radial manner) immediately before it meets with B and C, while B and C flow towards each other immediately before the joining.

The conical shape of the dieparts shown in fig. 5 can as it already has been mentioned be advantageous, especially if the exit orifice (21) has a large diameter, since the conical form acts mechanically stabilising against the high melt pressures, and therefore allows that the clamped-together dieparts can be made thinner.

A presentation analogous to that of fig. 3 is omitted because the conical shape would make it rather complicated, and fig. 3 gives a sufficient understanding also of the channel shapes in the die of fig. 5.

Apart from the conical forms, the die of fig. 5 is generally similar to that of fig. 4a, with the exit orifice (21) arranged at the periphery, and a cooling ring (22) fixed to the die for turning the molten tubular B/A/C film. There is shown an exchangeable insert-shim (8a) similar to (8a) in figs. 2a, 2b, 4a and 4b, except for its conical shape with the downstream front surfaces (16) and (16a) - the latter not shown here but in fig. 3 - parallel to the axis (1).
Instead of the flexible lip (25) in fig. 4a with the screws (26) for adjustment, there is an exchangeable exit ring (27) which can compensate for different thicknesses of the exchangeable insert-shim (8a) and also, by small displacements upwards and downwards, can provide a proper mutual centering of the two surfaces of the extruded tubular material. For the sake of simplification there is not shown any cavity-filling insert like (8b) in figs. 2a, 2b, 4a and 4b, but such inserts may be present.

In fig. 6 there are shown two further shell ("bowl")-formed dieparts (28) and (29) in addition to the five shell- or disc-formed parts (5), (6), (7a) and (7b) in fig. 2a. Channels are established in these parts for labyrinthine dividing and helical-groove equalisation of two further molten polymer materials D and E, namely between dieparts (28) and (7a) for D and between dieparts (7b) and (29) for E, these channels terminating in the internal orifices (30) and (31), which are immediately adjacent to the internal orifices for B and C (19) and (20). Fig. 3 is also relevant for the understanding of this drawing. There is not shown any insert for adjustment of the overflow between the helical grooves, but if desired such inserts can of course be provided like the inserts (8a) or (8b) described above. If B has a melt viscosity close to that of D, these two flows may if desired by joined with each other well before the coextrusion with A, or B can be joined to D after the joining of D and A. Similar applies to the joining of C with E.

The die shown in figs. 7, 8 and 9 comprises, compared to that of fig. 4a, the additional discs (32), (33) and (34). From the inlets (10), here a hole in (32), each of the molten polymer materials A, B and C divide out on the two channel branches (35a) and (35b) - see fig. 9 - which here is shown as grooves in both (32) and (33), but it could be a groove in one part only. From each end of these branches each component passes through a hole in the disc (33), and at the other surface of (33) each of the two part-flows divide out into two part-flows (36a) and (36b), in total four branches, so that each component A, B and C now has become four part-flows. At the end of each of the four branches each component passes through a hole (37) in (34) which leads into the dieparts (5), (7a) and/or (7b).

Each hole (37) continuous as a bore (38) through shell-part (5), see fig. 7. For component B the bores (38) directly form the four inlets to the system of grooves between (5) and (7a). For component A and C the bores (38) are continued as bores (39) through (7a). For component A the bores (39) directly
form the four inlets to the system of grooves between (7a) and (7b). For
cOMPONENT C the bores (39) are continued as bores (40) through (7b), and these
bores directly form the four inlets to the system of grooves between (7b) and (6).
Since the sections e-f, g-h and i-j are considered identical except for the inlets fig. 8
does in fact show the continued system of flow of each component B, A and C.
The dieparts (5), (7a), (7b), (6) and the insert-shim (8a) are clamped together by
the two circular rows of bolts (41) and (42).

As shown in fig. 8 each of the four part flows divide out into two, so that
each component forms a total of eight part-flows, see fig. eight and these eight
part-flows proceed through the helical grooves with overflow. Alternatively, not
only the four but all eight part-flows of each component may be formed by
labyrinthine dividing upstream of the dieparts (5), (7a) and (6), or it may be
advantageous, especially for dies of a large exit orifice diameter, to divide to more
than eight part-flows, e.g. to 16 or 32 part-flows. The disc of figs. 7 to 9 has its exit
orifice (21) in the peripheral surface.

In figs. 10 and 11 the cavity-filling insert (8a) has a flexible annular zone
extending between a circular inner limit (16a) and a circular outer limit (16c). (16a)
in this figure corresponds to (16a) in fig. 3 and (16c) corresponds approximately to
the end of the helical grooves. Upstream (inward relative to the die axis) and
downstream of this flexible annular zone the insert (8b) is stiff, thus the flexible
zone can be considered an annular membrane. The stiff part on the downstream
side, i.e. outward of limit 8c, is fixed to the adjacent die-disc (7c) by a circular row
of bolts welded to the insert (8b), of which one (43) is shown.

The pressure in component A pushes the membrane part of (8b) towards a
circular row of spirally curved taps (44) each on a turnable shaft (45) which is
nested in a bore in the die disc (7c). There are many such shafts with taps, and they extend in a star-like manner through the disc (7c). By turning these shafts the
position of the membrane and thereby the overflow between the helical grooves
can be continuously adjusted. The means for turning the many shafts (45) and
coordinating, and fixing their positions (e.g. under use of spindles and spindle
wheels) are not shown.

In fig. 12, the equalisation of B takes place between the inside cylindrical
surface of (5) and the outside cylindrical surface of (7a) the former supplied with
helical grooves (14). The equalisation of A takes place between the inside conical
surface of (7a) and the outside conical surface of (7b), the latter also supplied with helical grooves (14). And the equalisation of C takes place between the opposite surface of (7b), which is substantially planar, and a planar surface in (6) supplied with helical grooves. What cannot be seen in the drawing is that (5) and (7a) are formed like “bowls” except that they are annular since the die preferably should have a continuous cavity around its centre. Similarly (6) is an annular disc and (7b) is an annular truncated cone. These four dieparts are bolted together in a similar manner to that shown in most of the other drawings, and upstream of the helical grooves, A, B and C are divided into part flows by labyrinthine dividing in a similar manner to the dividing shown in other drawings. The internal orifices which lead the flow of materials B and C into the flow of A are almost directly facing each other, and for rheological reasons it is also preferable that the length of the common channel (18) from these internal orifices to the exit orifice is as short as practically possible.
CLAIMS

1. A process of forming a tubular film by coextruding at least one thermoplastic polymer material A with at least two thermoplastic polymer materials B and C of a melt flow index which is at least double that of A, B being applied on one and C on the other side of A, said extrusion being carried out by means of a circular extrusion die having at least one inlet for each component and having a common exit passageway ending in a circular exit orifice whereby the or each inlet is located closer to the axis of the circular die than the exit orifice and the extrudable materials in molten state flow outwards towards the exit orifice, and in which process the shaping of each flow of each component is established by an arrangement of first dieparts having planar or conical surfaces, which dieparts are clamped together with said surfaces supplied with grooves shaped to form channels for the flow of each polymer material in manner to equalise the flow over the circumference of the exit orifice, whereby at least the flow of A between the or each inlet and the exit is divided into a number of part-flows of generally helical form at least through a portion of each channel with space provided for overflow between said helical portions and said part flows with overflows gradually join to one common, circular flow characterised in that the joining of A with B is established at the same location as its joining with C or the immediate vicinity thereof, and that A flows outward with respect to the axis of the die immediately before it joins with B and C, while B and C flow towards each other immediately before the joining.

2. A process according to claim 1, characterised in that said part flows of a generally helical form extend in a generally planar manner.

3. A process according to claim 1, characterised in that said part flows of a generally helical form extend in a geometrical arrangement as along a circular conical surface, the tangent planes of said conical surface forming an angle of at least 20° to the axis of the die at least over the most downstream part of said surface.

4. A process according to claim 3, characterised in that said angle is at least 45°.

5. A process according to claim 3, characterised in that said surface describing the extension of the helical form is a right conical surface.
6. A process according to claim 1, characterised in that each said part-flow is formed by labyrinthine dividing in the die of one or more flows.

7. A process according to claim 6, characterised in that at least a part of the channels for the labyrinthine dividing are formed integrally with the channels for the generally helical flow between the planar or conical surfaces of said first diepart by grooves in at least one surface of a pair of contacting surfaces.

8. A process according to claim 6, characterised in that at least the beginning of said labyrinthine dividing is established by use of second dieparts having planar or conical surfaces, the second dieparts being clamped together with the first dieparts, the arrangement of channels for said beginning of the labyrinthine dividing being established partly by grooves in contacting surfaces between said second parts or between one second part and one first part and partly by interconnecting channels through said second and/or first parts.

9. A process according to claim 1, characterised in that said overflow between the part flows is adjustable by exchangeable inserts between first dieparts or by a positionally adjustable apparatus part opposite the grooves.

10. A process according to claim 1, characterised in that after joining of the flows of different polymer materials, the common flow in the common exit passageway is turned towards the axial direction or immediately proceeds in this direction to flow generally axially when it reaches the exit orifice.

11. A process according to claim 1, characterised in that after joining of the flow of different polymer materials, the common flow proceeds right to the peripheral surface of the die, where the exit orifice is located, and leaves the exit under an angle of at least 20 degrees to the axis of the die, and an adjusted overpressure is applied inside the tubular film to establish the desired diameter of the tube while it is drawn down and solidified.

12. A process according to claim 11, characterised in that having left the exit orifice the tubular film in molten state meets a ring which is concentric with the die and in fixed relation to the latter, and the film is turned over the outside of the ring so that the angle between the axis of the die and direction of movement of the film is reduced and a frictional force is set up between the ring and the film to assist in a molecular orientation of the film, while the latter is drawn over the ring.
13. A process according to claim 12, characterised in that the cross-section of the ring is round at least on the part of the surface which contacts the film.

14. A process according to claim 12, characterised in that said ring is cooled by internal circulation of a cooling system.

15. A process according to claim 12, characterised in that said ring is mounted in the immediate vicinity of the exit orifice.

16. A process according to claim 11, characterised in that at least one side of the exit orifice is defined by a lip which is sufficiently flexible to allow adjustment of the gap of the orifice and that devices are provided for this adjustment.

17. A process according to claim 1, characterised in that in addition to B and C, at least one further thermoplastic polymer material D exhibiting a melt-flow index at least twice that of A is joined with B or C at any stage after the equalisation of the flow of said B or C.

18. A process according to claim 1, characterised in that coextrusion of a further component E, having the same or lower melt-flow index than A, takes place and A and E are either directly joined with each other prior to their joining with the flows of B and C, or are directly joined with each other at essentially the same location as their joining with B and C.

19. A process of forming a tubular film by extruding at least one thermoplastic polymer material A by means of a circular extrusion die having at least one inlet for A and having an exit channel ending in a circular exit orifice whereby the inlet or inlets are located closer to the axis of the circular die than the exit orifice and A in a molten state flows outwards towards the exit orifice, and in which process the shaping of the flow of A is established by an arrangement of dieparts having planar or conical surfaces, which dieparts are clamped together whereby said surfaces are supplied with grooves shaped to form channels in manner to equalise the flow over the circumference of the exit orifice, the flow between the inlet or inlets and the exit being hereby divided into a number of part flows of generally helical form at least through a portion of each channel with space provided for overflow between said portions, characterised in that the exit channel conducts the molten material to the peripheral surface of the die, the exit orifice is located at the peripheral surface, the tubular film leaves the exit orifice
under an angle of at least 20° to the axis of the die, and an adjusted overpressure is applied inside the tubular film to establish the desired diameter of the tube while it is drawn down and solidified.

20. A process according to claim 19, characterised in that at least one more thermoplastic polymer material is coextruded with A, and in molten state is joined with A.

21. A process according to claim 19, characterised in that having left the exit orifice the tubular film in molten state meets a ring which is concentric with the die and in fixed relation to the latter, and the tubular film is turned over the outside of this ring so that the angle between the axis of the die and the direction of movement of the film is reduced and a frictional force is set up between the ring and the film to assist in a molecular orientation of the film, while the latter is drawn over the ring.

22. A process according to claim 21, characterised in that the cross-section of the ring is round at least on the part of the surface which contacts the film.

23. A process according to claim 21, characterised in that said ring is cooled by internal circulation of a cooling medium.

24. A process according to claim 21, characterised in that said ring is mounted in the immediate vicinity of the exit orifice.

25. A process according to claim 19, characterised in that said part flows of a generally helical form extend in a generally planar manner.

26. A process according to claim 19, characterised in that said part flows of a generally helical form extend in a geometrical arrangement as along a circular conical surface, the tangent planes of said conical surface forming an angle of at least 20° to the axis of the die at least over the downstream part of said surface.

27. A process according to claim 26, characterised in that said angle is at least 45°.

28. A process according to claim 28, characterised in that said surface describing the extension of the helical form is a right conical surface.

29. A process according to claim 19, characterised in that each said part-flow is formed by labyrinthise dividing in the die of one or more flows.

30. A process according to claim 19, characterised in that at least one side of the exit orifice is defined by a lip which is sufficiently flexible to allow
adjustment of the gap of the orifice and that devices are provided for this adjustment.

31. A process according to claim 19, characterised in that said overflow between the part flows is adjustable by exchangeable inserts between said dieparts or by a positionally adjustable apparatus part opposite the grooves.

32. A process of forming a tubular film by extruding at least one thermoplastic polymer material A by means of a circular extrusion die having at least one inlet for A and having an exit passageway ending in a circular exit orifice whereby the inlet or inlets are located closer to the axis of the circular die than the exit orifice and A in a molten state flows outwards towards the exit orifice, and in which process the shaping of the flow of A is established by an arrangement of dieparts having planar or conical surfaces, which dieparts are clamped together whereby said surfaces are supplied with grooves shaped to form channels in manner to equalize the flow over the circumference of the exit orifice, the flow between the inlet or inlets and the exit being hereby divided into a number of part flows of generally helical form at least through a portion of each channel with space provided for overflow between said portions, characterised in that said overflow between the part flows is adjustable by exchangeable inserts between said dieparts or by a positionally adjustable apparatus part opposite the grooves.

33. A process according to claim 32, characterised in that such positionally adjustable apparatus part either comprises a flexible flat generally annular sheet which at its inward and outward boundaries is fixed to a stiff diepart forming part of the channel system, or comprises a stiff flat generally annular plate which at its inward and outward boundaries is hinged through a flexible generally annular sheet to such stiff diepart, in each case with a circular row of adjustment devices on the side of the flat generally annular sheet or plate which is opposite to the flow.

34. A process according to claim 31, characterised in that such positionally adjustable apparatus part either comprises a flexible flat generally annular sheet which at its inward and outward boundaries is fixed to a stiff diepart forming part of the channel system, or comprises a stiff flat generally annular plate which at its inward and outward boundaries is hinged through a flexible generally annular sheet to such stiff diepart, in each case with a circular row of adjustment
devices on the side of the flat generally annular sheet or plate which is opposite to the flow.

35. A process according to claim 19, characterised in that such positionally adjustable apparatus part either comprises a flexible flat generally annular sheet which at its inward and outward boundaries is fixed to a stiff diepart forming part of the channel system, or comprises a stiff flat generally annular plate which at its inward and outward boundaries is hinged through a flexible generally annular sheet to such stiff diepart, in each case with a circular row of adjustment devices on the side of the flat generally annular sheet or plate which is opposite to the flow.

36. A circular coextrusion die for coextruding at least one thermoplastic polymer material A with at least two thermoplastic polymer materials B and C, B being applied on one and C on the other side of A to form a tubular film, said circular extrusion die having at least one inlet (10) for each component and having a common exit channel (18) ending in a circular exit orifice (21), whereby the or each inlet (10) is located closer to the axis (1) of the circular die than the exit orifice (21) and the extrudable materials are directed to flow outwards towards the exit orifice (21), and in which the shaping of each flow of each component is established by an arrangement of first dieparts (5, 6, 7, 28, 29) having planar or conical surfaces, which are clamped together with surfaces of said parts supplied with grooves (14) shaped to form channels (11, 12, 13) for the flow of each polymer material in manner to equalise the flow over the circumference of the exit orifice (21), whereby at least the flow of A (12) between each inlet (10) and the exit (21) is divided into a number of part flows (13) of generally helical form with space (15) provided for overflow between said part flows and adapted for said part flows with overflows gradually joining to one common, circular flow, characterised in that the joining of A with B is established at the same location as its joining with C or in the immediate vicinity thereof, and that the channels are adapted to make A flow outward with respect to the axis of the die at least immediately before it joins with B and C, and that the channels (19, 20) are adapted to make B and C flow towards each other immediately before their joining with A.

37. A coextrusion die according to claim 36, characterised in that said channels (11, 12) of generally helical form extend in a generally planar manner.
38. A coextrusion die according to claim 36, characterised in that said channels (11, 12) of generally helical form are formed in a conical surface, the tangent planes of said conical surface forming an angle of at least 20° to the axis of the die at least over the most downstream part of said surface.

39. A coextrusion die according to claim 38, characterised in that said angle is at least 45°.

40. A coextrusion die according to claim 38, characterised in that the conical surface has right conicity.

41. A coextrusion die according to claim 36, characterised in that each of the channels of generally helical form is shaped in continuation of a labyrinthine dividing system of channels.

42. A coextrusion die according to claim 41, characterised in that at least a part of the channels for the labyrinthine dividing are formed integrally with the channels of generally helical form between the clamped together first dieparts by grooves in at least one surface of a pair of contacting surfaces.

43. A coextrusion die according to claim 41, characterised in that at least the first part of said labyrinthine dividing system comprises second dieparts (32, 33, 34) having planar or conical surfaces, the second dieparts being clamped together with said first dieparts, the arrangement of channels for said part of the labyrinthine dividing being established partly by grooves (35, 36) in contacting surfaces between said second parts or between one second part (34) and one first part (5) and partly by interconnecting channels (37, 38, 39, 40) through said second and/or first parts.

44. A coextrusion die according to claim 36, characterised in that the overflow between the part flows is made adjustable by exchangeable inserts (8a) in the die or by a positionably adjustable apparatus part (8b) opposite the grooves.

45. A coextrusion die according to claim 36, characterised in that downstream of the location for joining of the flows of different polymer materials, the channel for the common flow (18) is turned towards the axial direction, or that this channel is generally axial all the way from the said location, to direct the flow generally axially when it reaches the exit orifice (21).

46. A coextrusion die according to claim 36, characterised in that downstream of the location for joining of the flows of different polymer materials the channel for the common flow (18) proceeds towards the peripheral surface of the
die, where the exit orifice (21) is located, and at the exit orifice said channel for the
common flow (18) forms an angle of at least 20° to the axis of the die, and means
are provided for drawing down the extruded tubular film while applying a controlled
inside overpressure to establish the desired diameter.

47. A coextrusion die according to claim 46, characterised by comprising
a ring (22) which is concentric with the die and in fixed relation to the latter at such
a level that the tubular film can be turned over the surface of this ring by devices
drawing the film generally in the axial direction.

48. A coextrusion die according to claim 47, characterised in that the
cross-section of the ring (22) is round at least on the part of the surface which is
adapted to contact the film.

49. A coextrusion die according to claim 47, characterised by means
(24) for cooling said ring by internal circulation of a cooling medium.

50. A coextrusion die according to claim 47, characterised in that said
ring is mounted in the immediate vicinity of the exit orifice (21).

51. A coextrusion die according to claim 46, characterised in that at
least one side of the exit orifice is constituted by a lip (25) which is sufficiently
flexible to allow adjustment of the gap and that the die comprises devices for this
adjustment.

52. A coextruding die according to claim 36, characterised in that in
addition to the total system of channels for B and C there is provided a system of
channels (10, 11, 30) for coextruding at least one further thermoplastic polymer
material D, said channels ending in an internal orifice (30) for joining D with B or C
downstream of the channels which equalise the flow of said B or C.

53. A coextrusion die according to claim 52, characterised in that the
location for joining D with B or C is essentially the same as the location of the
joining of A with B and C.

54. A circular extrusion die for forming a tubular film consisting of at
least one thermoplastic polymer material A, said circular extrusion die having at
least one inlet (10) for A and having an exit channel (18) ending in a circular exit
orifice (21), whereby the or each inlet is located closer to the axis (1) of the circular
die than the exit orifice (21) and A is directed to flow outwards towards the exit
orifice (21), and in which die the shaping of the flow of A is established by an
arrangement of dieparts (7a, b) having planar or conical surfaces, which are
clamped together with surfaces of said parts supplied with grooves (14) shaped to form channels (11, 12, 13) for the flow in manner to equalize the flow over the circumference of the exit orifice, whereby the flow between the inlet or inlets and the exit channel is divided into a number of part flows (13) of generally helical form with space (15) provided for overflow between said part flows, characterised in that the exit channel for A (18) is directed to conduct the material towards the peripheral surface of the die, the exit orifice is located at the peripheral surface, and the exit channel (18) meets this orifice under an angle of at least 20° to the axis of the die and means are provided for drawing down the extruded tubular film while applying a controlled inside overpressure to establish the desired diameter.

55. An extrusion die according to claim 54, characterised in that means are provided for coextrusion of at least one more thermoplastic polymer material with A.

56. An extrusion die according to claim 54, characterised by comprising a ring (22) which is concentric with the die and in fixed relation to the latter at such a level that the tubular film can be turned over this ring by devices drawing the film generally in the axial direction.

57. An extrusion die according to claim 54, characterised in that the cross-section of the ring (22) is round at least on the part of the surface which is adapted to contact the film.

58. An extrusion die according to claim 56, characterised by means (24) for cooling said ring by internal circulation of a cooling medium.

59. An extrusion die according to claim 56, characterised in that said ring is mounted in the immediate vicinity of the exit orifice (21).

60. An extrusion die according to claim 54, characterised in that said channels (13) of generally helical form extend in a generally planar manner.

61. An extrusion die according to claim 54, characterised in that said channels (13) of generally helical form are formed (14) in a conical surface, the tangent planes of said conical surface forming an angle of at least 20° to the axis of the die at least over the most downstream part of said surface.

62. An extrusion die according to claim 61, characterised in that said angle is at least 45°.

63. An extrusion die according to claim 61, characterised in that the conical surface has right conicity.
64. An extrusion die according to claim 54, characterised in that each of the channels (13) of generally helical form is shaped in continuation of a labyrinthine dividing system (11, 12) of channels.

65. An extrusion die according to claim 54, characterised in that at least one side of the exit orifice is constituted by a lip (25) which is sufficiently flexible to allow adjustment of the gap and the die comprises devices (26) for this adjustment.

66. A circular extrusion die for forming a tubular film consisting of at least one thermoplastic polymer material A, said circular extrusion die having at least one inlet (10) for A and having an exit channel (18) ending in a circular exit orifice (21), whereby the or each inlet (10) is located closer to the axis (1) of the circular die then the exit orifice (21) and A is directed to flow outwards towards the exit orifice (21), and in which die the shaping of the flow of A is established by an arrangement of dieparts (7a, b) having planar or conical surfaces, which are clamped together with surfaces of said parts supplied with grooves (14) shaped to form channels (11, 12, 13) for the flow in manner to equalize the flow over the circumference of the exit orifice, whereby the flow between the inlet or inlets and the exit channel is divided into a number of part flows of generally helical form (13) with space (15) provided for overflow between said part flows, characterised in that said overflow between the part flows is adjusted by exchangeable inserts (8a) in the die or by a positionally adjustable apparatus part (8b) opposite the grooves.

67. A circular extrusion die according to claim 66, characterised in that such positionally adjustable apparatus part either comprises a flexible flat generally annular sheet (8b) which at its inward (16a) and outward (16c) boundaries is fixed to a stiff diepart forming part of the channel system, or comprises a stiff flat generally annular plate which at its inward and outward boundaries is hinged through a flexible generally annular sheet to such stiff diepart, in each case with a circular row of adjustment devices (45, 46) on the side of the flat generally annular sheet (8b) or plate which is opposite to the flow.

68. A circular coextrusion die according to claim 56, characterised in that such positionally adjustable apparatus part either comprises a flexible flat generally annular sheet (8b) which at its inward (16a) and outward (16c) boundaries is fixed to a stiff diepart forming part of the channel system, or comprises a stiff flat generally annular plate which at its inward and outward boundaries is hinged through a flexible generally annular sheet to such stiff diepart, in each case with a
circular row of adjustment devices (45, 46) on the side of the flat generally annular sheet or plate which is opposite to the flow.

69. A circular extrusion die according to claim 54, characterised in that such positionally adjustable apparatus part either comprises a flexible flat generally annular sheet (8b) which at its inward (16a) and outward (16c) boundaries is fixed to a stiff diepart forming part of the channel system, or comprises a stiff flat generally annular plate which at its inward and outward boundaries is hinged through a flexible generally annular sheet to such stiff diepart, in each case with a circular row of adjustment devices (45, 46) on the side of the flat generally annular sheet or plate which is opposite to the flow.
Fig. 11.

Fig. 12.

SUBSTITUTE SHEET (RULE 26)
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER
    IPC 7    B29C47/06    B29C47/20    B29C47/28

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
    IPC 7    B29C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
    PAJ, WPI Data, EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
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<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
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column 7, line 36 - line 57 claims | 32,66 |
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Further documents are listed in the continuation of box C.

Patent family members are listed in annex.

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Date of the actual completion of the international search

1 March 2002

Date of mailing of the international search report

08/03/2002

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Authorized officer

Jensen, K
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