

SPECIFICATION

Process of manufacturing articles by drawing and blow-moulding

5 The present invention relates to a process of manufacturing articles of thermoplastic material.

In the manufacture of products from thermoplastic material, the starting material is in most cases a substantially flat blank. An end product may be formed from the blank substantially in one deformation step, or a pre-moulding may be formed which is later reshaped to form the end product. The shaping of the blank is effected, according to methods known at present, either by a blow-moulding process or by a thermo-forming process. Where the element to be formed is a hollow body with a closed bottom, such as a cup, blow-moulding generally produces a bottom having a thick section. In the thermo-forming process, either negative thermo-forming or positive thermo-forming can be used. In the negative thermo-forming process, a hollow body having a thin bottom is produced, whilst a thick bottom is produced in the positive thermo-forming process.

25 In negative thermo-forming, a warm sheet or a warm film is placed over cavities, after which the material of the film or the sheet is pressed and sucked into the cavities by external pressure and internal reduced pressure. This has the result that the material is stretched and becomes thin, when it is sucked into the particular cavities. If the cavity is in the shape of a cup, a thin stretched bottom and a wall thickness which increases towards the top edge of the cup are obtained.

35 In positive thermo-forming the cup mould forms a projecting body and the material of the film or sheet is pressed and sucked over this projecting body. This has the result that the material on the upper part of the projecting body, that is to say the bottom of the cup, remains thick and essentially unstretched, whilst the thickness of the material decreases towards the top edge of the cup.

To obtain an adequate material thickness in the bottom part of the cup in negative thermo-forming, a sufficient thickness in the starting material must be chosen. To obtain an adequate thickness in the edge zone of the cup by positive thermo-forming, which is necessary for the stability of the cup, a sufficient thickness of starting material must likewise be chosen. In negative thermo-forming, the areas of material between the shaped cups remain uninfluenced and are subsequently severed, after the manufacture of the actual cups. In positive thermo-forming, the material between the cups is drawn into recesses and severed from the cups formed. In positive thermo-forming, cup bottoms are thus obtained which have substantially the same thickness as the starting material. Both forming processes require an unnecessarily high consumption of material, which is of economic importance in the mass production of articles.

The present invention is particularly suitable for the manufacture of articles from thermoplastic material 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 exclusively to the use of either this material or other materials already mentioned; instead, it is also suitable for many other thermoplastic materials.

For a better understanding of the invention and of the problems of the known methods, 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 corresponding 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, 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 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 and likewise the crystallinity X_c rises and the glass transition temperature T_g is raised. It can be seen from the diagram on page 317 that, after stretching, with assuming the value of 3.1, a stress of 10cN/tex applied to the material produces a very small elongation, whilst after stretching with assuming the value 2.8 the elongation 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 at least 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 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.

According to the present invention there is provided a process of manufacturing an article of thermoplastic material, wherein a substantially flat blank of material having a crystallinity of less than 10%, is clamped between clamping devices to define one or more zones which are completely surrounded by closed clamped areas of the blank, a pressing device is applied against each said zone, the contact surface area of the pressing device with the zone being smaller than the area of said zone such that a closed intermediate strip-like region is defined between the clamped areas and the part of the zone in contact with the pressing device, the pressing device is moved relative to the clamping device by means of drive mechanisms whilst in contact with said zone such that the material in the intermediate region is stretched by drawing to such an extent that flow takes place in the material of the intermediate region which is thus oriented, whereby an element is formed which consists of an edge part of material from the clamped areas and a body which is sunk relative to the edge part, at least a part of said body comprising material which has been drawn until flow sets in and which originates from the intermediate region, the crystallinity of the material which has flowed being between 10% and 25% whilst the crystallinity of the material in the edge part and in the undrawn parts of the body retains its former value of crystallinity of less than 10%, and wherein at least part of the body is reshaped at a temperature above the glass transition temperature of the material by blow-moulding to produce the article.

In an embodiment, blanks are drawn to produce elements having an edge part and a cup part. The blank is substantially flat and of material which is amorphous or has a crystallinity of less than 10%. The material in annular sections of the blank is transformed into the state of flow by the drawing process. The cup part is formed in this way. In certain applications, the ratio between the radial and the axial expansion of the cup is such that production of the beaker in a single drawing step is not possible. Accordingly, the desired ratios are obtained by a number of redrawing steps of the cup, the diameter of the cup being reduced in each redrawing step, whilst the thickness of the material remains more or less unchanged. The cup part of the element or the drawn cup is reshaped by a blow-moulding process to produce the article.

The invention enables an element to be produced which consists of an edge part and a cup part. The material is preferably of more or less uniform thickness and orientation in the entire bottom of the cup part. In an embodiment of the invention, the material in the bottom part of the cup moreover consists completely or partially of material of the same thickness as that of the material of the wall. The remaining sections of material have the thick-

ness and material properties of the starting material. In certain applications, the bottom is more or less completely flat, whilst in other applications the bottom consists of parts which are axially displaced relative to the axis of the cup. In this case, in some embodiments, annular edge sections are formed adjoining the lower edge of the wall, whilst in other embodiments central bottom sections are displaced further away from the upper opening edge of the element.

In general the element consists of an edge part which surrounds a top opening of a hollow body which is sunk relative to the edge part. The material in the edge part is mainly amorphous or has a crystallinity of less than 10%. The body has a wall and a bottom. The wall consists of material which has been drawn at a temperature below the glass transition temperature T_g , until flow sets in, and in which the crystallinity is between 10% and 25%. In an embodiment, the bottom consists of mainly amorphous material or of material having a crystallinity of less than 10%. In other embodiments of the invention, the bottom consists of material which has been drawn at a temperature below the glass transition temperature T_g and at a crystallinity between 10% and 25%, until flow sets in, that is to say of a material having properties which are substantially identical to the material properties of the wall of the element. Alternatively, the bottom may have sections which have been drawn until flow sets in and which alternate with sections of mainly amorphous material or material having a crystallinity of less than 10%. The sections of the bottom may be displaced in the axial direction relative to the lower edge of the wall.

During the production of an element, a substantially flat blank of thermoplastic material, having a crystallinity of less than 10%, is clamped at a temperature below the glass transition temperature T_g between counter-holders, such that a zone is formed which is completely surrounded by clamped areas of the blank. A pressing device the contact surface area of which is smaller than the surface area of the zone, is applied against this zone. Thus, a closed intermediate strip-like region is formed between the clamped areas of the blank and that part of the zone which is in contact with the pressing device. Subsequently, a drive mechanism moves the pressing device relative to the counter-holders with the pressing device remaining in contact with the zone. The material in the intermediate region is thus stretched in such a way that flow of the material occurs; the material being oriented, whilst at the same time the thickness of the material is reduced by about 3 times in the case of PET. The wall of the element is formed during the stretching process.

Since the circumference of the contact surface of the pressing device is smaller than the inner circumference of the clamping devices, the material which adjoins the edge of the pressing device is subjected to the greatest stress, for which reason the flow of the material normally starts at this point. This effect is further reinforced by the fact that the transition from the contact surface of the pressing device to the side walls of the pressing device is made relatively

sharp-edged. When flow has set in, the zone of flow of the material is gradually shifted in the direction of the clamping devices. In some embodiments, the pressing step is interrupted when the flow zone has reached the pressing devices. In other embodiments, the pressing step continues, renewed flowing of the material taking place adjoining the edges of the pressing device and being displaced from these zones towards the centre of the material. When all the material which is in contact with the contact surface of the pressing device has undergone flow, that material between the clamping devices which is located next to the inner circumference of the clamping devices is utilised for a further drawing step in some embodiments. To make this possible, a somewhat elevated temperature in the material is normally required. The starting temperature, however, is still below the glass transition temperature T_g .

In some embodiments, accelerated cooling of the drawn material is necessary. In this case, the pressing device may be provided with a cooling device which is arranged in such a way that the zones of the material, which flow during drawing of the material, are in contact with the cooling device.

The flow of the material may be caused to start adjoining the clamping devices. This is accomplished by providing the clamping devices with heating devices which raise the temperature of those material sections where flow is to start. The temperature in the material, however, is still below the glass transition temperature T_g of the material. When flow has set in, this continues in the direction of the contact surface of the pressing device and, in some cases it continues past the transition from the side walls to the contact surface of the pressing device. To ensure that the clamping devices retain the blank in the future edge sections of the element, the clamping devices are generally provided with cooling devices.

It is also possible by using a number of drawing steps one after the other, both in the wall and in the bottom of the body, to obtain material sections which alternately consist of material sections which have been drawn until flow sets in and have in this way been given a reduced wall thickness, and undrawn material sections which have retained their wall thickness. In material sections located in the bottom of the body, a displacement of the material in the axial direction of the body may also take place in conjunction with the drawing step.

After the element has been formed, the edge part is removed therefrom and then the element is reshaped by a number of drawing steps. These drawing steps take place at a temperature below the glass transition temperature T_g and effect a reduction in the diameter of the body, whilst the length of the body is extended at the same time in the axial direction. These drawing steps only redistribute the material without flow setting in.

The cup formed after the end of the drawing steps has an opening at one end, whilst it has a bottom part at the other end. Depending on the manner in which the element has been shaped, the bottom part consists wholly or partially of amorphous material or of unoriented material. In the first-mentioned case,

the bottom part thus retains the thickness of the starting material in the amorphous zone or in the amorphous zones. The amorphous material is suitable for use as a fixing material for welding additional parts to the cup. This requirement will be present, for example, when the cup is used as a container and the bottom part of the cup simultaneously represents the bottom part of the container. In this case, it is advantageous to weld an external foot to the container. The cup shaped in the manner described possesses an opening part which, if appropriate after working, is preferably expanded in such a way that a beaded edge results, the stability of the beaded edge being increased by heating up to the maximum crystallisation temperature of the material. The beaded edge is thus suitable for fitting, for example, a loose lid of a suitable material, for example metal, by crimping.

In another embodiment, the drawing steps of the cup are interrupted so that a part of the cup has a reduced diameter compared with the initial diameter. By removing the bottom from this part of smaller diameter, expanding the edge formed and stabilizing the opening which has been formed in the manner described above, a mouth part is obtained which is suitable for fitting, for example, a closure or a crown cap. The other still open part of the cup is closed, for example, by an end disc.

In the blow-moulding process, the starting point is either a body which has been removed from the edge part of the element, or from a cup drawn from the body. By blow-moulding against warm mould walls, the cup, the material of which is at a temperature above the glass transition temperature T_g , is reshaped in such a way that it has exactly the form of the intended end product. In certain embodiments, a warm blowing mandrel is used in order to prevent excessive cooling of the material during the blow-moulding step.

It will be appreciated that the combination of drawing, until flow sets in to obtain an element, redrawing of the body of the element formed and then blow-moulding makes it possible to produce many different shaped articles.

An article produced in the manner described above is thus not only suitable for use as a container, but many applications are possible.

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 alternative bands of thermoplastic material which are suitable for reshaping,

Figure 3 shows a longitudinal section of an element having a bottom part of the body consisting mainly of amorphous material,

Figures 4 to 8 show progressive steps in the formation of an element using clamping devices,

Figures 9 and 10 show steps in the formation of an element using alternative clamping devices,

Figure 11 shows a part of a device for redrawing the body of the element,

Figure 12 shows the body of the element before redrawing,

Figure 13 shows the body of the element after partial redrawing,

Figure 14 shows the body of the element after complete redrawing.

Figure 15 shows the body of the element, having the part of the body which was partially redrawn, as shown in Figure 13, after renewed redrawing,

Figure 16 shows a container produced from a body as shown in Figure 15.

Figures 17 to 19 show counterparts of Figures 12 to 14, the bottom part of the body having sections of amorphous material and

Figures 20 to 22 show embodiments of blow-moulded articles produced by a process according to the present invention.

Figure 1 shows a plan view from above of a thermoplastic band or blank 14'. The material of the blank has a crystallinity of less than 10% and preferably, less than 5%. A number of material zones are represented in the blank and these material zones are formed when the blank is drawn to form elements of the invention. Thus, the blank 14' has a number of inner material zones 15' each surrounded by a material zone 17' in the form of a frame. Similarly, the material zones 17' are each enclosed by an outer zone 16' also in the form of a frame.

Figure 2 shows an alternative thermoplastic band or blank 14". In the blank of Figure 2, the inner material zone 15" is circular and the enclosing zones 17" and 16" are annular.

When a blank 14' or 14" is drawn to form an element, the outer material zone 16 is that zone which is clamped between clamping devices, such as devices 30a and 30b in Figure 4. The inner material zone 15 is that zone which, on drawing of the blank, is in contact with a pressing tool for example in contact with the face 21 of the pressing tool 20 in Figure 4. The intermediate material zone 17 is that zone which, on drawing of the blank, is brought into a state of flow. Generally, immediately before the blank is drawn the material thereof is at room temperature. The width of the clamped zone 16 is preferably selected such that flow of the material at the end of the drawing of the element extends into the zone 16.

An element 10 consisting of an edge part 12 and a body 13 is shown in Figure 3. The body 13 consists of a wall 18 and a bottom 11. In the Figure, the wall 18 is formed of drawn material having a reduced thickness as compared with the thickness of the starting material. The bottom 11 is formed of material which, while retaining its material properties, has been displaced relative to the edge part 12 in the axial direction of the body. Moreover, a zone 19 is represented in which material from the edge part 12 had been brought into the state of flow.

In Figures 4 to 8 the formation of an element is illustrated. As is shown in Figure 4, the blank 14 is held between a number of clamping devices 30. A pressing device 20 having a press contact face 21 is located between the clamping devices 30. In Figure 4, the pressing device 20 is in a position in which the press contact face 21 is located directly next to the upper surface of the blank 14. In Figure 5, the pressing device has been moved downwardly, flow of the material of the blank having started. In Figure 6, the pressing device 20 has been moved down-

wardly to such an extent that an element as shown in Figure 3 has been formed. In Figure 7, the pressing device 20 has been moved further downwardly, further flow of the material having taken place. An element 10' has thus been formed, the body 13' of which has a bottom 11' of which the central portions are formed of amorphous undrawn material which is surrounded by drawn oriented material in which flow has taken place. Finally, in Figure 8, the pressing device 20 has been moved to such an extent that virtually the entire material in the bottom 11" of the body 13" has undergone flow. An element 10' has thus been formed in which both the wall and the bottom of the body have a reduced wall thickness because the material has been in the state of flow and has at the same time been oriented.

The material of the element which has been in a state of flow and has been oriented assumes a crystallinity of between 10% and 25%, and preferably of between 12% and 20%.

In Figures 9 and 10, an alternative embodiment of the clamping devices is shown. The clamping devices 33a and 33b of Figures 9 and 10 are provided with cooling channels 31 and heating channels 34. In Figures 9 and 10, only the feedline for the heating channels is shown, the discharge line for the heating channels being located behind the feedline in the Figures and being indicated by an upwardly pointing arrow. The cooling channels, like the heating channels, are covered by plates 35, the external surface of which at the same time represents the contact surface of the clamping devices for clamping the blank. An insulation 32 separates the cooled zone of the clamping devices from the heated zone. In certain applications, the heating channels are used as the cooling channels in the same way.

Figures 9 and 10 also show an alternative embodiment of a pressing device 20a which is also provided with cooling channels 22. The cooling channels are covered by a cooling jacket 23 which at the same time forms the outer contact surface of the pressing device. Figure 9 shows a position of the pressing device 20a which corresponds to the position shown in Figure 5, and Figure 10 shows a position of the pressing device 20a which corresponds to the position shown in Figure 8. The pressing device has an outer surface with a rotationally symmetrical curvature, which is shaped in such a way that, on drawing within the flow range the drawn thermoplastic material is always in contact with the cooling jacket, whilst that material which has not yet been in the state of flow is not in contact at any point with any device in the zone between the pressing device and the clamping devices.

By heating the material with the aid of the heating channels 34 the readiness of the material to flow is increased. Heating is limited, however, inasmuch as the temperature of the material must always be lower than the glass transition temperature T_g . Heating makes it possible to allow the drawing step of the material to continue a little into the zone between the jaws of the clamping devices, as shown in Figure 10. In another application, the increased readiness of the material to flow is exploited so as to obtain, during the drawing step, initial flow of the

material in the zone next to the inner edges of the clamping devices. After initial flow has taken place, the flow zone is gradually displaced in the direction away from the clamping devices towards the bottom of the pressing device, as the pressing device gradually moves downwardly as illustrated.

The result of this is that flow always propagates in the same direction, and a new start of flow such as takes place when the embodiment of the invention shown in Figures 4 to 8 is used, is avoided.

Figure 11 shows part of a device for redrawing the element previously formed. In Figure 11 a press plunger 40, a counterholder ring 41, a clamping ring 42 and a wall 18 of the element are shown, the wall 18 being in the process of being shaped. Moreover, the bottom 11' of the body 13 of the element is shown. The clamping ring 42 is provided with a calibration device 43 which determines the thickness of the material in the redrawn wall 18.

Figure 12 shows an element body 50 which has been formed by means of the pressing device 20a of Figure 9 and in which the edge part of the element has been removed from the body. Figure 13 shows the body 50 upon initiation of the shaping process using a device as shown in Figure 11. In Figure 13, the shaping process has progressed to such an extent that a body 51 has been formed which has a mainly cylindrical larger part, having the same diameter as the body 50, and a shorter part 59 of smaller diameter. In Figure 14, the shaping process has been completed, a mainly cylindrical body 52 of the same diameter as in the shorter part 59 in Figure 13 having been formed.

Figure 15 shows a body 53, the shorter part 59' of which has been reshaped with the aid of a device as shown in Figure 11 for the purpose of further reducing the diameter of the shorter part 59'. There is a transition 58 between the shorter cylindrical part 59' and the larger part of the body 53.

Figure 16 shows a bottle-like container 70' produced by blow-moulding a body 53 as shown in Figure 15. The bottom part of the shorter part 59' has been severed and replaced by a closure 55, for example a cap. The mouth edges formed on severing the bottom part were expanded and beaded, after which the material in the beaded material zones has preferably been given an increased crystallinity as a result of heating the material up to the crystallisation temperature. This gives additional strength at the mouth edge so that the latter is well suited for closing the container, for example by means of a cap or a crown cork. The transition, already mentioned, between the shorter part and the larger part of the body now forms a bottle neck 58'. The Figure also shows how an end disc 56 is fixed at the other end of the container 70', after the container has been filled. As a result of expanding, beading and heating of the material, material sections are here also obtained which are suitable, for example, for fitting an end disc by crimping, in order to close the container.

In containers formed from reshaped bodies such as illustrated in Figures 12 to 15 substantially all the material of the container is oriented and has a crystallinity which is 60% or less, preferably between

10% and 40%.

Figures 17 to 19 show counterparts to Figures 12 to 14. These Figures show how an element body, formed from the body 11' shown in Figure 7, is lengthened axially, with simultaneous reduction in the diameter of the body, and forms an almost completely cylindrical body 61, the bottom part of this body consisting of a material section 62 of mainly amorphous material. During the shaping process an intermediate form of the body results, which is marked 60 in Figure 18.

In the embodiment of the invention in which a body is formed which comprises an amorphous bottom part, a material zone is obtained which is suitable as a fixing material for welding on additional parts to the body. By rendering the material crystalline, a zone of extreme dimensional stability is obtained, whereby it becomes possible to use the container for storing liquids under pressure, for example beverages to which carbonic acid has been added, without a risk of deforming the bottom part. If required, the plane bottom part may be replaced by a convex or concave face.

Figures 20 to 22 show embodiments of blow-mould containers. All the containers are closed by end discs in the manner already described above in connection with Figure 16. Of course, this combination of a blow-moulded container and an end disc is to be regarded only as an example of the possibilities available for closure.

Figure 20 shows an embodiment in which all the material in the blow-moulded container consists of material previously drawn. The container is formed from a body either as shown in Figure 12 or as shown in Figure 14.

Figure 21 shows an embodiment of a blow-moulded container which has been formed from a body as shown in Figure 17 or Figure 19. On blow-moulding, the amorphous material zone 22 remains in the amorphous state without change, and it forms a thicker section in the bottom part of the container. If required, this section may be heated to the crystallisation temperature of the material in order to form a bottom section which is particularly suitable for withstanding deformation forces, for example, forces due to an internal pressure in the container. The amorphous material is also suitable for the purpose of welding additional plastic parts thereto.

Figure 22 shows an embodiment of a blow-moulded container which has been formed from a body, the bottom of the body consisting alternately of material sections, which have been drawn until flow sets in, and of material sections which have retained their original thickness. In this way, a simple amorphous material section 71 has been formed which is surrounded by an annular amorphous section 72 which is located below the central section. The central section and the annular section are connected by material which has been drawn until flow sets in. The annular material section thus forms supporting surfaces for the container. The parts forming the shell of the container are generally shaped from redrawn material. At least in the cases where the container has a relatively large axial

dimension, such redrawing is necessary.

Blow-moulding is carried out in any known manner at a temperature of the material, which is above the glass transition temperature T_g . Normally, blow-moulding takes place against heated mould walls. In certain embodiments, a heated elongate blow mandrel is required in order to avoid excessive cooling of the material during the blow-moulding step.

The material oriented by flow possesses improved strength properties in the direction of orienting which is largely the same as the direction of drawing the material. Since the material has been heated to a temperature above the glass transition temperature T_g , there are no difficulties in a blow-moulding process with regard to reshaping the element by stretching the material in a direction which is mainly at right angles to the said direction of orienting. An element reshaped in this way forms, for example, a container having a central shell surface of a diameter which exceeds the diameter of the opening, and having a bottom which consists of a supporting surface defined by the transition between the lower edge of the shell surface and the bottom surface, the bottom surface either being slightly concave or consisting of annular material sections which are displaced relative to one another in the axial direction of the container.

The above description merely represents examples for the application of the invention. The invention allows the combination of individual drawing steps, and zones of drawn and undrawn material may be alternately formed. For example, the wall may be formed with sections which contain undrawn material, whilst the bottom of the body may be formed of sections, for example annular sections, which contain undrawn material and which are displaced in the axial direction of the body relative to the lower edge of the wall of the body.

In an alternative embodiment, drawing until the material in the body of the element flows is effected by a number of successive drawing steps, the contact area of the pressing device decreasing for each drawing step. The result of this is that the width of the material zone is adapted to the extent to which the drawing step has proceeded.

A process of manufacturing articles of thermoplastic material and a container manufactured thereby are described and claimed in our copending application No. 8018901 (2052364A) to which reference is made.

An element of thermoplastic material and a method of manufacturing the element are described and claimed in our copending application No. 8018902 (2052365A) to which reference is made.

CLAIMS

1. A process of manufacturing an article of thermoplastic material, wherein a substantially flat blank of material having a crystallinity of less than 10%, is clamped between clamping devices to define one or more zones which are completely surrounded by closed clamped areas of the blank, a pressing device is applied against each said zone, the contact surface area of the pressing device with the zone

being smaller than the area of said zone such that a closed intermediate strip-like region is defined between the clamped areas and the part of the zone in contact with the pressing device, the pressing device is moved relative to the clamping devices by means of drive mechanisms whilst in contact with said zone such that the material in the intermediate region is stretched by drawing to such an extent that flow takes place in the material of the intermediate region which is thus oriented, whereby an element is formed which consists of an edge part of material from the clamped areas and a body which is sunk relative to the edge part, at least a part of said body comprising material which has been drawn until flow sets in and which originates from the intermediate region, the crystallinity of the material which has been flowed being between 10% and 25% whilst the crystallinity of the material in the edge part and in the undrawn parts of the body retains its former value of crystallinity of less than 10%, and wherein at least part of the body is reshaped at a temperature above the glass transition temperature of the material by blow-moulding to produce the article.

2. A process as claimed in Claim 1, wherein the edge part is removed from the body of the element before the body is reshaped by blow-moulding against warm mould walls.

3. A process as claimed in Claim 1 or 2, wherein the material of the blank has a crystallinity of less than 5% and the crystallinity of the material which has flowed is between 12% and 20%.

4. A process as claimed in any preceding claim, wherein at least part of the body is elongated in the axial direction before blow-moulding by a number of redrawing steps, the dimension of at least part of the body at right angles to the axial direction being reduced whilst the thickness of the drawn material is substantially unchanged.

5. A process as claimed in any preceding claim, wherein the drawing of the element is continued until substantially all the material in said zone has undergone flow such that substantially all the material in the body has flowed.

6. A process as claimed in any preceding claim, wherein the area and the shape of the contact surface of the pressing device are arranged such that the flow of the material is caused to start at the pressing device.

7. A process as claimed in any preceding claim, wherein the width of the clamped areas is selected such that flow of the material at the end of the drawing of the element extends into the said areas.

8. A process as claimed in any preceding claim, wherein, immediately before the blank is drawn, the material of the blank is at a temperature below the glass transition temperature of the material.

9. A process as claimed in claim 8, wherein the material of the blank is at room temperature.

10. A process as claimed in any preceding claim, wherein the material is subjected, at least during the drawing of the element, to accelerated cooling in the flow zone.

11. A process as claimed in Claim 10, wherein the pressing device is provided with cooling devices which are arranged such that, on drawing the blank,



dimension, such redrawing is necessary.

Blow-moulding is carried out in any known manner at a temperature of the material, which is above the glass transition temperature T_g . Normally, blow-moulding takes place against heated mould walls. In certain embodiments, a heated elongate blow mandrel is required in order to avoid excessive cooling of the material during the blow-moulding step.

The material oriented by flow possesses improved strength properties in the direction of orienting which is largely the same as the direction of drawing the material. Since the material has been heated to a temperature above the glass transition temperature T_g , there are no difficulties in a blow-moulding process with regard to reshaping the element by stretching the material in a direction which is mainly at right angles to the said direction of orienting. An element reshaped in this way forms, for example, a container having a central shell surface of a diameter which exceeds the diameter of the opening, and having a bottom which consists of a supporting surface defined by the transition between the lower edge of the shell surface and the bottom surface, the bottom surface either being slightly concave or consisting of annular material sections which are displaced relative to one another in the axial direction of the container.

The above description merely represents examples for the application of the invention. The invention allows the combination of individual drawing steps, and zones of drawn and undrawn material may be alternately formed. For example, the wall may be formed with sections which contain undrawn material, whilst the bottom of the body may be formed of sections, for example annular sections, which contain undrawn material and which are displaced in the axial direction of the body relative to the lower edge of the wall of the body.

In an alternative embodiment, drawing until the material in the body of the element flows is effected by a number of successive drawing steps, the contact area of the pressing device decreasing for each drawing step. The result of this is that the width of the material zone 15 is adapted to the extent to which the drawing step has proceeded.

A process of manufacturing articles of thermoplastic material and a container manufactured thereby are described and claimed in our copending application No. 8018901 (2052364A) to which reference is made.

An element of thermoplastic material and a method of manufacturing the element are described and claimed in our copending application No. 8018902 (2052365A) to which reference is made.

CLAIMS

1. A process of manufacturing an article of thermoplastic material, wherein a substantially flat blank of material having a crystallinity of less than 10%, is clamped between clamping devices to define one or more zones which are completely surrounded by closed clamped areas of the blank, a pressing device is applied against each said zone, the contact surface area of the pressing device with the zone

being smaller than the area of said zone such that a closed intermediate strip-like region is defined between the clamped areas and the part of the zone in contact with the pressing device, the pressing device is moved relative to the clamping devices by means of drive mechanisms whilst in contact with said zone such that the material in the intermediate region is stretched by drawing to such an extent that flow takes place in the material of the intermediate region which is thus oriented, whereby an element is formed which consists of an edge part of material from the clamped areas and a body which is sunk relative to the edge part, at least a part of said body comprising material which has been drawn until flow sets in and which originates from the intermediate region, the crystallinity of the material which has been flowed being between 10% and 25% whilst the crystallinity of the material in the edge part and in the undrawn parts of the body retains its former value of crystallinity of less than 10%, and wherein at least part of the body is reshaped at a temperature above the glass transition temperature of the material by blow-moulding to produce the article.

2. A process as claimed in Claim 1, wherein the edge part is removed from the body of the element before the body is reshaped by blow-moulding against warm mould walls.

3. A process as claimed in Claim 1 or 2, wherein the material of the blank has a crystallinity of less than 5% and the crystallinity of the material which has flowed is between 12% and 20%.

4. A process as claimed in any preceding claim, wherein at least part of the body is elongated in the axial direction before blow-moulding by a number of redrawing steps, the dimension of at least part of the body at right angles to the axial direction being reduced whilst the thickness of the drawn material is substantially unchanged.

5. A process as claimed in any preceding claim, wherein the drawing of the element is continued until substantially all the material in said zone has undergone flow such that substantially all the material in the body has flowed.

6. A process as claimed in any preceding claim, wherein the area and the shape of the contact surface of the pressing device are arranged such that the flow of the material is caused to start at the pressing device.

7. A process as claimed in any preceding claim, wherein the width of the clamped areas is selected such that flow of the material at the end of the drawing of the element extends into the said areas.

8. A process as claimed in any preceding claim, wherein, immediately before the blank is drawn, the material of the blank is at a temperature below the glass transition temperature of the material.

9. A process as claimed in claim 8, wherein the material of the blank is at room temperature.

10. A process as claimed in any preceding claim, wherein the material is subjected, at least during the drawing of the element, to accelerated cooling in the flow zone.

11. A process as claimed in Claim 10, wherein the pressing device is provided with cooling devices which are arranged such that, on drawing the blank,



the areas in which the material flows are in contact with the cooling devices.

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

13. A process as claimed in Claim 12, wherein the material is chosen from polyethylene terephthalate, polyhexamethylene-adipamide, polycaprolactam, polyhexamethylene-sebacamide, polyethylene
10 2,6- and 1,5-naphthalate, polytetramethylene 1,2-dihydroxybenzoate and copolymers of ethylene terephthalate, ethylene isophthalate or other similar polymeric plastics.

14. A container manufactured by a process as
15 claimed in any preceding claim, comprising a mouth part including a mouth edge, a container part, a transition between the mouth part and the container part, and a bottom part including a transition between the container part and the bottom part,
20 wherein substantially all the material of the container is oriented and has a crystallinity which is 60% or less.

15. A container as claimed in Claim 14, wherein the material of the container has a crystallinity
25 between 10% and 40%.

16. A container manufactured by a process as claimed in any of claims 1 to 4, or 6 to 12, comprising a mouth part including a mouth edge, a container part, a transition between the mouth part and the
30 container part, and a bottom part including a transition between the bottom part and the container part, wherein substantially all the material in the mouth part, the transition between the mouth part and the container part is oriented and has a crystallinity which is 60% or less whilst at least a part of the
35 bottom has a thickness which is substantially identical to that of the blank.

17. A container as claimed in Claim 15, wherein the material in the transition between the container
40 part and the bottom is also oriented, and the oriented material has a crystallinity between 10% and 40%..

18. A process of manufacturing an article of thermoplastic material as claimed in Claim 1 and
45 substantially as hereinbefore described with reference to the accompanying drawings.

19. A container of thermoplastic material manufactured by a process as claimed in Claim 1, substantially as hereinbefore described with reference to and as illustrated in Figure 16, and Figures 20
50 to 22 of the accompanying drawings.