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A PROCESS AND APPARATUS FOR MANUFACTURING
TUBULAR PRE-MOULDINGS OF THERMOPLASTIC MATERIAL

The present invention relates to a process and apparatus for manufacturing tubular pre-mouldings of thermoplastic material. Such pre-mouldings may, for example, be reshaped subsequently to produce containers and the like.

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 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 containers 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.

- 5 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
- 10 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".
- 15 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

20 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

25 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.

- 5 The strength in the direction of orientation is here markedly improved, whilst at the same time the density

ρ and likewise the crystallinity χ_c rises and the glass transition temperature T_g is raised. It can be seen from the stress-strain diagram on page 317 that,

- 10 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 of 2.8 the elongation at the same stress is substantially larger. In the text, the term
- 15 "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

20 obtained on mono-axial orientation of the material.

In biaxial orientation, similar effects are obtained in both directions of orientation. Orientation is carried out as a rule 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.

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-moulding 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
5 theoretically, the largest possible wall thickness of the extruded tubes is less than about 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
10 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
15 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
20 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
25 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 containers 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 body 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

5 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.

10 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.

15 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

20 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.

25 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 part 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 utilised 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 unoriented 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
5 the material in the actual container body.

According to the present invention there is provided a process of manufacturing tubular pre-mouldings of thermoplastic material, wherein one or more zones of a tube of thermoplastic material are stretched in the
10 axial direction to reduce the thickness of the material of the or each zone and orient the material substantially in the axial direction, the material in the or each zone is heated to a temperature above the glass transition temperature and is expanded in the radial direction of the tube
15 until it makes contact with mould walls such that a mouth part and an adjacent neck section are shaped, the material of the mouth part and neck section then being cooled below the glass transition temperature, and an end of the tube spaced from the mouth part is closed.

20 A blank or pre-moulding produced by a process of the invention 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
25 is oriented to a satisfactory extent.

This results in the advantage of a raised glass transition temperature T_g in all the said parts of the container. This means that all the said parts will have

the same heat resistance, and this is a great advantage compared with containers which are formed according to the known technology and which, at least as far as containers with mainly clear and transparent materials are concerned, have neck sections and mouth parts which are more sensitive to heat stresses than the actual container body.

In an embodiment, a tube of thermoplastic material is clamped between two mutually separate clamping devices. The material in the zone between the two clamping devices is stretched in the axial direction of the tube by moving the clamping devices away from one another. When PET is used, stretching by a factor of at least 3 takes place.

According to one embodiment of the invention, the material in the tube is stretched, while the material is at a temperature above the glass transition temperature T_g , whereas in another embodiment the material is stretched in the cold state, which means that the material is at a temperature below the glass transition temperature T_g at the beginning of the stretching step. On stretching "in the cold state", the material is drawn until flow sets in.

After stretching, at least the central sections of the drawn material are blow-moulded against a mould at a temperature above the glass transition temperature T_g in order to form, for example, threads and, in some cases parts of the adjacent neck sections, while two future mouth parts are in adjacent positions.

Subsequently, the tube is severed at the transition between the two future mouth parts. Each of the two severed blank parts thus produced form a tubular pre-moulding, after closing at one end, and if appropriate, reworking at the other end in order to obtain the required closure surfaces.

In optional embodiments of the invention, the material is heated before the axial stretching to a temperature above the glass transition temperature T_g , or the stretching step is preceded by a blow-moulding step in which the heated material is subjected to a certain expansion in order to increase the diameter of the zone.

In another embodiment of the invention, the mouth parts of the pre-mouldings are shaped by simultaneous axial stretching, and blow-moulding for the purpose of a radial expansion of the heated material.

In some embodiments, the heated material zone has a temperature profile such that one or several annular sections are at a temperature which exceeds the temperature of the adjacent material by 3° to 20°C , preferably 10° to 15°C . The actual drawing or stretching step starts in the sections of higher temperature.

Where the material in the tube is, at the start of axial stretching of the material, at a temperature which is less than the glass transition temperature T_g , the drawing or stretching step may be initiated with the aid of pressure forces. This is achieved,

for example, by means of a ring which surrounds the tube, the inner surface of the ring being brought into contact with the outer surface of the tube by reducing the internal diameter of the ring.

5 On axial stretching of the material, the external diameter of the tube is reduced. It is thus possible to produce a pre-moulding, the mouth part of which has an external diameter which is less than the external diameter of the tube.

10 The invention also extends to apparatus for manufacturing tubular pre-mouldings of thermoplastic material by the process defined above, the apparatus comprising first and second clamping devices for holding parts of the tube are thermoplastic material, drive means for moving said clamping
15 devices towards and away from each other for stretching one or more zones of the tube in the axial direction to reduce the thickness of the material of the or each zone and orient the material substantially in the axial direction, means for heating the material of the or each zone to a
20 temperature above the glass transition temperature, a blowing mandrel for insertion within the tube and a mould for arrangement around the tube, said mould having mould surfaces shaped to produce a mouth part and an adjacent neck section in the part of the tube brought into contact therewith,
25 and means for closing the end of the tube spaced from the mouth part.

The clamping devices are provided for clamping a tube, and the two sets of clamping devices are arranged in such a way that they can be moved towards

one another or away from one another. The contact surfaces of the clamping devices with the tube may be cooled. Appropriate devices may be provided for heating the material in the tube between the said
5 sets of clamping devices, and also the blow-moulds against which the heated material is blown. Moreover, the apparatus may comprise elements for sealing a space within the tube before blow-moulding and also means for applying an elevated pressure to the sealed
10 space. In an embodiment, a cylindrical rod is also fitted axially in the tube. In addition, an element for severing the tube into two preferably equal parts may be provided.

In an embodiment, the clamping devices are
15 arranged such that the tube can be rotated about its own axis. In this way, heating of the material in the zone between the two sets of clamping devices and also the severing of the tube into two equal parts are facilitated.

To form a blank, the tube is fixed between the
20 two clamping devices, after which the latter are moved away from one another. This movement may take place after the material between the two sets of clamping devices has first been heated to the desired temper-
25 ature profile and if required may occur simultaneously

with radial expansion of the material in the tube or after a first radial expansion of the material in the tube has taken place. The length of the displacement relative to the length of the part of the tube to be stretched, is selected in the case of PET in such a way that the material reaches a crystallinity of at least 10% on axial orientation. In some cases, the cylindrical rod is introduced into the tube before the material is stretched. In certain examples, the rod is heated. To effect radial expansion, the two ends of the tube are closed, the material between the two sets of clamping devices may be heated, and the closed space in the tube is subjected to pressure, the heated material expanding in such a way that it makes contact with the mould surfaces, for example for the purpose of moulding the mouth thread and adjacent neck sections. When the material has cooled to a sufficient extent to reach dimensional stability, the tube is severed into two parts by the severing element. Each of the two parts is closed at one end by reshaping and, if appropriate, reworked at the other end, that is to say the mouth end, in order to produce the requisite closing surfaces. Thus, the pre-moulding is completed.

25 The process described above generally produces

two blank parts from each tube which, after a certain reworking and reshaping, each form a pre-moulding. In this manner, no losses of material arise in the production of pre-mouldings. Of course, the stretched material formed during the drawing step can be adapted in such a way that it is used for forming only a single future mouth part with adjacent neck sections. Due to the severing of parts of the piece of tube, which cannot be used for further production of the pre-moulding, however, this leads to undesired losses of material, so that this embodiment of the invention is only used in special cases, for example in the production of pre-mouldings which are intended for containers having long mouth sections and neck sections.

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

FIGURE 1 shows a perspective view of a stretching and blow-moulding apparatus having two sets of clamping devices, with the two sets of clamping devices positioned to receive a piece of tube, FIGURE 2 shows a perspective view of the apparatus of Figure 1 with the clamping devices positioned for fixing a piece of tube,

FIGURE 3 shows a longitudinal section of the stretching and blow-moulding apparatus during the heating of a central part of a piece of tube,

5 FIGURE 4 shows a longitudinal section of the stretching and blow-moulding apparatus with the piece of tube fixed and drawn,

FIGURE 5 shows a longitudinal section of the stretching and blow-moulding apparatus with the internal volume of the piece of tube subjected to pressure to form mouth sections and adjacent neck sections,

10 FIGURE 6 shows a device for severing the piece of tube into two separate blank parts,

FIGURE 7 shows diagrammatically apparatus
15 for the stepwise production of blank parts for pre-mouldings,

FIGURE 8 shows a longitudinal section of a stretching and blow-moulding apparatus having a device for heating an annular section in the
20 piece of tube,

FIGURE 9 shows a longitudinal section of a stretching and blow-moulding apparatus during a cold-drawing step of the piece of tube,

FIGURE 10 shows a longitudinal section of a
25 stretching and blow-moulding apparatus after the cold-drawing step of the piece of tube has been carried out,

FIGURE 11 shows a longitudinal section of part of a stretching and blow-moulding apparatus with the length of the axially drawn zone increased,

5 FIGURE 12 shows a partial longitudinal section of the stretching and blow-moulding apparatus of Figure 11, in which the internal volume of the piece of tube has been subjected to pressure to form neck sections adjacent to a mouth part,

10 FIGURE 13 shows a longitudinal section of a completed tubular pre-moulding which has been produced as illustrated in Figure 5, and

15 FIGURE 14 shows a longitudinal section of a completed tubular pre-moulding which has been produced as illustrated in Figure 12.

20 Figures 1 and 2 show a stretching and blow-moulding apparatus having a frame on which two separate sets of clamping devices 20a and 20b, and 21a and 21b are located. Each set of clamping devices comprises an upper clamping part 20a, 21a and a lower clamping part 20b, 21b. In both sets of clamping devices, the upper clamping part can be moved transversely to the longitudinal axis of the apparatus between an open position and a closed position. In
25 the closed position, each set of clamping devices

holds a respective end of a tube 50. The two sets of clamping devices can be moved longitudinally from the starting position shown in Figure 1 towards one another to an inward position in which they are arranged to accommodate the length of the tube 50 (Figure 2). The clamping devices can also be moved back from the inward position to the starting position. In the starting position, each upper clamping part is in its open position and remains in the open position until the two sets of clamping devices have been moved towards one another to the inward position. In the inward position, the upper clamping parts assume the closed position and each covers a relatively large length of the tube 50. Hence, a large length of the tube 50 is both surrounded by and held by the sets of clamping devices. With the upper clamping parts still in their closed positions, the two sets of clamping devices are subsequently moved back to the starting position.

The transverse movement of the upper clamping parts 20a, 21a of the two sets of clamping devices is effected by means of a respective drive mechanism 25, 26. In addition, a drive mechanism 24 is provided for moving the two sets of clamping devices longitudinally and with respect to one another. The two upper

clamping parts slide in grooves 22, 23 provided in the lower parts, whilst the lower parts slide in grooves 13a and 13b provided in the frame 11.

5 A gripper 28 is provided for inserting and removing the tube 50 from the clamping devices. When the two sets of clamping devices are at their inward position a heating element consisting of the two heating jaws 29a and 29b is brought into a position in which it can heat the central sections
10 of the tube 50. The motion of the heating jaws is effected by means of a drive mechanism 33 including a reciprocable rod. A lead 31 for supplying energy to the heating jaws, for example for supplying electrical power, is shown in the figures.

15 A cylindrical forming and blowing mandrel 27 is provided adjoining one of the two sets of clamping devices. This mandrel 27 is movable by means of a drive mechanism 39 from and to a position in which the cylindrical part of the mandrel projects a little
20 into an opening of the other set of clamping devices. The mandrel projects into the said opening even when the two sets of clamping devices are in their starting positions.

The external diameter of the mandrel and the
25 internal diameter of the tube 50 are arranged such

that the mandrel can be introduced into the tube. Moreover, the mandrel is provided with a row of orifices 40 which communicate with a cavity in the interior of the mandrel, which cavity is connected
5 to a line 32 for supplying a pressure medium.

A pressure medium is also fed via lines 30a, 30b, 30c, 30e (the pressure line 30d is not shown in the figure) to the individual drive mechanisms 24, 25, 26, 33 and 39.

10 In Figure 3, the two sets of clamping devices 20a, 20b, 21a, 21b are shown in their inward position. In addition, Figure 3 shows the cavity 42 in the mandrel 27, a gasket 41 between one end of the tube 50 and the set of clamping devices 21a, 21b, and
15 a gasket 34 between the other end of the tube 50 and the set of clamping devices 20a and 20b. A gasket 35 is also provided between the mandrel 27 and the set of clamping devices 20a, 20b. An outlet valve 36 is located in the lower clamping device 21b.
20 Thus, a sealed space which can be subjected to pressure through the orifices 40 is formed around the mandrel 27 within the tube 50.

Figure 4 shows the two sets of clamping devices moved back to their starting position with the
25 surrounded parts of the tube 50 still held firmly

by the clamping devices. The Figure illustrates that the mandrel 27 continues to project into the set of clamping devices 21a, 21b. A central zone 51 of the tube 50 has been stretched in the axial direction by the movement of the clamping devices and has a smaller wall thickness than the remainder of the tube.

In Figure 5, the central zone 51 has been blow-moulded against a two-part mould 57a, 57b. The shaping surface of the mould corresponds to the form of two mouth parts 52a, 52b, facing one another, for containers which are to be formed from the pre-mouldings in the process of manufacture.

Figure 6 shows the mandrel 27 in its starting position. A severing disc 58 is located in position for severing the tube 50, that is at the transition between the two moulded mouth parts 52a and 52b.

Figure 7 shows a turntable 10 which is rotatable about a bearing 12. A number of positions A-U are indicated around the turntable. One frame 11 with its associated sets of clamping devices, drive mechanisms, tubular mandrel, heating device and the like as described above is located on the turntable at each position. In each position, the particular working step is indicated diagrammatically by the position of mandrel, heating jaws, sets of clamping devices and the like.

Figure 8 shows an embodiment of the invention, which is particularly suitable for cold-drawing of the tube 50. An annular heating element 38 is located between the two sets of clamping devices.

5 By means of this heating element, an annular zone of the central section of the tube 50 is heated to an elevated temperature.

Figures 9 to 10 show the subsequent cold-drawing of the tube 50. In Figure 9, the formation of a
10 centrally located drawn zone 53 has started, whilst in Figure 10 the entire centrally located drawn zone 54 has been formed.

Figures 11 and 12 show an embodiment of the invention wherein a centrally located stretched zone
15 51a of the tube 50 is formed which is longer than in the previously described embodiments. Figures 11 and 12 show only one of the two sets of clamping devices. Figure 11 shows the position after drawing of the tube has been completed, whilst Figure 12 shows the
20 central zone 51a (Figure 11) after it has been blow-moulded against an outer mould 59. The moulding surface of the outer mould corresponds to the shape of two mutually facing mouth parts (only one, 52a, is shown in the figure) and parts of the adjacent
25 future neck section 60a of the containers which are

105

to be formed from the pre-mouldings which are in the process of production. A zone 56, having the largest diameter in the moulded future neck sections, preferably has a diameter which is at least three times the
5 original diameter of the tube.

Figures 13 and 14 show completed tubular pre-mouldings, the pre-moulding shown in Figure 13 having been formed from a blank part as shown in Figure 5, and the pre-moulding shown in Figure 14 having been
10 formed from a blank part as shown in Figure 12. At one end, the pre-mouldings have a mouth part 62a, 62b with an 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 closure
15 61a, 61b and the neck sections 63a, 63b.

Figures 1 to 6 show successive steps in the formation of a pre-moulding according to the invention. Initially, a tube 50 is brought into the position shown in Figure 1 with the aid of the gripper 28. The
20 two sets of clamping devices 20 and 21 are shifted towards one another with the aid of the drive mechanism 24 until the two ends of the tube are in contact with the gaskets 34 and 41 and the gripper 28 is removed. The upper clamping devices are brought into
25 their closed position with the aid of the drive

mechanisms 25, 26 the tube 50 being firmly held at both its ends and at the same time being enclosed over a relatively large part. This situation is shown in Figure 2. The mandrel 27 is then moved within the tube 50. Alternatively, the mandrel 27 may be inserted within the tube during the preceding steps.

When the tube is clamped and the mandrel is in position as shown in Figure 3, the heating jaws 29 are positioned around the central section of the tube.

Energy is supplied to the heating jaws for such a period as is necessary to heat the material in the central section of the tube to a temperature below the glass transition temperature T_g . The drive element

24 then moves the two sets of clamping devices away from one another, and the central section of the tube is thus stretched, with simultaneous thinning of the tube wall. The stretched central section of the tube is shown in Figure 4. Preferably, the central section is stretched by at least a factor of 3, and the

corresponding reduction in wall thickness is thus and also amounts by at least a factor of 3. During the entire drawing step, the mandrel 27 remains within the interior of the tube, within the stretched zone, and this prevents the stretched zone from assuming an undesirably small diameter.

The sealed space within the interior of the tube is then subjected to pressure, and the material in the corresponding section of the tube is expanded until it makes contact with the outer mould 57. In this step, future mouth parts and parts of adjacent neck sections in two blank parts connected to one another are shaped to give pre-mouldings. On contact with the surfaces of the outer mould, the material in the tube is cooled so that it becomes dimensionally stable. With simultaneous retraction of the mandrel 27 into its starting position, the outer mould is opened and a severing disc 28 divides the tube at the transition between the two future mouth parts. This produces two separate blank parts which are closed at one end by reshaping and are provided with the requisite closing surfaces at the other end by reworking. In this way, a tubular pre-moulding as shown in Figure 13 is obtained.

Apparatus for closing one end, and for performing any reworking of the mouth part which may be necessary is not shown in the drawings as conventional apparatus known in the art can be used. Normally, closing is effected by heating the material at the one end of the tube to a temperature above the glass transition temperature T_g , after which the

end is forced in the axial direction against a substantially spherical shell which compresses the soft material and closes the end. Subsequently, the gripper 28 grips the two blank parts formed and
5 removes the two blank parts from the apparatus after the two sets of clamping devices have released the pre-mouldings. The process described above can then be repeated.

Preferably, the process described above is
10 carried out using the apparatus shown in Figure 7. In position A, a tube is fed to the two sets of clamping devices, in position B the two sets of clamping devices are moved towards one another, whilst the mandrel is simultaneously introduced
15 into the tube. In positions C to E the central zone of the tube is heated, and the heating process is interrupted at position F. In positions G to H, the central sections of the tube are stretched. In position I the outer moulds move into the moulding
20 position and in position J the interior of the tube is subjected to pressure and is formed to give the future mouth parts with the adjacent neck sections. In position K, the outer moulds open, whilst in position L the mandrel is retracted into its starting
25 position. Position M is a cooling position for

stabilising the form of the tube or, alternatively,
is a reserve position, whilst in position N the tube
is severed into two blank parts. In position O,
the two future mouth parts are heated for reworking,
5 if appropriate, and they obtain their final form
in position P. In position R, the devices for
reworking the mouth parts have assumed again their
starting position, and subsequently, in position S,
the blank parts have been shifted in the direction
10 towards one another in order to enable the gripper
to engage in position T and to enable the clamping
devices to open in position U, so that the mouldings
formed can be removed from the apparatus shown in
Figure 7. Advantageously, the gripper device here
15 transfers the blanks to devices for closing one of
their ends. Such devices can either be provided
independently of the apparatus of Figure 7 or they
can form part of this apparatus.

In the latter case, the apparatus must be
20 provided with a further number of positions.

During cold-drawing of the central zone of the
tube, the material is heated before the drawing
step with the aid of an annular heating element 38
(Figure 8) over an annular zone within the central
25 section. This heating element is preferably arranged

to heat the central section as far as one of the sets of clamping devices. To control the direction of displacement during the flow which sets in on drawing, the material is normally cooled immediately next to the heated annulus in that direction in which it is intended that the flow step should not propagate. In the embodiments in which the entire material of the tube is to be drawn between the two sets of jaws, the required cooling is obtained by the cooled jaws. In other embodiments, annular cooling devices are used which, in principle, are arranged in a manner corresponding to the arrangement of the heating device 38.

On warm-drawing of the central zone of the tube, one or several annular heating elements are used in certain embodiments in order to produce the desired temperature profile in the central section of the tube before the latter is drawn. The annular heating elements may comprise zones of elevated temperature in the heating jaws 29.

On cold-drawing of the material in the central section of the tube, flow of the material sets in first in the annular zone which has been heated by the annular heating element 38. On further stretching of the central zone of the tube, the flow zone of

the material is displaced in the direction of the other set of clamping devices, see Figure 9, so that, after completion of the stretching step, a central drawn zone has formed, the appearance of which is shown in Figure 10. On cold-drawing, the central zone has no tendency towards a reduction of the internal diameter of the tube, as long as stretching is limited to about a factor of 3. In this embodiment of the invention, it is thus not necessary to cause the mandrel 27 to assume its position in the tube before the actual stretching step. Figures 11-12 show an embodiment of the invention in which the stretched central zone 51a has a greater length than in the embodiments of the invention so far described. When the interior of the tube is subjected to pressure, parts of adjacent neck sections are also formed, in addition to the two future mouth parts, these neck sections being given a greater diameter than that of the actual mouth part. At this stage, it is preferable to allow the future neck section to be shaped to such an extent that the greatest rise in diameter is at least 3-fold. This has the advantage that a relatively dimensionally stable neck section is formed which, during the subsequent heating in conjunction with the shaping of the remaining part of the container,

is affected only to a small extent. The appearance of a pre-moulding, which was formed from a blank part partially shown in Figure 12, can be seen in Figure 14.

In the above description, it has been explained how the blank parts are formed by severing the drawn and shaped tube. In a preferred embodiment of the invention, severing of the blank parts from one another is effected with the aid of one or more severing discs which revolve under pressure about the circumferential surface of the tube formed at the transition between the two future mouth parts.

In the processes described above, heating of the central section of the tube is effected by heating jaws. To obtain the most uniform heating of the material possible, the tube should preferably rotate relative to the heating element. To make this possible, the clamping devices are modified, if appropriate having cone-type bearings or having heating jaws which revolve about the tube.

In the case where the central section of the tube is drawn at an initial temperature which is below the glass transition temperature T_g , the material is heated after the drawing step to a temperature above the glass transition temperature T_g , after which the future mouth part and parts of the adjacent neck sections are shaped.

A tubular pre-moulding of thermoplastic material is described and claimed in copending application No. 8018904 from which the present application is divided.

CLAIMS:

1. A process of manufacturing tubular pre-mouldings of thermoplastic material, wherein one or more zones of a tube of thermoplastic material are stretched in the axial direction to reduce the thickness of the material of the or each zone and orient the material substantially in the axial direction, the material in the or each zone is heated to a temperature above the glass transition temperature and is expanded in the radial direction of the tube until it makes contact with mould walls such that a mouth part and an adjacent neck section are shaped, the material of the mouth part and neck section then being cooled below the glass transition temperature, and an end of the tube spaced from the mouth part is closed.
2. A process as claimed in Claim 1, wherein only a central zone of the tube is stretched and during the radial expansion of the material of the central zone two mouth parts located facing one another are shaped together with a respective adjacent neck section, and wherein after the material has cooled to a temperature below the glass transition temperature the two mouth parts are severed to thereby form two pre-mouldings.

3. A process as claimed in Claim 1 or 2, wherein the or each zone of the tube is stretched to reduce the thickness of the material by a factor of at least 3.
4. A process as claimed in any of Claims 1 to 3,
- 5 wherein the shaped mouth part is subsequently reheated and reworked.
5. A process as claimed in any preceding claim, wherein the material in the or each zone of the tube is heated to a temperature above the glass transition
- 10 temperature before the material is stretched in the axial direction of the tube.
6. A process as claimed in any of Claims 1 to 4, wherein the material in the or each zone of the tube is heated to a temperature above the glass transition
- 15 temperature before the material is stretched, and stretching of the material in the axial direction of the tube and radial expansion thereof are carried out substantially simultaneously.
7. A process as claimed in any of Claims 1 to 4,
- 20 wherein the material in the or each zone of the tube is heated to a temperature above the glass transition temperature, and radial expansion of the material is initiated before the material is stretched in the axial direction.

8. A process as claimed in any of Claims 1 to 4, wherein the material in the or each zone of the tube is, before stretching, at an initial temperature which is substantially below the glass transition temperature of the material, and on stretching the material is caused to flow, at least in an annular zone which is displaced in the axial direction of the tube with simultaneous substantial reduction in the thickness of the material.

9. A process as claimed in Claim 8, wherein the or each zone of the tube is initially at room temperature.

10. A process as claimed in any of Claims 1 to 9, wherein the or each zone of the tube has one or more annular sections in which the temperature exceeds the temperature of the adjacent material by $3^{\circ} - 20^{\circ}\text{C}$, such that during the axial stretching of the material flow starts in the material in the section or sections of elevated temperature.

11. A process as claimed in Claim 10, wherein the temperature of the or each annular section exceeds the temperature of the adjacent material by 10° to 15°C .

12. A process as claimed in any of Claims 1 to 11, wherein the or each zone of the tube has one or more annular sections which are subjected to an external pressure, such that during the axial stretching of the material flow starts in the section or sections subjected to pressure.

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13. A process as claimed in any of Claims 1 to 12,
wherein during the radial expansion of the material in
the or each zone neck sections are formed which are
stretched in the circumferential direction of the tube
5 by a factor of more than 2.

14. A process as claimed in any of Claims 1 to 13,
wherein the thermoplastic material is a polyester or a
polyamide.

15. A process as claimed in Claim 14, wherein the
10 thermoplastic material is chosen from polyethylene
terephthalate, polyhexamethylene-adipamide, polycaprolactam,
polyhexamethylene-sebacamide, polyethylene 2,6- and 1,5-
naphthalate, polytetramethylene 1,2-dihydroxybenzoate
and copolymers of ethylene terephthalate, ethylene
15 isophthalate or other similar polymeric plastics.

16. Apparatus for manufacturing tubular pre-mouldings
of thermoplastic material by the process of Claim 1,
comprising first and second clamping devices for holding
parts of a tube of thermoplastic material, drive means
20 for moving said clamping devices towards and away from
each other for stretching one or more zones of the tube
in the axial direction to reduce the thickness of the material
of the or each zone and orient the material substantially
in the axial direction, means for heating the material
25 of the or each zone to a temperature above the glass

transition temperature, a blowing mandrel for insertion within the tube and a mould for arrangement around the tube, said mould having mould surfaces shaped to produce a mouth part and an adjacent neck section in the part
5 of the tube brought into contact therewith, and means for closing the end of the tube spaced from the mouth part.

17. Apparatus as claimed in Claim 16, further comprising means for severing the formed mouth part from adjacent
10 material on the side thereof remote from the associated neck section.

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

15 19. Apparatus for manufacturing tubular pre-mouldings of thermoplastic material substantially as hereinbefore described with reference to and as illustrated in Figures 1 to 12 of the accompanying drawings.

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