

SPECIFICATION

A process and apparatus for manufacturing a tubular pre-moulding of thermoplastic material

The present invention relates to a process and apparatus for manufacturing a tubular pre-moulding of a thermoplastic material.

In a production process used for the manufacture of containers from thermoplastic material, blanks for containers are produced from severed parts of extruded long tubes consisting of an amorphous thermoplastic material, these blanks normally being called pre-mouldings. At one end, the severed pieces are shaped in such a way that they form the mouth part of the container, whilst they are closed at the other end.

The present invention is particularly suitable for the manufacture of pre-mouldings from a thermoplastic of the polyester or polyamide type. Examples of such materials are polyethylene terephthalate, polyhexamethylene-adipamide, polycaprolactam, polyhexamethylene-sebacamide, polyethylene 2,6- and 1,5-naphthalate, polytetramethylene 1,2-dihydroxybenzoate and copolymers of ethylene terephthalate, ethylene isophthalate and similar polymers. The description of the invention below relates mainly to polyethylene terephthalate, called PET in the further text, but the invention is not restricted only to the use of either this material or one of the other materials already mentioned; instead, it is also applicable to other thermoplastic materials.

For a better understanding of the invention, several characteristic properties of the polyester polyethylene terephthalate are described below. From the literature, for example "Properties of Polymers", by D.W. van Krevelen, Elsevier Scientific Publishing Company, 2nd compl. revised edition 1976, it is known that the properties of the material change when amorphous polyethylene terephthalate is oriented. Some of these changes are shown in the diagrams, Figures 14.3 and 14.4 on pages 317 and 319 in the book "Properties of Polymers". The symbols used in the discussion below correspond to the symbols in that book.

PET, like many other thermoplastic materials can be oriented by stretching the material. Normally this stretching takes place at a temperature above the glass transition temperature T_g of the material. The strength properties of the material are improved by orienting. The literature shows that, in the case of the thermoplastic PET, an increase in the stretching ratio Λ , that is to say the quotient of the length of the stretched material and the length of the unstretched material, also leads to an increase in the improvement of the material properties. When the stretching ratio Λ is increased from about 2 to a little more than 3, particularly large changes in the material properties are obtained. The strength in the direction of orientation is here markedly improved, whilst at the same time the density ρ and likewise the crystallinity X_c rises and the glass transition temperature T_g is raised. It can be seen from the stress-strain diagram on page 317 that, after stretching with Λ assuming

the value of 3.1, a stress of 10 CN/tex applied to the material produces a very small elongation, whilst after stretching with Λ assuming the value 2.8 the elongation at the same stress is substantially larger.

In the text, the term "step" is sometimes used to designate orienting which is obtained by stretching, or a reduction in thickness by about 3 times, and which leads to the marked improvements of the material properties, indicated above.

The diagrams quoted above show changes which are obtained on mono-axial orientation of the material. In biaxial orientation, similar effects are obtained in both directions of orientation. Orientation is carried out by successive stretchings.

Improved material properties, corresponding to those which are obtained by the "step" defined above, are also obtained if an amorphous material is stretched until it flows and, before flowing, the material is at a temperature which is below the glass transition temperature T_g . In a rod being drawn, a reduction of the diameter of about 3 times results in the flow zone. On drawing, the flow zone is continuously displaced into the amorphous material, whilst at the same time the material, which has already undergone the state of flowing, absorbs the tensile forces of the test rod without an additional permanent stretching.

Furthermore, it has been found, surprisingly, that an improvement of the material properties, obtained in the "step", is also achieved even if the material is caused to flow by means of pressure and the pressure-generating element at the same time reduces the thickness of the material to about 1/3 of the previous thickness (this applies to PET), the reduction in the thickness leading to an elongation of the section of material by a factor of about 3 in a direction which is at right angles to the direction in which the reduction in thickness takes place.

For bottles, defined external diameters of the mouth with the associated thread are standardised and, in the technology known at present when using the moulding process described as an introduction, this determines the greatest diameter which is permissible in the blow-moulded container body. The reasons for this are explained in more detail in the following text. In order to obtain an amorphous starting material for the pieces of tube, which are to be shaped into pre-mouldings, the material must be cooled rapidly to below the glass transition temperature T_g after extruding - in the case of extruded tubes from which the pieces of tube are severed. In the case of excessive wall thickness, the material does not possess adequate heat conductivity to enable the central sections of the wall to be cooled as rapidly as required, so that the material located in the centre becomes crystalline and opaque. For this reason, viewed theoretically, the largest possible wall thickness of the extruded tubes is less than 9 mm. In practice, however, wall thicknesses of less than 4 mm are used. In fact, in blow-moulding of a pre-moulding having wall material of excessive thickness, problems arise due to the cooling of the material during the actual blow-moulding step and before the material reaches the wall of the mould. The blow-moulded container is no longer clear as

glass and, instead contains opaque white sections. In blow-moulding, in order to obtain containers having the requisite resistance against stresses and penetration of the container wall, the wall thickness of the finished container must not fall below a defined value. Moreover, a reduction of the external diameter of the tube during the shaping of the mouth part of the pre-moulding is not possible in accordance with known technology. The result is that the desired mouth diameter of the blow-moulded container is decisive for the diameter of the pre-moulding and thus for the maximum diameter of the blow-moulded container body. If bottles of large capacity are required, these bottles are extended, according to known technology, in the axial direction after they have reached the maximum possible diameter. In addition to the disadvantage of a certain instability, the extension represents an unsatisfactory utilisation of the quantity of material in the container body since the requisite quantity of material per unit volume of storage capacity is greater than would be necessary if both the diameter and the length of the container body were adapted to the actual volume required. Moreover, the unnecessarily large surface of the container leads to a corresponding increase in the overall penetration of carbon dioxide during the storage of beverages containing carbonic acid.

To utilise the material properties of the material in the best way, it is desirable that the diameter of those parts of the pre-moulding which, after the blow-moulding step, represent the actual container body, is given a value which has the result that the material in the blow-moulded container body assumes the desired orientation. In container of PET it is desirable that the material, in conjunction with blow-moulding, is biaxially stretched in such a way that the product of the stretchings is about 9.

The above shows that, according to known technology, the quantity of material in the mouth part is not determined by the calculated stresses but by the maximum diameter of the container body. As a rule, this leads to a considerable excess of material in the mouth part. For example, in a PET bottle of 1 litre capacity, the mouth part can, according to known technology, contain up to 25-30% of the total quantity of material. Disregarding the unpleasant appearance of the oversizing of the mouth part, this fact also results in a waste of material, which is of importance in the mass production of articles.

In the technology used at present, the mouth part and adjacent neck parts consist of unoriented material, that is to say amorphous material. This means that the material in the mouth part including the adjacent neck parts has properties which differ from those of the container body. In containers of, for example, PET, the material in the mouth part has a glass transition temperature T_g of 71°C, whilst the glass transition temperature of the material in the container is about 81°C. It follows from this that the material in the mouth part softens at a lower temperature than the material in the container body.

It is already known, by cold-forming of the mouth part of the blank, to displace material downwards from the mouth part into the sections of the blank,

which later represent the wall sections of the container body. In this way, a certain matching of the quantity of material in the mouth part to the future stresses is achieved but, between the actual container body and the mouth part, neck sections are formed in which the material is stretched by a factor of less than 3. These neck sections in the moulded container thus consist of inadequately oriented material, whilst at the same time the wall thickness is undesirably large. This method is described in British Patent No. 2016360B.

U.S. Patent No. 4,108,937 describes a method wherein a tubular blank, which is closed at one end and which is provided at the other end with beading for fixing the blank in a downstream blowing element, is injection-moulded and wherein the tubular blank is blow-moulded after a certain reshaping to give a container. Material in the tubular part of the blank is expanded in the radial direction at a temperature above the glass transition temperature T_g in order thus to form the mouth part of the container. A container formed in the manner described possesses a mouth part and a neck section in which the material has been exposed to only very slight stretching and hence orienting, so that the disadvantages, already indicated, with respect to the mouth parts of the known containers are also present in this container. The invention described in the U.S. Patent also has the disadvantage that only a part of the material content of the injection-moulded tubular blank is utilized when reshaping the blank to give the finished container. It is obvious that the losses of material, which occur in this process, represent an economic disadvantage in the mass production of articles.

From Federal German Offenlegungsschrift DOS 2,540,930, a process is known wherein a tubular blank of PET is reshaped to give a container and wherein the container wall consists of a material which is stretched by a factor of, for example, more than 1.5. The bottom part of the container consists of an amorphous unoriented material, whilst the neck sections of the container consist of material which has been oriented only to a slight extent. As a result of heating and crystallisation, caused thereby, the strength of the material is improved in the un-oriented zones which, at the same time become opaque. Furthermore, a combination of the methods indicated above results in an undesired oversizing of the neck sections of the containers, whilst the latter at the same time have poorer properties than the material in the actual container body.

According to the present invention there is provided a process of manufacturing a tubular pre-moulding of thermoplastic material, wherein external pressure is applied to one or more zones of a tube of thermoplastic material which is at a temperature below the glass transition temperature of the material, the external pressure being applied to the or each zone of the tube by displacing one or more pressure-generating elements relative to the tube in both the circumferential and axial directions of the tube, the pressure being arranged to reduce the thickness of the material until flow sets in and to simultaneously displace the material in the axial

direction of the tube whereby the material is oriented substantially in the axial direction.

In an embodiment, at least part of the oriented material is heated to a temperature above the glass transition temperature of the material and is expanded in the radial direction to contact mould walls shaped to form a mouth part and adjacent neck section. The end of the tube remote from the mouth part is closed. Preferably, two mouth parts, which face towards one another and have respective adjacent neck sections are formed by the radial expansion of the material of a zone of reduced thickness of material.

The neck section may be formed by the radial expansion of the material of a zone of reduced thickness of material, the material of the neck section having been stretched in the circumferential direction of the tube by a factor of more than 2.

Preferably, the temperature of contact surfaces of said pressure-generating elements with the tube is kept below the glass transition temperature of the material of the tube. In this respect, cooling devices may be located adjacent said pressure-generating elements to keep the temperature of their contact surfaces below the glass transition temperature.

In one embodiment a zone of a tube of PET or a comparable material is oriented such that material in the zone is gradually caused to flow by means of the external pressure and at the same time the thickness of the material is reduced to about 1/3, preferably at most 1/3, of the previous thickness, the reduction in thickness entailing an elongation of the zone being worked by a factor of about 3, preferably a factor of at least 3, in the axial direction of the tube. Before flowing, the material is at a temperature which is below the glass transition temperature T_g and preferably at room temperature. The external pressure is generated, for example, by one or several rollers which roll over the outer or inner surface of the tube and which move in the axial direction of the tube. After working, the material is oriented in the axial direction of the tube.

The zones of reduced wall thickness are as a rule found in those parts of the tube which, in the blow-moulded container to be formed, correspond to the material zones, the material thickness of which would be greater than about 1/9 of the material thickness of the tube, if the material thickness of the tube in the zone concerned had not already been reduced before blow-moulding. In certain applications, the wall thickness is reduced in all zones of the tube as a result of pressure against the outer surface of the tube and, in other applications, the reduction is effected in all zones as a result of pressure against the inner surface of the tube. Moreover, embodiments are used wherein the wall thicknesses of a number of zones are reduced as a result of pressure against the inner surface and, simultaneously, the wall thicknesses of a number of other zones are reduced as a result of pressure against the outer surface of the tube. Furthermore, embodiments are used wherein the wall thickness in a number of zones is reduced by simultaneous pressure in each zone against the inner and outer surfaces of the tube.

In a preferred embodiment of the invention, one of

the oriented zones in the tube is located at one end of the tube. The material in this zone is then blow-moulded at a temperature above the glass transition temperature T_g against a mould in order to form, for example, a thread with parts of adjacent neck sections in a future mouth part. Subsequently, the tube is reshaped at the opposite end in such a way that it is closed, whilst the future mouth part is treated such that the requisite closure surfaces are obtained.

A pre-moulding manufactured by the process defined above can be used to form a container in which the mouth part, the neck section and the container body are all of a material which is adapted to the stresses occurring and in which the material in the said parts is oriented to a satisfactory extent. Preferably, the material is stretched, at least in the axial direction, by a factor of more than 3.

This has the advantage that all the said parts of the container have a raised glass transition temperature T_g , and thus that all the said parts will have the same heat resistance.

Moreover, the invention enables a container having a smaller mouth diameter to be manufactured, the length and diameter of the container body being matched to the storage capacity of the container in such a way that the smallest possible quantity of material per unit volume of storage space results.

In addition, a container with a neck part of any desired shape may be formed from the pre-moulding, the material in the mouth part and in the neck part also being oriented and having a crystallinity of more than 10%. This is achieved by stretching the material to the requisite extent, for example in the case of containers of PET by stretching in the axial direction by a factor of more than 3. According to known technology it was hitherto not possible to obtain such a degree of orienting, unless the mouth part and neck sections of the containers were to consist of mainly unoriented material, in which case the neck sections merge in the shortest possible distance with oriented sections of the container body, where the wall thickness has been reduced by a factor of at least 3. This shaping represented an attempt to reduce the size of that zone in the neck part, which has mainly amorphous material and low orientation and hence a lower glass transition temperature T_g .

The invention also extends to apparatus for manufacturing a tubular premoulding of thermoplastic material, comprising one or more pressure-generating elements displaceable relative to a tube of thermoplastic material both in the circumferential and axial directions of the tube, displacement of the pressure-generating elements when in contact with the tube being arranged to reduce the thickness of the material in at least one zone of the tube until flow sets in and to simultaneously displace the material in the axial direction of the tube whereby the material is oriented substantially in the axial direction.

The apparatus further comprises holders for the tube and a blowing mandrel, and a mould for expanding the material of said zone of reduced wall thickness against the walls of the mould for forming a mouth part and an adjacent neck section. Means to

close the end of the tube remote from the mouth part are also provided.

Preferably, the apparatus also comprises a fixing element for holding one end of the tube and drive means for rotating the fixing element and hence the tube whereby the tube is rotatable about its own axis, and further comprising a support shaft arranged to extend within the tube during the application of the pressure-generating elements.

The pressure-generating element may comprise one or several forming rollers. In an embodiment, several forming rollers are arranged at a slight offset in the axial direction relative to one another. In a preferred embodiment, each forming roller has, as viewed in the axial direction of the roller, a central press surface and, on each side thereof, a respective holding surface. The difference in diameter between the press surface and each holding surface is twice the reduction in thickness, which is obtained on orienting of the material. The transition surfaces between the press surface and holding surfaces preferably form an angle of about 45° to the roller axis when forming a tube of PET. The said angle is adjusted to the slope which results on cold-forming of the material between the amorphous material and the drawn material.

Embodiments of the present invention will hereinafter be described, by way of example, with reference to the accompanying drawings, in which:

Figures 1 and 2 show pressure-forming apparatus in different working positions,

Figure 3 shows different phases of the pressure-forming step,

Figures 4 and 5 show longitudinal sections of alternative embodiments of apparatus for blow-moulding mouth parts and adjacent neck sections,

Figure 6 shows apparatus for severing the tube formed by blow-moulding and

Figures 7 and 8 show alternative embodiments of completed tubular pre-mouldings.

Figures 1 and 2 show apparatus for the pressure-forming of a tube from a thermoplastic material. Figures 1a and 2a show the front view of the apparatus and Figures 1b and 2b show a side view of the apparatus. In Figure 1, the apparatus is in the starting position and, in Figure 2, it is in the working position.

As is shown in Figures 1 and 2, the apparatus comprises a frame 10 on which a holder 11 is arranged such that it can reciprocate relative to track 21. The holder 11 consists of an upper holder arm 12 and a lower holder arm 13, which are movably connected to a pressure cylinder 14. The upper end of the pressure cylinder 14 is fastened via a bearing 20 to a carriage 19 which runs on the track 21. A line 26 for supplying pressure medium is connected to the pressure cylinder 14. A sensor 16 is actuated by the lower holder arm 13 and indicates that the holder 11 is in the working position. Sensors 17 and 27 indicate the two end positions for the reciprocating movement of the holder 11.

A feed shaft 18, driven by a drive mechanism (not shown), extends through an internally threaded bore 32 in the holder 11. The feed shaft 18 has an external thread 31 corresponding to the internal thread of the

bore 32. The end of the shaft 18 remote from the drive mechanism is fixed to the frame 10. A forming roller 22 is mounted in a bearing in the holder 11.

A tube 50 of thermoplastic material is fixed by a fixing element 30 and is rotatable by a drive mechanism (not shown).

The apparatus illustrated in Figures 1 and 2 is used to form a tubular blank from the tube 50. In its simplest embodiment, the tubular blank comprises a cylindrical part which is closed at one end and consists mainly of amorphous material, and a future mouth part and adjacent neck section of oriented material having a crystallinity of more than 10%. The material in the future mouth part and adjacent neck section has pronounced orientation in the axial direction of the tube and generally a lesser degree of orientation in the circumferential direction of the tube. The circumferential orientation is produced during radial expansion of the material and depends on the extent of this radial expansion.

If more than one oriented zone is present, the material properties indicated above apply of course to all the oriented zones.

In an embodiment, a central zone of the tube is worked in order to obtain the orientation of the material described above. This central zone of oriented material is surrounded, in the axial direction of the tube, by two tube parts of amorphous material. When the material being worked, which is oriented mainly axially, is blow-moulded, mouth parts and neck sections for two blank parts are formed, the mouth parts of which face each other. The tube is then severed at the transition between the two mouth parts, two blank parts being formed which, after closing and, if appropriate, reworking of the mouth edges in order to obtain the required closing surfaces, form pre-mouldings for subsequent reshaping to produce containers.

By using the process described in the preceding paragraph it is possible to set up production apparatus which works efficiently.

In apparatus for the manufacture of pre-mouldings a tube of PET or comparable material is clamped between two holders. The first holder fixes one end of the tube, whilst the second holder acts as a support for the tube and enables the tube to be rotated about its own axis. The second holder may simultaneously act as the working element, that is the pressure-generating element which effects the flow of the material of the tube.

To stabilise the position of the tube 50, a cylindrical inner support shaft 28 is provided, one end of which is fixed by the fixing element 30. The other end of the support shaft 28 is rotatably mounted in a bearing 29. The length of the inner support shaft 28 is selected such that it is possible to elongate the tube 50.

Figures 3a to 3d show the design of the forming roller 22 in more detail. The forming roller has a central press surface 23 and two holder surfaces 24a and 24b on either side of the press surface, as seen in the axial direction of the roller. The diameter of each holder surface 24a and 24b is smaller than that of the press surface 23, the difference in diameter being twice the displacement of the tube 50 in the

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axial direction, to which the roller is subjected in moving from the position shown in Figure 3a to the position shown in Figure 3b. Between the press surface 23 and each holder surfaces 24a, 24b a respective transition surface 33a, 33b is formed, each transition surface 33 being arranged at an oblique angle to the axial direction of the roller. The angle of each transition surface 33 is adjusted to the inclination of the transition which is produced on cold-forming in the flow zone of the material.

Figure 3a shows an untreated tube 50, the roller 22 being in contact with the outer surface of the tube. Figures 3b to 3c show the tube 50b, 50c during different phases of the working step, and Figure 3d shows the tube 50d at the end of the working step. In the figures, the distances x, y, z and 3x, 3y, 3z respectively are indicated, wherein x, y, z denote the feed of the roller in the axial direction of the tube and 3x, 3y, 3z denote the lengths, corresponding thereto, of the worked zone. The elongation of the tube during working is thus of the order of magnitude of 2z. The reference numeral 51 marks a worked part of the tube.

Figure 4 shows apparatus for reshaping the worked part 51d of the tube 50d by blow-moulding. The apparatus comprises holders 80a, 80b and 81a, 81b which each fix a respective end of the tube. The end faces of the tube bear against gaskets 34 and 41. One of the two holders 81a, 81b is provided with an outlet valve 36. Between the holders 80, 81, a two part mould 57a, 57b is located, the moulding surface of which corresponds to the desired shape of the tube after the blow-moulding of the worked part 51d of the tube. The reference numerals 52a and 52b mark two mouth parts, facing towards one another, of the radially expanded tube 50d. A blowing mandrel 87 with orifices 40 is provided for supplying pressure medium to the sealed cavity which is formed in the interior of the tube 50d with the aid of the gaskets 34, 41. A gasket 35 is located between the blowing mandrel and the holder 80 in order to seal the mandrel 87 against the holder.

Figure 5 shows a further embodiment of apparatus for reshaping the worked part 51d of the tube, this apparatus being identical in principle with that shown in Figure 4. In Figure 5, however, only one of the two holders and only one part of the mould 59, corresponding to mould 57 in Figure 4, are shown. The figure also shows the central worked zone which is blown against the mould 59. The moulding surfaces of the mould 59 match the shape of two mouth parts, which face towards one another (and of which only one, 52a, is shown in the figure) and of parts of adjacent neck sections 60a of the container which is to be formed from the blanks in the process of production. A zone 56 with the largest diameter of the moulded neck sections preferably has a diameter which is at least three times the original diameter of the tube.

Figure 6 shows apparatus for severing the tube formed by blow-moulding. A severing device 58 severs the blow-moulded tube 50d the transition between the two mouth parts 52a, 52b which have been formed.

Figures 7 and 8 show completed tubular pre-

mouldings 60, the pre-moulding 60a shown in Figure 7 having been formed from a blank part as shown in Figure 4 and the pre-moulding 60b shown in Figure 8 having been formed from a blank part shown in Figure 5. At one end in each case, the pre-mouldings have a mouth part 62a, 62b with adjacent neck section 63a, 63b. At the other end the pre-mouldings have a closure 61a, 61b. A tubular section 64a, 64b can be seen between the closures 61a, 61b and the neck sections 63a, 63b.

In the pressure-forming of a tube 50, the latter is fixed in the fixing element 30. It thus surrounds the inner support shaft 28. Pressure is applied to the pressure cylinder 14 such that it displaces the holder 11 and the lower holder arm 13 is moved towards the sensor 16. The roller 22 is thus displaced in the axial direction relative to the tube 50 and, in a first phase, the roller assumes the position shown in Figure 1. At the same time as pressure is applied to the pressure cylinder 14, the drive mechanism for the fixing element 30 is started so that the tube 50 is rotated about its axis.

Subsequently, the pressure cylinder 14 further displaces the holder 11 until the lower holder arm 13 bears against the sensor 16 and the holder assumes the position shown in Figure 2. The displacement of the holder 11 has the effect that the roller 22 assumes its other position, that is to say the working position. Material in the wall of the tube 50 is thus displaced. In an initial phase of this feeding process, the wall is deformed purely elastically but, in the state of highest pressure, flow in the material sets in and the result deformation is permanent and corresponds to a reduction in the wall thickness to about 1/3 of the original thickness.

As already stated, the sensor 16 indicates that the roller is in the working position. The sensor 16 actuates the drive mechanism for the feed shaft 18 so that the shaft 18 rotates. As the shaft 18 rotates the holder 11 is displaced therealong due to the engagement of the thread of the feed shaft 18 with the thread of the bore 32. When the holder 11 abuts against the sensor 17, the sensor 17 causes the rotary motion of the fixing element 30 to be switched off and the pressure cylinder 14 to be retracted so that the holder assumes a position corresponding to that shown in Figure 1. The shaped tube can then be taken out of the forming device.

Figures 3a to 3d show in principle the reshaping of the tube 50. Figure 3a corresponds to the position shown in Figure 1. Figures 3b and 3c illustrate the course of the reshaping step and Figure 3d shows the position corresponding to Figure 2. Due to the reduction in wall thickness, the tube is elongated in its axial direction. The total feed z of the roller in the axial direction of the tube results in a worked part 51d of length 3z, and this means that the tube has been elongated by the length 2z during the working.

Figure 3b shows how the transition face 33b of the roller is in contact with the material in the flow zone, whilst at the same time the holding surface 24b eliminates any tendencies to form corrugations in the material adjoining the flow zone.

In the above description it has been assumed that the holder 11 and the roller 12 are displaced from

right to left as shown in the drawings, that is in the direction of elongation of the tube. Alternatively, the forming process can take place in the opposite direction. Advantageously, apparatus is arranged such that every second tube is formed by feeding the roller against the direction of elongation of the tube. For this purpose, the sensor 27 is provided which indicates that the holder 11 has, during the motion against the direction of elongation of the tube, assumed the position which represented the original starting position. During feeding in the direction of elongation of the tube, the speed of rotation of the feed shaft 18 is about 3 times the speed of rotation when being fed in the opposite direction.

During blow-moulding of the worked tube, the tube is fixed at the holders 80, 81, whereupon the blowing mandrel 87 is introduced into the tube, making a seal. The outlet valve 36 is closed at this stage. The worked zone 51d of the tube is heated by devices according to known technology, whereupon the mould 57 or 59 is closed. To accelerate heating of the material, it is also possible to provide the mandrel 87 with heating means. The sealed space in the interior of the tube 50d is subjected to pressure, and the heated part of the tube is blow-moulded until it makes contact with the cold mould surface of the mould 57 or 59. When the material has cooled sufficiently to be dimensionally stable, the mould 57 or 59 is opened and the severing device 58 severs the blow-moulded tube into two blank parts at the transition between the two mouth parts.

In a preferred embodiment of the invention, the blank parts are severed using one or more severing discs which rotate under pressure right around the circumferential surface of the moulded tube at the transition between the two mouth parts.

To obtain a pre-moulding as shown in Figure 7 or Figure 8 from the blank parts produced, the end of the particular blank part spaced from the mouth part and which has not been moulded is closed by reshaping. This may be done by known means, for example, by heating, the material is heated to a temperature above the glass transition temperature T_g , whereupon the blank is pressed into a spherical shell which reshapes the heated material and closes the end of the tube.

In the embodiments illustrated, the pressure-forming apparatus includes a single forming roller. If required, a number of forming rollers or pressure-generating elements may be used. Particular advantages can be obtained by using apparatus having three pressure-generating elements which are arranged in the corners of an equilateral triangle.

Heat is always generated during the reshaping of the tube by the pressure-generating elements or forming rollers. In certain applications, the pressure-generating elements are cooled in order to ensure that their contact surfaces are always below the glass transition temperature of the material of the tube. In particular when pressure-generating elements of relatively small dimensions are used, the temperature rise can assume such values that cooling is necessary.

CLAIMS

1. A process of manufacturing a tubular pre-moulding of thermoplastic material, wherein external pressure is applied to one or more zones of a tube of thermoplastic material which is at a temperature below the glass transition temperature of the material, the external pressure being applied to the or each zone of the tube by displacing one or more pressure-generating elements relative to the tube in both the circumferential and axial directions of the tube, the pressure being arranged to reduce the thickness of the material until flow sets in and to simultaneously displace the material in the axial direction of the tube whereby the material is oriented substantially in the axial direction.

2. A process as claimed in Claim 1, wherein at least part of the oriented material is heated to a temperature above the glass transition temperature of the material and is expanded in the radial direction to contact mould walls shaped to form a mouth part and adjacent neck section.

3. A process as claimed in Claim 2, wherein the end of the tube remote from the mouth part is closed.

4. A process as claimed in Claim 2 or 3, wherein two mouth parts, which face towards one another and have respective adjacent neck sections are formed by the radial expansion of the material of a zone of reduced thickness of material.

5. A process as claimed in any preceding claim, wherein the neck section, is formed by the radial expansion of the material of a zone of reduced thickness of material, the material of the neck section having been stretched in the circumferential direction of the tube by a factor of more than 2.

6. A process as claimed in any preceding claim, wherein the pressure is arranged to reduce the thickness of the material at least by a factor of 3.

7. A process as claimed in any preceding claim, wherein the temperature of contact surfaces of said pressure-generating elements with the tube is kept below the glass transition temperature of the material of the tube.

8. A process as claimed in Claim 7, wherein the contact surfaces of said pressure-generating elements are kept below the glass transition temperature of the material by cooling devices located adjacent said elements.

9. A process as claimed in any preceding claim, wherein the reduction in the thickness of the material of the tube in the or each zone is effected by applying pressure against either the outer surface of the tube, or against the inner surface of the tube or by simultaneous application of pressure against both the inner and outer surfaces of the tube.

10. A process as claimed in any preceding claim, wherein the thermoplastic material is a polyester or a polyamide.

11. A process as claimed in Claim 10, wherein the thermoplastic material is chosen from polyethylene terephthalate, polyhexamethylene-adipamide, polycaprolactam, polyhexamethylene-sebacamide, polyethylene 2,6- and 1,5-naphthalate,



right to left as shown in the drawings, that is in the direction of elongation of the tube. Alternatively, the forming process can take place in the opposite direction. Advantageously, apparatus is arranged

5 such that every second tube is formed by feeding the roller against the direction of elongation of the tube. For this purpose, the sensor 27 is provided which indicates that the holder 11 has, during the motion against the direction of elongation of the tube,

10 assumed the position which represented the original starting position. During feeding in the direction of elongation of the tube, the speed of rotation of the feed shaft 18 is about 3 times the speed of rotation when being fed in the opposite direction.

15 During blow-moulding of the worked tube, the tube is fixed at the holders 80, 81, whereupon the blowing mandrel 87 is introduced into the tube, making a seal. The outlet valve 36 is closed at this stage. The worked zone 51d of the tube is heated by

20 devices according to known technology, whereupon the mould 57 or 59 is closed. To accelerate heating of the material, it is also possible to provide the mandrel 87 with heating means. The sealed space in the interior of the tube 50d is subjected to pressure,

25 and the heated part of the tube is blow-moulded until it makes contact with the cold mould surface of the mould 57 or 59. When the material has cooled sufficiently to be dimensionally stable, the mould 57 or 59 is opened and the severing device 58 severs

30 the blow-moulded tube into two blank parts at the transition between the two mouth parts.

In a preferred embodiment of the invention, the blank parts are severed using one or more severing discs which rotate under pressure right around the circumferential surface of the moulded tube at the transition between the two mouth parts.

To obtain a pre-moulding as shown in Figure 7 or Figure 8 from the blank parts produced, the end of the particular blank part spaced from the mouth part

40 and which has not been moulded is closed by reshaping. This may be done by known means, for example, by heating, the material is heated to a temperature above the glass transition temperature T_g , whereupon the blank is pressed into a spherical shell which reshapes the heated material and closes

45 the end of the tube.

In the embodiments illustrated, the pressure-forming apparatus includes a single forming roller. If required, a number of forming rollers or pressure-generating elements may be used. Particular advantages can be obtained by using apparatus having three pressure-generating elements which are arranged in the corners of an equilateral triangle.

Heat is always generated during the reshaping of

55 the tube by the pressure-generating elements or forming rollers. In certain applications, the pressure-generating elements are cooled in order to ensure that their contact surfaces are always below the glass transition temperature of the material of the tube. In particular when pressure-generating elements of relatively small dimensions are used, the temperature rise can assume such values that cooling is necessary.

CLAIMS

1. A process of manufacturing a tubular pre-moulding of thermoplastic material, wherein external pressure is applied to one or more zones of a tube of thermoplastic material which is at a temperature below the glass transition temperature of the material, the external pressure being applied to the or each zone of the tube by displacing one or more pressure-generating elements relative to the tube in both the circumferential and axial directions of the tube, the pressure being arranged to reduce the thickness of the material until flow sets in and to

70 simultaneously displace the material in the axial direction of the tube whereby the material is oriented substantially in the axial direction.

2. A process as claimed in Claim 1, wherein at least part of the oriented material is heated to a temperature above the glass transition temperature of the material and is expanded in the radial direction to contact mould walls shaped to form a mouth part and adjacent neck section.

3. A process as claimed in Claim 2, wherein the end of the tube remote from the mouth part is closed.

4. A process as claimed in Claim 2 or 3, wherein two mouth parts, which face towards one another and have respective adjacent neck sections are formed by the radial expansion of the material of a zone of reduced thickness of material.

5. A process as claimed in any preceding claim, wherein the neck section, is formed by the radial expansion of the material of a zone of reduced thickness of material, the material of the neck section having been stretched in the circumferential direction of the tube by a factor of more than 2.

6. A process as claimed in any preceding claim, wherein the pressure is arranged to reduce the thickness of the material at least by a factor of 3.

7. A process as claimed in any preceding claim, wherein the temperature of contact surfaces of said pressure-generating elements with the tube is kept below the glass transition temperature of the material of the tube.

8. A process as claimed in Claim 7, wherein the contact surfaces of said pressure-generating elements are kept below the glass transition temperature of the material by cooling devices located adjacent said elements.

9. A process as claimed in any preceding claim, wherein the reduction in the thickness of the material of the tube in the or each zone is effected by applying pressure against either the outer surface of the tube, or against the inner surface of the tube or by simultaneous application of pressure against both the inner and outer surfaces of the tube.

10. A process as claimed in any preceding claim, wherein the thermoplastic material is a polyester or a polyamide.

11. A process as claimed in Claim 10, wherein the thermoplastic material is chosen from polyethylene terephthalate, polyhexamethylene-adipamide, polycaprolactam, polyhexamethylene-sebacamide, polyethylene 2,6- and 1,5-naphthalate,



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polytetramethylene, 1,2-dihydroxybenzoate and copolymers of ethylene terephthalate, ethylene isophthalate or other similar polymeric plastics.

12. Apparatus for manufacturing a tubular pre-moulding of thermoplastic material, comprising one or more pressure-generating elements displaceable relative to a tube of thermoplastic material both in the circumferential and axial directions of the tube, displacement of the pressure-generating elements when in contact with the tube being arranged to reduce the thickness of the material in at least one zone of the tube until flow sets in and to simultaneously displace the material in the axial direction of the tube whereby the material is oriented substantially in the axial direction.

13. Apparatus as claimed in Claim 12, further comprising holders for the tube and a blowing mandrel and a mould for expanding the material of said zone of reduced wall thickness against the wall of the mould for forming a mouth part and an adjacent neck section.

14. Apparatus as claimed in Claim 13, further comprising means to close the end of the tube remote from the mouth part.
15. Apparatus as claimed in any of Claims 12 to 14, further comprising a fixing element for holding one end of the tube and drive means for rotating the fixing element and hence the tube whereby the tube is rotatable about its own axis, and further comprising a support shaft arranged to extend within the tube during the application of the pressure-generating elements.

16. Apparatus as claimed in any of Claims 12 to 15, wherein the pressure-generating elements consist of rollers which are each provided with a cylindrical central press surface and a respective cylindrical holding surface on each side of the press surface, the diameter of each holding surface being smaller than the diameter of the press surface by an amount which approximately corresponds to twice the reduction in thickness of the material, and wherein the transition between the press surface and each holding surface consists of a respective transition surface which each extend at an angle to the axis of the roller which corresponds to the angle between the drawn material and the amorphous material of the tube when the tube is cold-drawn.

17. Apparatus as claimed in Claim 16, wherein each transition surface extends at an angle of 45° to the axis of the roller.

18. A process of manufacturing a tubular pre-moulding of thermoplastic material substantially as hereinbefore described with reference to the accompanying drawings.

19. Apparatus for manufacturing a tubular pre-moulding of thermoplastic material substantially as hereinbefore described with reference to and as illustrated in Figures 1 to 6 of the accompanying drawings.