

A TUBULAR OBJECT OF POLYETHYLENE TEREPHTHALATE

The present invention relates to a tubular object of polyethylene terephthalate.

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U.K. Published Patent Application No. 2052367A describes a tubular object of thermoplastic material in which the wall thickness preferably at a central point of said object has been reduced to approximately 1/3 of the original thickness of the material. The reduction in thickness is produced by clamping each end of a tubular blank in which the material is at an initial temperature below the glass transition temperature (TG) in two jaws which are then moved apart. By causing an annular area of the material to have a higher temperature than the surrounding material, the obtained material properties of the area will cause the reduction in thickness to commence in the area during the stretching operation. In certain applications the internal diameter of the blank is stabilized by the use of an internal mandrel. The process as disclosed will produce an object in which the material is axially oriented and has a crystallinity of less than approximately 30%, usually being of the order of 10 to 25%.

UK Published Patent Application No. 2052366A describes a method for causing the thickness of the material in a tubular blank to be reduced mechanically by the use of an external device. The device consists of one or more rollers which make contact with the external and/or internal surface of the blank with such force that the desired reduction in thickness will occur as the initial temperature of the material approaches the glass transition temperature. The external device is moved around the periphery of the blank and along the axis of the blank simultaneously. This method will also produce an object in which the crystallinity in the areas of reduced material thickness will be less than approximately 30% and will be of the order of

10 to 25%.

5 However, the material will not have been oriented axially to such a high degree as when the process described in the previous paragraph is used.

10 The previously disclosed methods described above produce objects which differ in respect of the transitional zone between stretched and non-stretched material. This condition will arise, for instance, if a central section of a tubular blank is stretched whilst the material in the blank is at an initial temperature below the glass transition temperature (TG) and if the blank is then separated into two parts so as to form two separate objects. The difference is due to the fact that one of the objects contains the start zone for the yielding of material produced by the stretching operation, whilst the other object contains the stop zone for the yielding of material.

20 When practising the invention described in U.K.Application No.2052367A an annular transitional zone between the thinner material which has been stretched and the thicker material which has not been stretched will normally be produced. In the zone the surface of the material will form an angle of approximately 45° with the surfaces of the stretched and non-stretched material respectively. Axially displaced tapering areas will occasionally be produced in the substantially annular transitional zone during the drawing operation, the presence of said areas usually requiring the object to be scrapped.

30 According to the present invention there is provided a tubular object of polyethylene terephthalate formed from a blank of material having a crystallinity of less than 10%, said object having a cylindrical part which consists of material which is oriented along the axis of the object only and has a maximum crystallinity of approximately 30%,

the material of said cylindrical part being obtained by reducing the thickness of the blank while substantially maintaining its diameter.

5 Preferably, the maximum crystallinity is between 10% and 25%, and is generally 17%.

10 The production of a tubular object of polyethylene terephthalate in accordance with an embodiment of the present invention starts from a tubular blank, the material in this blank being in an amorphous state. In one single operation or in a number of consecutive operations the thickness of the material in the blank is reduced to approximately 1/3 of its original thickness. This reduction in thickness takes place either along the entire length of the blank or in one or more sections of the blank. Use is made of a draw ring in 15 certain applications, in which the relationship between the internal circumference of the draw ring and the external circumference of the blank is such that the thickness of the material will be reduced as the draw ring is moved axially along the blank. The temperature of the material immediately before the reduction in thickness takes 20 place will be in the range of the glass transition temperature (TG) of the material, which temperature will be abbreviated to TG in the following, and preferably deviates from TG by no more than 15°C. It is advantageous to use an initial temperature close to TG, for instance a temperature which is between 1 to 30°C below TG, since 25 material at this initial temperature will permit the draw ring to be moved at high speed. In certain typical applications, the draw ring operates in conjunction with an internal shaping device located inside the blank, whereby the external dimension of the shaping device fits the internal surface of the blank.

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During the re-shaping operation a transitional zone is formed between a region of material with the original thickness and a region of material with reduced thickness, and said transitional zone is

gradually displaced axially along the blank. This movement of the transitional zone elongates the region of thinner material and reduces the region of thicker material. The material in the transitional zone is kept at a temperature close to TG during the re-shaping operation by the transfer of heat to the draw ring and/or the shaping device located inside the tubular blank. In certain applications the material in the transitional zone is, however, allowed to assume a temperature which exceeds TG by no more than 300C, and preferably by no more than 150C.

In certain applications the material in the area adjacent to the transitional zone is cooled to a temperature below TG immediately after it has been reduced in thickness.

In the case of sections with reduced wall thickness requiring to be produced in areas situated between the ends of the blank, the reduction in thickness is begun by forming one or more peripheral grooves in the wall of the blank at the same time as external devices are used to subject the blank to tensile stress along its axis. This stretching operation reduces the wall thickness in the grooves to about 1/3 of its original thickness at the same time as the blank is elongated axially. Further reduction of the thickness of the wall of the blank is produced by positioning the draw ring in the aforementioned groove or grooves and moving it axially along the blank. Certain applications use two rings, whereby the reduction in wall thickness takes place simultaneously from a specific groove outwards towards the two ends of the blank.

In the case of a blank which is sealed at one end and in which the wall thickness is to be reduced adjacent to the seal, the draw ring should preferably be moved from the seal towards the other end of the blank. In certain applications the reduction in thickness is allowed to continue along the entire length of the blank.

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5 In those applications in which the blank is in the form of a tube open at both ends, this may be sealed in certain cases after the reduction in thickness by heating the material at one end of the object and then by press moulding the material in a mould which may for example, be cup-shaped. Patent Specification DE PS 1 704 119 contains examples of methods suitable for achieving sealing of this kind.

10 The reduction of the thickness of the material in several stages is used mainly in the event of the material being so thick that problems arise in transferring sufficient heat away from the transitional zone. By reducing the thickness of the material a number of times before the final reduction in thickness is made, a thinner material will be produced which will facilitate the transfer of heat away from
15 the transitional zone to the adjacent draw ring and/or internal shaping device.

20 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 drawing apparatus for producing a tubular object;

25 Figure 2 shows a longitudinal section through the apparatus of Figure 1 in which draw rings are shown in their initial position before drawing;

30 Figure 3 shows part of a longitudinal section corresponding to that of Figure 2, in which the draw rings have been separated from each other;

Figure 4 shows a support plate of the apparatus of Figure 1 fitted with a draw ring in its operating position;

Figure 5 shows a longitudinal section through a tubular blank with a draw ring in its initial position;

5 Figure 6 shows a longitudinal section through a tubular blank during drawing in the direction away from its sealed part;

10 Figure 7 shows a section through a tubular blank with a draw ring in the initial position prior to drawing the blank in a short section at one end;

15 Figure 8 shows a section of the tubular blank in accordance with Figure 7 with the draw ring in its final position;

20 Figure 9 shows a longitudinal section through an alternative embodiment of apparatus for producing a tubular object having a central clamping device and with the draw rings or the clamping device in the initial position before drawing;

25 Figure 10 shows part of a longitudinal section corresponding to Figure 9 with the draw rings moved apart;

Figure 11 shows the central area in accordance with Figure 9 in detail;

30 Figure 12 shows the central area in accordance with Figure 10 in detail;

Figures 13 - 15 show alternative embodiments of tubular objects.

35 Figure 1 shows an overall perspective view of a drawing apparatus having a base 30 from which a number of guide pins 31 project vertically upwardly.



The base 30 is fitted with drive devices with gearing (not shown in the Figure) for a number of drive screws 32 which extend parallel to the guide pins 31. Four support plates 50, 60, 70 and 80 are positioned at right angles to the guide pins and to the drive screws. Each support plate is provided with bearings through which the guide pins 31 extend and threaded holes 52, 62, 72 and 82 through which selected drive screws 32 extend in engagement therewith. The support plates are also provided with openings 58, 68, 78, 88 for those drive screws which are not in threaded contact with the actual support plate. The top and bottom support plates 50 and 60 are in engagement with the two drive screws 32_a and 32_c, whereas the two interjacent support plates 70 and 80 are in engagement with the two remaining drive screws 32_b and 32_d. Furthermore, the upper part of the drive screws which operate in conjunction with the support plates 50 and 70 are threaded in the opposite direction to the lower parts of the drive screws which operate in conjunction with the support plates 60 and 80. This means that as the drive screws are rotated the two upper support plates 50 and 70 will move in the same direction, although this will be opposite to the direction in which the two lower support plates 60 and 80 will move.

Since the top and bottom support plates 50 and 60 are driven by the screws 32_a and 32_c and the two middle support plates 70 and 80 are driven by the screws 32_b and 32_d, the speed at which the respective support plates move will be determined by the rotational speed and the pitch of the screws which drive the respective support plate. The pitch of the thread on the drive screws is selected such that the top and bottom support plates will always move at a lower speed than the two middle support plates. In the initial position, the two middle plates are in close contact with each other and the top and bottom plates are positioned such that movement towards the ends of the guide pins can take place. After movement has taken place, the middle support plates will have moved away from each other and

closer to the upper and lower support plate respectively.

5 The top support plate 50 and the bottom support plate 60 are provided with clamping devices 51 and 61, each of which holds one end of a tubular blank 10. The blank is provided with a peripheral starting track 12 (Figure 2), preferably positioned substantially centrally of its length, in which the thickness of the material is approximately 1/3 of its original thickness. The starting track is preferably formed before the blank is positioned in the device by the application of external pressure to the wall of the material, for example by means of a number of interacting rollers, at the same time as the tubular blank is subjected to tensile stresses along its axis. When forming the start track, the use of rollers in conjunction with a stretching operation produces a track having a predetermined axial length which has a profile which is substantially identical to the profile of parts of draw rings which are to be introduced into the track, as described below, to re-shape the blank into a tubular object. The axial length of the tubular blank is increased when the start track is formed.

20 The two middle support plates 70 and 80 are each fitted with a respective draw ring 71 and 81, the draw ring 81 being obscured in Figure 1. The clamping device 51 of the top support plate and the draw rings 71, 81 of the two middle support plates each consist of two halves 51a, 51b, 71a, 71b, and 81a and 81b which are movable by a respective drive 53, 73 and 83 to and from the closed position which is shown in Figure 1.

30 Figure 2 shows a longitudinal section of the apparatus of Figure 1, the left-hand part of this Figure showing the upper clamping device 51 and the two draw rings 71, 81 in their open position, while the right-hand part of the Figure portrays the device with the upper clamping device 51 and the two draw rings 71, 81 in their closed

(operating) position.

5 The Figure also shows the blank 10. At its centre is a peripheral start track 12 which is formed in accordance with the above description.

10 In addition to the details shown in Figure 1, Figure 2 shows that the upper and lower clamping devices 51 and 61 are each provided with a respective sprung support plate 54 and 64 against which the end edges of the tubular blank 10 make contact. The required spring function is provided by springs 55 and 65 around guide rods 56 and 66 for the support plates 54 and 64, the guide rods being screwed firmly to the support plates.

15 The Figure also shows that the two draw rings 71 and 81 each consist of two draw ring halves 71a, 71b and 81a, 81b. In addition, each draw ring is divided into three sections 74, 75, 76 and 84, 85, 86 each of which is split into two ring sections. The ring sections are separated from each other by a certain degree of thermal insulation.

20 The ring sections are held together by means of ring casings 77a, 77b and 87a 87b such that they combine to form the two halves of the draw rings. Each ring section is provided with channels 174, 175, 176 and 184, 185, 186 to permit the flow of liquid.

25 The draw ring sections consist of a first section 74 and 84 having an internal circumference which corresponds to the circumference of the material in the blank in the areas in which the thickness of the material has not been reduced, a second section 76 and 86 having an internal circumference which corresponds to the circumference of the material in the blank in the areas in which the thickness of the material has been reduced, and a further section 75 and 85 having an internal profile which forms contact surfaces for contacting the material in the transitional zone between material in the blank which has and which has not been reduced in thickness.

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Figure 2 also shows a mandrel 20 which fits the internal surface of the blank 10 and which is provided with channels 21 for liquid.

5 Figure 3 shows part of a longitudinal section of the apparatus of Figure 2 showing the central area with the draw rings 71, 81 spaced apart or in the course of moving apart along the axis of the blank such that the thickness of the material on a central section 11 of the blank 10' has been reduced. It will also be seen that the diameter of the central section 11 has been substantially
10 maintained. At the transitional zone 13, 14 between material with its original wall thickness and material with reduced wall thickness, contact surfaces are formed between the middle draw rings 75, 85 and the material in the transitional zone. In this way the draw rings are able to control the shape of the transitional surface between
15 material with its original wall thickness and material with reduced wall thickness.

Figure 4 shows a plan view of the support plate 70 viewed from above with the draw ring 71 in its closed position. The Figure also
20 illustrates the locations of the bearings for the guide pins 31 and the openings 78 and the threaded holes 72 for the drive screws 32. The other support plates which are fitted with the draw ring 81 or with the clamping devices 51 or 61 are similarly equipped. As has already been mentioned, the clamping device 61 is not divided, and
25 does not therefore have a drive corresponding to the drive 73.

Figures 5 and 6 show the reduction in the wall thickness of a tubular blank 15, 15' which is sealed at one end, the reduction starting at the sealed end of the blank and being produced by way of a draw ring
30 23. As shown, the draw ring is made up of three ring sections 24, 25, 26 having respective channels 124, 125, 126 for liquid. The ring sections are dimensioned similarly to the ring sections which have already been described and are held together by a ring casing 27. A

mandrel 28 operates in conjunction with the draw ring 23 in the re-shaping of the blank. The mandrel is normally provided with liquid channels, which however, cannot be seen in the Figure. The draw ring 23 is preferably dimensioned such that both before and at the start of the drawing operation contact will be made between both the middle ring section 25 and the upper ring section 24 and the outer surface of the tubular blank.

Figure 6 shows the manner in which re-shaping is begun and shows a section 16 of the blank with reduced wall thickness which has been formed in the lower section of the blank. Re-shaping normally continues until all the material in the cylindrical part of the blank has had its wall thickness reduced. If the mouth of the blank has already been formed, which may be the case with an injection-moulded blank, the re-shaping of the blank is, of course, interrupted as the draw ring reaches the mouth. The transitional zone between material with its original wall thickness and material with reduced wall thickness is indicated in the Figure by the designation 113.

Figures 7 and 8 show the use of a draw ring 29 composed of only two ring sections 96 and 97 each having separate liquid channels 94 and 95. Preferably, there is a certain degree of thermal insulation between the ring sections. If necessary, the draw ring may be extended by the addition of a third ring section having a separate liquid channel and which is dimensioned as already described above. The draw ring 29 operates in conjunction with an internal mandrel 28, which is normally provided with liquid channels which are not shown in the Figures. The draw ring 29 re-shapes the mouth of a tubular blank 17 which is sealed at one end. In an area which is usually quite close to the opening in the blank, a peripheral start track 19 is provided in which the thickness of the material has been reduced to approximately 1/3 of its original thickness. The start track is produced in the manner which has already been described.

In Figure 8 the draw ring 29 has been moved relative to the blank with the help of the mandrel 28 in such a way that a section 18 of the blank with reduced wall thickness is produced adjacent to the opening in the blank 17'.

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Figures 9 and 10 show apparatus in which a central clamping device 41a, 41b is located between the draw rings 71 and 81. The clamping device 41a, 41b is positioned on a central support plate 40 which has a fixed position in the device. This fixed position is obtained, for example, by attaching the support plate 40 to the guide pins 31. The central support plate is also fitted with drives 43a, 43b for moving the two parts 41a, 41b of the clamping device to and from the operating position of the respective parts. If required the central clamping device is provided with liquid channels 141a, 141b. In other respects the apparatus shown in Figures 9 and 10 corresponds to the apparatus shown in Figures 1 to 4, and similar features have been accorded the same reference numerals as used in Figures 1 to 4. An equivalent device to the clamping device 51 is not present in the apparatus of Figures 9 and 10.

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Figures 11 and 12 show details of the central areas in Figures 9 and 10, i.e. those areas in which the wall of the material in the blank is provided with a start track or in which the wall of the material has undergone a reduction in thickness in conjunction with the movement of the draw rings. The reference numeral 112 indicates an area of contact between the internal surface of the blank 10, 10' and the external surface of the mandrel 20 caused by a certain amount of deformation in the wall of the blank produced by the clamping device 41a when this is in the operation position. The reference numerals 115, 116 indicate areas of contact with the mandrel by the internal surface of sections of the material in the blank 10' of which the thickness has been reduced by the drawing operation.

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The central clamping device 41 may have one of several alternative configurations. The clamping device 41a, 41b in its operating position surrounds the wall of the blank, thus forming contact surfaces with the external surface of the wall of the blank which are distributed at various points around the periphery of the blank. Such a distribution of contact surfaces may be provided by a clamping device having internal surfaces which face the blank which are not cylindrical surfaces of circular cross-section, but instead are cylindrical surfaces of, for example, elliptical or polygonal cross-section.

Figures 13 to 15 show examples of tubular objects 210', 210'' and 210''' in accordance with the invention. The object 210' in Figure 13 has at its lower part a cylindrical wall section 213 of amorphous material adjacent to a sealed bottom 211' which is also of amorphous material. Figure 14 shows an object 210'' in which the external cylindrical surface has the same diameter along the entire length of the object. The sealed bottom 211'' of the object is also of amorphous material in this embodiment. Finally, Figure 15 shows an embodiment in which the edge of the mouth 212 of the object consists of material with its original thickness, whereas the remaining parts of the object are similar in design to those in Figure 14.

To produce a tubular object using the apparatus illustrated in Figures 1 to 4, a tubular blank 10 is positioned over the mandrel 20. The clamping device 51 and the draw rings 71 and 81 are in their open position as shown in the left-hand part of Figure 2. The blank which is placed around the mandrel 20 forms contact surfaces with the mandrel. Once the blank is in place and is in contact with the sprung support plate 64 of the lower clamping device 61 the upper clamping device 51 and the draw ring halves are moved to their closed position. The two draw rings 71 and 81 enter the start track 12 and in so doing form contact surfaces with the outer wall of the blank



where the wall thickness has not been reduced, where the wall thickness has been reduced to its minimum value, and at the transitional zone between the two aforementioned areas.

- 5 The material of the blank will preferably be at a high temperature, although preferably below TG, when it is placed on the mandrel. The final temperature of the material is set by the transfer of heat between the mandrel and the blank and/or between the draw rings and the blank. The temperature is controlled by means of the liquid
- 10 which flows through the liquid channels 21 in the mandrel and/or through the liquid channels 174, 175, 176 and 184, 185, 186 in the draw rings. The thermal insulation which is provided between the ring sections of the draw rings generally maintains a predetermined difference in temperature between different areas of material in the
- 15 blank. The ring sections 74, 84 which have the largest internal diameter will, when in the position shown in the right-hand part of Figure 2, set the material to a temperature in the range of TG, and preferably to a temperature which is not more than 150° C below TG. The ring sections 75, 85 have a similar function, whereas the ring
- 20 sections 76, 86 will preferably maintain a temperature well below TG, and preferably at a temperature which is at least 150° C below TG, in order to cool the material once it has undergone the reduction in thickness.
- 25 Once the material has reached the specified temperatures the drive devices in the base 30 will begin to rotate the drive screws 32, causing the support plates 50 and 70 and the associated clamping device 51 and draw ring 71 to move upwardly as shown in the Figures. The support plates 60 and 80 and the associated clamping device 61
- 30 and draw ring 81 will be moved downwardly as shown in the Figures. As the draw rings 71 and 81 move apart they each axially displace the respective transitional zone between material with reduced thickness and material with the original thickness such that the region of

thinner material is elongated and the thickness of the material in the region of thicker material is reduced. This elongation and reduction in thickness continues as long as movement continues. The axial elongation of the blank will be

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proportional to the reduction in the thickness of the material and to the axial movement of the draw rings. The speeds at which the support plates 50 and 60 move are therefore selected such that the positions of the clamping devices 51, 61 will match the elongation of the blank. Any irregularities which may occur will be absorbed by the sprung support plates 54 and 64.

The middle draw ring sections 75 and 85 are in contact with the transitional zone between material with reduced thickness and material with its original thickness. The profile of the middle ring section is selected such that the material during the re-shaping operation will form contact surfaces with the internal surfaces of the ring section. In this way the ring section will control the shape of the transitional surface between material with reduced thickness and material with its original thickness. The ring section also has a temperature regulating function in that the transfer of heat takes place at the aforementioned contact surfaces such that the material in the transitional zone is maintained at a temperature close to TG throughout the entire drawing operation. It is important, particularly when drawing takes place at high speed or when the material used is very thick, that the middle draw ring sections have excellent heat conducting properties so that the material in the transitional zone will not reach too high a temperature.

Once the draw rings have been moved apart so that the central section 11 of the blank has reached a predetermined length, the movement of the support plates is stopped. The drives 53, 73, 83 then move the clamping device 51 and the draw rings 71 and 81 to their open position, and the object which has been formed in the manner described is then removed from the mandrel, whereupon a new tubular blank is placed on the mandrel and the operation is repeated.

The section 11 which has the reduced wall thickness forms the central

section of the finished object and this central section is cut in order to produce two symmetrical parts. Each part is then sealed at the end having the original wall thickness, thus producing a preform which may be used, for example, to produce a blow-moulded container.

5 Those sections of the preform which have reached wall thickness are subsequently re-shaped to form the basis for the mouth of the future container.

The apparatus indicated in Figures 5 and 6 is in principle operated identically to that described above. The internal mandrel 28 acts as a dolly which takes up those forces which arise as the draw ring 23 is moved axially along the blank. Regulation of the temperature in the different areas of the material is also important in this application. The mandrel 28 is normally provided with liquid

10 channels corresponding to the liquid channels 21 in the mandrel 20 shown in Figures 2 and 3. In certain applications the thickness of all the material in the cylindrical section of the blank is reduced, whilst the re-shaping stops sooner in other applications.

The method of producing a tubular object indicated in Figures 7 and 8 is applicable to those cases in which it is required to produce a number of areas of material in which the thickness of the material has been reduced. Each such area of material requires a start track in which the reduction in the thickness of the material may begin.

20 When producing the object the draw ring 29 is moved to an initial start track and the halves of the draw ring take up their operating position. The draw ring is moved from the start track over a short distance along the axis of the blank, reducing the thickness of the material until the first section of material with reduced wall

25 thickness has been produced. The draw ring halves are then moved apart and the draw ring is moved to the next start track, when the draw ring halves take up their new operating position. The draw ring is now moved once more along the axis of the blank in order to produce

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a new area of material with reduced wall thickness, and so on. The operation is repeated until the desired number of areas with reduced material thickness have been produced.

- 5 The blank used in conjunction with the unidirectional drawing described in connection with Figures 5 to 8 is shown as being sealed at one end. In this way the seal will have operated in conjunction with the internal mandrel to absorb the axial forces produced during the drawing operation. It is, of course, possible to use external clamping devices which replace the function of the mandrel in this respect. This alternative is used when drawing tubular blanks which are open at both ends.

- 15 When using the apparatus shown in Figures 9 to 12 to produce a tubular object, a blank 10 is slid over the mandrel 20 until it makes contact with the lower clamping device 61. In this case the clamping device 61 serves as a device for determining the axial position of the blank, thereby ensuring that the track 12 on the blank adopts a position which is suitable for the positioning of the draw rings 71, 81 and for the clamping device 41. This situation corresponds to the left-hand half of Figure 9. The drives 43, 73, 83 then move the clamping device 41 and the draw rings 71, 81 into contact with the external surface of the blank in and adjacent to the track 12. The temperature conditioning of the material in the blank then takes place in the manner which has already been described, in addition to which in certain typical applications liquid is also caused to flow through the channels 141 in the clamping device 41. This situation corresponds to what is shown in the right-hand part of Figure 9 and in detail in Figure 11.

- 30 In its operating position the central clamping device 41 surrounds the blank 10 in the bottom of the track 12. This forms contact surfaces with the bottom of the track which are divided into a

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number of areas around the circumference of the blank. The contact pressure present at these surfaces in turn causes the internal surface of the blank and the surface of the mandrel to bear against each other. The bearing surfaces adopt positions which correspond to the distribution of the contact surfaces. The bearing surfaces are produced because the clamping device deforms the shape of the surface defining the internal limits of the blank. The contact pressure of the clamping device is selected such that in the event of the shape being deformed, the thickness of the material in the bottom of the track will remain largely unchanged. A bearing surface is shown in detail in Figure 12 and is given the reference designation 112.

The drive devices in the base 30 (Figure 1) then rotate the drive screws 32 causing the draw rings 71, 81 to move apart along the axis of the blank, simultaneously re-shaping the wall of the material and elongating the blank. The friction between the blank and the mandrel at the aforementioned bearing surfaces 112 fixes the position of the blank on the mandrel and ensures that the re-shaping of the blank will take place symmetrically around the track 12. The driving of the support plate 60 is selected such that the clamping device 61 will be reliably moved away from the end of the tube so as not to have any effect on the elongation of the tube which occurs in conjunction with the reduction in the thickness of the wall of the blank. This operating situation corresponds to Figures 10 and 12. Figure 12 also show that, in addition to the stretching of the material which occurs during the re-shaping of the wall of the blank, contraction of the blank also takes place, causing its internal surface to be moved into contact with the mandrel 20. These contact surfaces are indicated in the Figure by the reference numerals 115 and 116. The formation of these contact surfaces contributes to the fixing of the position of the blank relative to the mandrel which is achieved with the help of the central clamping device 41. It has been found in the majority of typical applications that additional fixing by means of the contact surfaces 115 and 116 is not essential

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to achieving the desired symmetrical re-shaping of the blank.

- 5 The description in the previous paragraph indicates that the apparatus shown in Figures 9 to 12 enables any desired length of the blank to have the thickness of its material reduced. Thus, it is possible to reduce the thickness of the material along the entire length of the blank, to interrupt the reduction in thickness immediately before the ends of the blank, or to reduce the thickness in a number of areas distributed axially along the blank and
- 10 separated by sections of material in which there has been no reduction in thickness. In each area with reduced material thickness, the reduction of the thickness is begun in a new start track.
- 15 Surprisingly, it has been found that when the blank is re-shaped at the temperatures indicated above, relatively low contact pressure is produced between the material of the blank and the mandrel, for which reason no problems are encountered in removing the moulded object from the mandrel after the moulding operation is complete.
- 20 Figures 13 to 15 show examples of tubular objects produced in the manner described above. When producing the object shown in Figure 13 the thickness of a tubular blank which is open at both ends may be reduced with an area of amorphous material left at the end of the
- 25 blank. This area of amorphous material is then heated and sealed in accordance with the method described above. Figures 14 and 15 relate to embodiments in which an already sealed tubular blank of amorphous material is given cylindrical areas of the walls consisting of substantially monoaxially oriented material. In Figure 14 the
- 30 monoaxially oriented material is present around the object over its entire length, whereas in Figure 15 the edge of the mouth 212 consists of material which has not undergone such orientation.

It is also possible to further increase the crystallinity of the

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material over and above the crystallinity which is produced in the material in conjunction with the monoaxial orientation by heating the material. This crystallinity should not be allowed to continue to such a point that the ability of the material to undergo further re-shaping is impaired where the object formed is a preform which will be re-shaped in a subsequent operation to produce a finished article. The crystallinity of an object is normally allowed to reach a maximum level of approximately 30% when the object is to undergo further re-shaping. Preferably, the crystallinity allowed to lie between 10 and 25%, the crystallinity produced by monoaxial orientation achieving a maximum value of approximately 17%.

It has been assumed in the above description that the reduction in the thickness of the material to the final value required takes place in a single reduction operation. However, the thickness of the material may be reduced in a number of consecutive reduction stages, before the thickness of the material is reduced finally to approximately $1/3$ of its original thickness. In this case the draw ring or draw rings will consist of a number of ring sections for the consecutive gradual reduction of the thickness of the material. The embodiment described in this paragraph is used mainly when the material in the blank has a large wall thickness and/or when the draw rings are moved at high speed.

The crystallinity values stated in the present application relate to the theories disclosed in the published "Die Makromolekulare Chemie" 176, 2459-2465 (1975).

The method and apparatus for producing a plastics material object from a tubular blank described above are described and claimed in copending British Patent Application No. 2092943 from which the present application is divided.



CLAIMS:

1. A tubular object of polyethylene terephthalate formed from a blank of material having a crystallinity of less than 10%, said
5 object having a cylindrical part which consists of material which is oriented along the axis of the object only and has a maximum crystallinity of approximately 30%, the material of said cylindrical part being obtained by reducing the thickness of the blank while substantially maintaining its diameter.
- 10 2. A tubular object as claimed in Claim 1, wherein said maximum crystallinity is between 10 and 25%.
- 15 3. A tubular object as claimed in Claim 2, wherein said maximum crystallinity is 17%.
- 20 4. A tubular object as claimed in any preceding claim, wherein the reduction of the thickness of the blank is obtained with the blank at a temperature in the vicinity of the glass transition temperature of the material.
- 25 5. A tubular object as claimed in Claim 4, wherein said temperature is no more than 30°C greater than the glass transition temperature.
- 30 6. A tubular object as claimed in any preceding claim, wherein the material of said cylindrical part is obtained by forming a transitional zone between a region of thinner material and a region of thicker material and displacing said transitional zone to elongate the region of thinner material and reduce the region of thicker material
7. A tubular object as claimed in any preceding claim, wherein the object is sealed at one end.



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8. A tubular object of polyethylene terephthalate substantially as hereinbefore described with reference to and as illustrated in the accompanying drawings.
