

Plastic containers with homogeneous wall thickness

The present invention relates to plastic containers with a homogeneous wall thickness. The present invention also relates to the production of these containers.

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Containers made of plastics material, in particular of polycarbonate, are basically known. These containers are produced, for example, from compositions (also called compounds) which contain a polymer, in particular polycarbonate, and conventional additives. These compositions consisting of the polymer (polycarbonate) and the additives are also called plastics material. The additives are, for example, stabilisers, processing aids, etc. In addition, the plastic containers can also comprise further components, such as seals made of rubber or grips made of metal or other materials. Therefore, it is more correct to speak of "containers containing plastics material" than of "plastic containers". In addition to the plastics material, the containers can, for example, comprise the aforementioned components and/or other components. Hereinafter "plastic containers" mean "containers containing plastics material".

Plastic containers have numerous advantageous properties, such as high transparency, good mechanical properties, great resistance to environmental influences and a long life, as well as low weight and easy, inexpensive producibility.

Plastic containers can be produced, for example by extrusion blow moulding or injection stretch blow moulding.

In extrusion blow moulding the plastics material is usually melted using a single-screw extruder and moulded by a die into a free standing parison. The parison generally hangs downwards from the die. The parison is then surrounded by a blow mould which squashes the parison together at the lower end. The parison is then inflated within the mould so the parison obtains the desired shaping. After a cooling time the mould is opened and the container (blow moulding) can be removed.



Extrusion blow moulding is disclosed, for example, in Brinkschröder, F. J.: "Polycarbonate" in Becker, Braun, Kunststoff-Handbuch, Vol. 3/1, Polycarbonate, Polyacetale, Polyester, Celluloseester, Carl Hanser Verlag Munich, Vienna 1996, pages
5 248 to 255).

Injection stretch blow moulding is a combination of injection moulding and blow moulding.

10 Injection stretch blow moulding proceeds in three stages:

1. Injection moulding the parison in the plastic temperature range of the plastics material
- 15 2. Inflating the parison in the thermoplastic range of the plastics material (the core of the injection mould is simultaneously the blowing mandrel)
3. Stripping the blow moulding and optionally cooling the blowing mandrel with air

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Injection stretch blow moulding is disclosed, for example, in Anders, S., Kaminski, A., Kappenstein, R., "Polycarbonate" in Becker, Braun, Kunststoff-Handbuch, Vol. 3/1, Polycarbonate, Polyacetale, Polyester, Celluloseester, Carl Hanser Verlag Munich, Vienna 1996, pages 213 to 216.

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The plastic containers known from the prior art have the drawback that they do not meet certain requirements which are important for practical use of the containers.

Therefore, great mechanical stress in the known plastic containers can lead to bursting
30 thereof. This can occur, for example, if a container filled with liquid falls onto the floor

from a great height, for example from the loading area of a lorry on which the container is being transported.

Of course the mechanical strength of the containers could be increased by using a great deal more plastics material per container so the wall is much thicker. However, this has the drawback that the material consumption increases and this *inter alia* causes high costs.

The object of the present invention is therefore to provide plastic containers having high mechanical strengths with the lowest possible expenditure on material.

It has accordingly been found that the cause of the aforementioned mechanical failure is an irregular container wall thickness.

The irregular container wall thicknesses which are known from the prior art, results during production thereof as the polymer melt produces irregular wall thicknesses during processing by extrusion blow moulding or by injection stretch blow moulding.

The object of the present invention is achieved by a container containing plastics material, wherein at its thickest point the regular container wall is at least three times as thick as at its thinnest point.

At its thickest point the regular container wall is preferably at most 2.6 times as thick as at its thinnest point.

At its thickest point the regular container wall is particularly preferably at most 2.2 times as thick as at its thinnest point.

The container is preferably a bottle.

The container is particularly preferably a water bottle.

The container preferably contains the plastics material polycarbonate.

5 The object of the present invention is also achieved by a method for producing the container according to the invention by injection blow moulding or by injection stretch blow moulding.

Rotationally symmetrical containers are preferred. Containers with only one aperture are preferred.

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Regular container wall is taken to mean the container wall at all the points at which thicker or thinner points are not intentionally provided. Such intentionally thicker points can be seen in Fig. 4 in the region of the bottleneck. Under ideal container production conditions the regular container wall would therefore be equally thick all over.

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The containers according to the invention have, for example, been produced from a polycarbonate with certain rheological properties. Therefore, the uniaxial stretching test with which these rheological properties can be measured is to be described hereinafter.

20 The uniaxial stretching test of polymer melts and its implementation are known to the person skilled in the art. The uniaxial stretching test can be carried out with apparatuses of the Münstedt type. These are described in H. Münstedt, J. Rheol., Vol. 23, pages 421 to 436 (1979). These are also described in current text books such as in Ch. W. Macosko: Rheology, Verlag Wiley/VCH, 1994, in particular pages 288 to 297 and in
25 M. Phal, W. Gleißle, H.-M. Laun: Praktische Rheologie der Kunststoffe und Elastomere, VDI-Verlag, 1995, in particular pages 349 to 357.

The methods for determining the shear viscosity as a function of time are known to the person skilled in the art.

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Determination of the shear viscosity as a function of time is preferably carried out in a rotary rheometer at low shear speeds. Determination of the shear viscosity can be carried out in the rotary rheometer also with oscillating deformation and can be converted into a time-dependent viscosity by means of common methods. The construction and mode of use of rotary rheometers are described in current text books. For example in M. Pahl, W. Gleißle, H-M. Laun: Praktische Rheologie der Kunststoffe und Elastomere, VDI-Verlag, 1995.

The stretching viscosity as a function of time is preferably determined by means of a Münstedt-type stretching rheometer. The uniaxial stretching test may also be carried out with a range of other rheometers, for example with the commercially available Meissner-type stretching rheometer. This is described in J. Meissner, Rheologica Acta 8, Vol. 78 (1969) and in J. S., Schulze et al., Rheol. Acta Vol. 40 (2001) pages 457 to 466.

The Hencky elongation ϵ is a non-dimensional variable. The stretching viscosity η_E has the unit Pascal multiplied by seconds. The shear viscosity η also has the unit Pascal multiplied by seconds.

The quotient S serves as a measure of the relevant increase in the stretching viscosity η_E . The quotient S is non-dimensional. S is the quotient from the quotient from the stretching viscosity η_E and three-fold shear viscosity 3η . S depends on the measuring temperature T , the Hencky elongation rate $\dot{\epsilon}$ (unit: 1 divided by seconds) and the Hencky elongation ϵ and the time.

The following formula applies:

$$S = \eta_E(t, \dot{\epsilon}) \text{ divided by } 3\eta(t)$$

The total stretching ε (unit: non-dimensional) is linked to the sample starting length L_0 (unit: meters) and the current sample length L (unit: meters) and the elongation rate of $\dot{\varepsilon}$ (unit: 1 divided by seconds) and the time t (unit: seconds) by:

5 $\varepsilon = \text{natural logarithm of } (L \text{ divided by } L_0) = \dot{\varepsilon} \text{ multiplied by } t.$

A plastics material, in particular polycarbonate, is preferred in which, at a temperature of 200°C, the ratio S is greater than 1.1 at a Hencky elongation ε of 2.0 and an elongation rate range $\dot{\varepsilon}$ of between 0.1 and 0.01, and is greater than 1.1 at a Hencky
10 elongation ε of 2.5 and an elongation rate range $\dot{\varepsilon}$ of between 0.1 and 0.01, wherein S is defined as $S = \eta_E$ divided by 3η .

A plastics material, in particular polycarbonate, is particularly preferred in which, at a temperature of 200°C, the ratio S is greater than 1.3 at a Hencky elongation ε of 2.0 and
15 an elongation rate range $\dot{\varepsilon}$ of between 0.1 and 0.01, and is greater than 1.3 at a Hencky elongation ε of 2.5 and an elongation rate range $\dot{\varepsilon}$ of between 0.1 and 0.01.

The present invention relates to a container containing plastics material. This means a container containing the plastics material, for example as wall material. It does not
20 mean a container made of completely different materials and which only contains the plastics material as filler.

The present invention also relates to a method for producing this container by extrusion blow moulding or by the injection stretch blow moulding.

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To obtain plastics materials, in particular polycarbonates, with the aforementioned rheological stretching properties the person skilled in the art can purposefully adjust various parameters of the plastics materials, in particular polycarbonates. For example, he can influence the molar mass and the degree of branching. The choice of the
30 monomers and comonomers or the terminal groups also has an effect on the rheological

stretching properties. The person skilled in the art can also use suitable additives to obtain the desired rheological stretching properties according to the invention.

5 The advantage of the aforementioned plastics material, in particular polycarbonate, is that it allows production of the containers according to the invention with their advantageous properties. The known and advantageous processes (extrusion blow moulding and/or injection stretch blow moulding) can be used here.

10 Of course the present invention is not limited to containers containing plastics material in which the plastics material has the aforementioned rheological properties. These are only preferred as they allow the containers to be produced by simple and known processes (extrusion blow moulding or injection stretch blow moulding). In general it is only important for said homogeneity of the wall thickness to be achieved. This can also occur using other methods and other plastics material (for example injection moulding
15 or pressing).

The containers according to the invention have the advantage that they have high mechanical strength with a predetermined quantity of plastics material per container.

20 The containers according to the invention have numerous further advantages. They are resistant to mechanical stresses, i.e. resistant to breaking, and also have an advantageous range of further mechanical properties. They have good optical properties, in particular a high degree of transparency. They have a high heat distortion temperature. Owing to the high heat distortion temperature the containers according to the invention can be
25 cleaned with hot water or sterilised with hot steam. They have high resistance to the conventional detergents which, for example, are used to clean reusable water bottles, a field of application of the containers according to the invention. They can be produced easily and inexpensively by known processes. The good processing properties of the plastics material, in particular polycarbonate, are advantageously manifested here. Their

material ages slowly in use and therefore they have a long service life. For possible repeated use this means many use cycles.

Containers in accordance with the present invention can be used for packaging, storing
5 or transporting liquids, solids or gases. Containers for packaging, storing or transporting liquids (liquid containers) are preferred, containers for packaging, storing or transporting water (water bottles) are particularly preferred.

Containers in accordance with the invention are preferably blow mouldings with a
10 volume of 0.1 l to 50 l, preferably 0.5 l to 50 l, with volumes of 1 l, 5 l, 12 l and 20 l being particularly preferred.

3 and 5 gallon water bottles are most particularly preferred.

15 The containers preferably have an empty weight of preferably 0.1 g to 3,000 g, more preferably 50 g to 2,000 g and particularly preferably of 650 g to 900 g.

The wall thicknesses of the containers are preferably 0.5 mm to 5 mm, more preferably
20 0.8 mm to 4 mm.

Containers in the sense of the invention preferably have a length of preferably 5 mm to
2,000 mm, particularly preferably 100 mm to 1,000 mm.

The containers preferably have a maximum circumference of preferably 10 mm to 250
25 mm, more preferably of 50 mm to 150 mm and most particularly preferably of 70 to 90 mm.

Containers in the sense of the invention preferably have a bottleneck of a length of
preferably 1 mm to 500 mm, more preferably of 10 mm to 250 mm, particularly
30 preferably of 50 mm to 100 mm and most particularly preferably of 70 to 80 mm.

The wall thickness of the bottleneck of the containers preferably varies between 0.5 mm and 10 mm, particularly preferably of 1 mm to 10 mm and most particularly preferably of 1 mm to 3 mm.

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The diameter of the bottleneck preferably varies between 5 mm and 200 mm. 10 mm to 100 mm are particularly preferred and 45 mm to 75 mm most particularly preferred.

The bottle base of the containers according to the invention has a diameter of preferably
10 10 mm to 250 mm, more preferably 50 mm to 150 mm and most particularly preferably 70 to 90 mm.

Containers in the sense of the present invention can have any geometric shape, for example they can be round, oval or polygonal with, for example, 3 to 12 sides. Round,
15 oval and hexagonal shapes are preferred.

The design of the containers can be based on any surface structure. The surface structures are preferably smooth or ribbed. The containers according to the invention can also have a plurality of different surface structures. Ribs or beads can run around
20 the periphery of the containers. They can have any spacing or a plurality of spacings which are different from one another. The surface structures of the containers according to the invention can be roughened or integrated structures, symbols, ornaments, coats of arms, manufacturer's emblems, trademarks, signatures, producer's details, material characteristics and/or information on volume.

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The containers according to the invention can have any number of handles which can be located on the sides, at the top or at the bottom. The handles could be on the outside or integrated into the contour of the container. The handles can be foldable or fixed. The handles can have any contour, for example oval, round or polygonal. The handles
30 preferably have a length of 0.1 mm to 180 mm, preferably 20 mm to 120 mm.

In addition to the plastics material according to the invention the containers according to the invention can also contain small amounts of other substances, for example seals made of rubber or handles made of other materials.

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The containers according to the invention are preferably produced by extrusion blow moulding or by injection stretch blow moulding.

In a preferred embodiment for producing the containers according to the invention, the plastics materials according to the invention are processed on extruders with a smooth or grooved, preferably a smooth, feed zone.

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The drive power of the extruder is selected in accordance with the screw diameter. By way of example it is mentioned that, with a screw diameter of 60 mm, the drive power of the extruder is approximately 30 to 40 kW, and with a screw diameter of 90 mm, approximately 60 to 70 kW.

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The universal three zone screws conventional in the processing of industrial thermoplastics are suitable.

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To produce containers having a volume of 1 l a screw diameter of 50 to 60 mm is preferred. To produce containers having a volume of 20 l a screw diameter of 70 to 100 mm is preferred. The length of the screws is preferably 20 to 25 times the diameter of the screw.

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In the case of blow moulding the temperature of the blow mould is preferably adjusted to 50 to 90°C to obtain a sparkling and high quality container surface.

To ensure uniform and effective temperature adjustment of the blow mould the base region and the external region can be adjusted in temperature separately.

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The blow mould is preferably closed with a compressive force of 1,000 to 1,500 N per centimetre of pinch-off weld length.

- 5 The plastics material is preferably dried before processing so the visual quality of the containers is not impaired by streaks or bubbles and is not hydrolytically disintegrated during processing. The residual moisture content after drying is preferably less than 0.01 % by weight. A drying temperature of 120°C is preferred. Lower temperatures do not ensure sufficient drying, and at higher temperatures there is the risk of plastics material granules sticking together and then no longer being capable of being processed.
10 Dry air driers are preferred.

The preferred melt temperature when processing plastics materials based on polycarbonate is 230° to 300°C.

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- The containers according to the invention can be used for packaging, storing or transporting liquids, solids or gases. The embodiment which, for example, is used for packaging, storing or transporting liquids, is preferred. The embodiment as a water bottle which, for example, can be used for packaging, storing or transporting water, is particularly preferred.
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Polycarbonates in the sense of the present invention are preferably thermoplastically processable aromatic polycarbonates. Both homopolycarbonates and copolycarbonates can be used.

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Particularly preferred polycarbonates are the homopolycarbonate based on bisphenol A, the homopolycarbonate based on 1,1 bis-(4-hydroxyphenyl)-3,3,5-trimethylcyclohexane and the copolycarbonates based on the two monomers bisphenol A and 1,1-bis-(4-hydroxyphenyl)-3,3,5-trimethylcyclohexane.

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The polycarbonates according to the invention also include polycarbonates in which up to 80 mol %, in particular from 20 mol % to 50 mol %, of the carbonate groups are replaced by aromatic dicarboxylic acid ester groups. Polycarbonates of this type which include both acid residues of carbon dioxide and acid residues of aromatic dicarboxylic acids incorporated in the molecule chain, are also called aromatic polyester carbonates.

The polycarbonates can be produced in a known manner from diphenols, carbon dioxide derivatives, optionally chain terminators and optionally branching agents. A portion of the carbon dioxide derivatives is replaced by aromatic diocarboxylic acids or derivatives of dicarboxylic acids to produce the polyester carbonates. This proceeds according to the carbonate structural units to be replaced in the aromatic polycarbonates by aromatic dicarboxylic acid ester structural units.

Details of the production of polycarbonates are known. Reference is made by way of example to:

1. Schnell, "Chemistry and Physics of Polycarbonates", Polymer Reviews, Volume 9, Interscience Publishers, New York, London, Sydney 1964;
- 20 2. D.C. Prevorsek, B.T. Debona und Y. Kesten, Corporate Research Center, Allied Chemical Corporation, Morristown, New Jersey 07960: "Synthesis of Poly(ester Carbonate) Copolymers" in Journal of Polymer Science, Polymer Chemistry Edition, Vol. 19, 75-90 (1980);
- 25 3. D. Freitag, U. Grigo, P.R. Müller, N. Nouvertne', BAYER AG, "Polycarbonates" in Encyclopedia of Polymer Science and Engineering, Vol. 11, Second Edition, 1988, pages 648-718;

4. U. Grigo, K. Kircher und P. R- Müller "Polycarbonate" in Becker/Braun, Kunststoff-Handbuch, Vol. 3/1, Polycarbonate, Polyacetale, Polyester, Celluloseester, Carl Hanser Verlag Munich, Vienna 1992, pages 117-299.
- 5 The polycarbonates, including the polyester carbonates, preferably have mean molecular weights M_w of 12,000 to 120,000 g/mol (determined by measuring the relative viscosity at 25°C in methylene chloride at a concentration of 0.5 g polycarbonate per 100 ml methylene chloride). 15,000 to 80,000 g/mol are preferred, 15,000 to 60,000 g/mol are particularly preferred.
- 10 Diphenols suitable for producing polycarbonates are, for example, hydroquinone, resorcinol, dihydroxydiphenyl, bis-(hydroxyphenyl)-alkanes, bis-(hydroxyphenyl)-cycloalkanes, bis-(hydroxyphenyl)-sulphides, bis-(hydroxyphenyl)-ether, bis-(hydroxyphenyl)-ketones, bis-(hydroxyphenyl)-sulphones, bis-(hydroxyphenyl)-sulphoxides, (α,α' -bis-(hydroxyphenyl)-diisopropylbenzenes, and their compounds
- 15 alkylated on the nucleus and halogenated on the nucleus.
- Preferred diphenols are 4,4'-dihydroxydiphenyl, 2,2-bis-(4-hydroxyphenyl)-1-phenylpropane, 1,1-bis-(4-hydroxyphenyl)-phenyl-ethane, 2,2-bis-(4-hydroxyphenyl)propane,
- 20 2,4-bis-(4-hydroxyphenyl)-2-methylbutane, 1,1-bis-(4-hydroxyphenyl)-m/p diisopropylbenzene, 2,2-bis-(3-methyl-4-hydroxyphenyl)-propane, bis-(3,5-dimethyl-4-hydroxyphenyl)-methane, 2,2-bis-(3,5-dimethyl-4-hydroxyphenyl)-propane, bis-(3,5-dimethyl-4-hydroxyphenyl)-sulphone, 2,4-bis-(3,5-dimethyl-4-hydroxyphenyl)-2-methylbutane, 1,1-bis-(3,5-dimethyl-4-hydroxyphenyl)-m/p-diisopropyl-benzene, 2,2
- 25 and 1,1-bis-(4-hydroxyphenyl)-3,3,5-trimethylcyclohexane.

Particularly preferred diphenols are 4,4'-dihydroxydiphenyl, 1,1-bis-(4-hydroxyphenyl)-phenyl-ethane, 2,2-bis-(4-hydroxyphenyl)-propane, 2,2-bis(3,5-dimethyl-4-hydroxyphenyl)-propane, 1,1-bis-(4-hydroxyphenyl)-cyclohexane, 1,1-bis-(4-

hydroxyphenyl)-m/p diisopropylbenzene und 1,1-bis-(4-hydroxyphenyl)-3,3,5-trimethylcyclohexane.

These and other suitable diphenols and their production are disclosed, for example, in
5 US-A 3 028 635, 2 999 835, 3 148 172, 2 991 273, 3 271 367, 4 982 014 and 2 999
846, in DE-A 1 570 703, 2 063 050, 2 036 052, 2 211 956 and 3 832 396, in FR-A 1
561 518, in the monograph "H. Schnell, Chemistry and Physics of Polycarbonates,
Interscience Publishers, New York 1964" and in JP-A 62039/1986, 62040/1986 and
105550/1986.

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In the case of the homopolycarbonates, only one diphenol is used, in the case of the
copolycarbonates a plurality of diphenols are used, wherein of course the diphenols
used (also called bisphenols) can be contaminated with the impurities originating from
their own synthesis, like all other chemicals and auxiliary agents added to the synthesis,
15 although it is desirable to work with raw materials which are as clean as possible.

Suitable chain terminators which can be used in the production of polycarbonates are
monophenols and monocarboxylic acids.

20 Suitable monophenols are, for example, phenol, alkyl phenols such as cresols, p-
tert.butylphenol, p-n-octylphenol, p-iso-octylphenol, p-n-nonylphenol and p-iso-
nonylphenol, halogen phenols such as p-chlorophenol, 2,4-dichlorophenol, p-
bromophenol and 2,4,6-tribromophenol and mixtures thereof.

25 Suitable monocarboxylic acids are, for example, benzoic acid, alkyl benzoic acids and
halogen benzoic acids.

Preferred chain terminators are the phenols of formula (I)

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wherein R⁶ represents H or a branched or unbranched C₁-C₁₈ alkyl radical.

5 The quantity of chain terminator to be used is preferably 0.5 mol % to 10 mol %, based on mol of the respectively used diphenols. The chain terminators can be added before, during or after phosgenation.

10 The polycarbonates can be branched. Suitable branching agents which can be used to branch the polycarbonates are the tri- or more than trifunctional compounds known in polycarbonate chemistry, in particular those with three or more than three phenolic OH groups.

15 Suitable branching agents are, for example phloroglucin, 4,6-dimethyl-2,4,6-tri-(4-hydroxyphenyl)-heptene-2, 4,6-dimethyl-2,4,6-tri-(4-hydroxyphenyl)-heptane, 1,3,5-tri-(4-hydroxyphenyl)-benzene, 1,1,1-tri-(4-hydroxyphenyl)-ethane, tri-(4-hydroxyphenyl)-phenylmethane, 2,2-bis-[4,4-bis-(4-hydroxyphenyl)-cyclohexyl]-propane, 2,4-bis-(4-hydroxyphenyl-isopropyl)-phenol, 2,6-bis-(2-hydroxy-5'-methyl-benzyl)-4-methylphenol, 2-(4-hydroxyphenyl)-2-(2,4-dihydroxyphenyl)-propane, hexa-(4-(4-hydroxyphenyl-isopropyl)phenyl)-orthoterephthalic acid ester, tetra-(4-hydroxyphenyl)-methane, tetra-(4-(4-hydroxy-phenyl-isopropyl)-phenoxy)-methane und 1,4-bis(4',4''-dihydroxy-triphenyl)-methyl)-benzene and 2,4-dihydroxybenzoic acid, trimesic acid, cyanurichloride and 3,3-bis-(3-methyl-4-hydroxyphenyl)-2-oxo-2,3-dihydroindol.

25 The quantity of branching agent to optionally be used is preferably 0.05 mol % to 2.5 mol %, based on mol of respectively used diphenols.

30 The branching agents can either be introduced with the diphenols and the chain terminators in the aqueous alkaline phase or be added prior to phosgenation dissolved in an organic solvent.

All of these measures for producing the polycarbonates are familiar to the person skilled in the art.

- 5 Aromatic dicarboxylic acids suitable for producing the polyester carbonates are, for example, phthalic acid, terephthalic acid, isophthalic acid, ter.-butylisophthalic acid, 3,3'-diphenyldicarboxylic acid, 4,4'-diphenyldicarboxylic acid, 4,4-benzophenonedicarboxylic acid, 3,4'-benzophenonedicarboxylic acid, 4,4'-diphenyletherdicarboxylic acid, 4,4'-diphenylsulphonicdicarboxylic acid, 2,2-bis-(4-
10 carboxyphenyl)-propane, trimethyl-3-phenylindane-4,5'-dicarboxylic acid.

Of the aromatic dicarboxylic acids, terephthalic acid and/or isophthalic acid are particularly preferably used.

- 15 Derivatives of the dicarboxylic acids are, for example, the dicarboxylic acid dihalides and the dicarboxylic dialkylesters, in particular the dicarboxylic acid dichlorides and the dicarboxylic acid dimethylesters.

- The carbonate groups are replaced substantially stoichiometrically and also
20 quantitatively by the aromatic dicarboxylic acid ester groups, so the molar ratio of the reaction partners is again found in the finished polyester carbonates. The aromatic dicarboxylic acid ester groups can be incorporated randomly and also block by block.

- 25 The polycarbonates are preferably produced by the interfacial process or the known melt transesterification process. In the first case phosgene preferably serves as carbon dioxide derivative, in the latter case preferably diphenylcarbonate.

- Catalysts, solvents, working up, reaction conditions, etc. for the production of
30 polycarbonate are known in both cases.

The melt transesterification process is described, in particular, in H. Schnell, "Chemistry and Physics of Polycarbonates", Polymer Reviews, Vol. 9, pages 44 to 51, Interscience Publishers, New York, London, Sidney, 1964 and in DE-A 1 031 512, in US-A 3 022 272, in US-A 5 340 905 and in US-A 5 399 659.

The polycarbonates can also contain the conventional additives, for example pigments, UV stabilisers, heat stabilisers, antioxidants and mould-release agents in the quantities conventional for polycarbonates.

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For the case where the polycarbonates contain additives, the compositions consisting of polycarbonate and additives are also called polycarbonate moulding compounds.

These conventional additives can be added to the polycarbonates in a known manner together with the components according to the invention or thereafter.

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When producing polycarbonate, raw materials and auxiliary agents with a low degree of contaminants are preferably used. The bisphenols used and the carbon dioxide derivatives used should be as free from alkali ions and alkaline earth ions as possible, in particular when produced by the melt transesterification process. Pure raw materials of this type may be obtained, for example, by recrystallising, washing or distilling the carbon dioxide derivatives, for example carbon dioxide esters.

20

When producing polycarbonates by the melt transesterification process, the reaction of the bisphenol and of the carbon dioxide diester can be carried out continuously or discontinuously, for example in agitated tanks, film evaporators, falling-film evaporators, series of stirred-tank reactors, extruders, kneaders, simple disc reactors and high viscosity disc reactors.

25

Carbon dioxide diesters which can be used to produce polycarbonates, are, for example, diarylesters of carbon dioxide, the two aryl radicals preferably each having 6 to 14 carbon atoms. The diesters of the carbon dioxide are preferably used on the basis of phenol or alkyl-substituted phenols, in other words, for example
5 diphenylcarbonate or dicresylcarbonate. Based on 1 mol bisphenol the carbon dioxide diesters are preferably used in a quantity of 1.01 to 1.30 mol, particularly preferably in a quantity of 1.02 to 1.15 mol.

If phenols, alkylphenols and/or arylphenols are used in the production of
10 polycarbonates they have the effect of chain terminators. This means they limit the maximum achievable mean molar mass. They can be added either together with the monomers required to produce the polycarbonate, or in a later phase of polycarbonate synthesis. They act as monofunctional compounds in the sense of the polycarbonate synthesis and therefore act as chain terminators.

15 The phenol, alkylphenols and/or arylphenols optionally used in production of the polycarbonates are preferably used in a quantity of 0.25 to 10 mol %, based on the sum of the respectively used bisphenols.

20 Mixtures of phenol and/or one or more alkylphenols and/or arylphenols can also be used.

The alkylphenols and/or arylphenols optionally used in the production of polycarbonates lead to terminal alkylphenol groups and to terminal arylphenol
25 groups. In addition, other terminal groups can occur in the resulting polycarbonate, depending on the production process, such as phenolic terminal OH groups or terminal chloroformic acid ester groups.

Phenol, alkylphenols and/or arylphenols without the addition of further substances which can act as chain terminators, are preferably exclusively used as chain terminators.

- 5 Suitable further substances which can act as chain terminators are monophenols and monocarboxylic acids. Suitable monophenols are, for example, phenol, p-chlorophenol or 2,4,6-tribromophenol. Suitable monocarboxylic acids are benzoic acid, alkylbenzoic acids and halogenbenzoic acids.
- 10 The preferred further substances which can act as chain terminators are phenol, p-tert.butylphenol, cumylphenol and isooctylphenol.

The quantity of further substances which can act as chain terminators is preferably between 0.25 and 10 mol %, based on the sum of respectively used bisphenols.

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The measuring process for determining the uniaxial stretching viscosity is described hereinafter.

- 20 To measure the uniaxial stretching viscosity a cylindrical plastic sample (effective dimensions: diameter substantially between 4 and 5 mm, length substantially between 20 and 25 mm) is fixed at the ends by means of clamping jaws and fixed in a stretching rheometer.

- 25 The sample is then adjusted in temperature by means of an oil bath which, at the measuring temperature of 200°C, has approximately the same density as the plastics material. After reaching the temperature constant, the deformation is predetermined via the take-off rod connected to the clamping jaws at one end of the sample. A constant Hencky elongation rate $\dot{\epsilon}$ is given hereby. This means that the take-off rate u increases exponentially with time.

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At the other end of the sample the tensile force is measured as a function of time or total elongation. The uniaxial stretching viscosity may be ascertained by referring the tensile stress ascertained to the time-dependent cross-sectional area.

- 5 In the stretching rheometer used for the measurements in the examples of the present document, the maximum take-off length is at approximately 500 mm and this corresponds to a maximum deformation of approximately $L/L_0 = 25$ or a maximum Hencky elongation of approximately $\ln(L/L_0 = 3.2)$. However, the total elongation is not always achieved in the polycarbonates investigated as the samples can tear off
10 or fail beforehand.

The evaluation of the uniaxial stretching test is as follows. The logarithm of the single stretching viscosity value and of the three-fold shear viscosity value are shown together in a graph as a function of time. It has been found that, in particular
15 the plastics materials suitable for producing containers are those in which the stretching viscosities increase greatly in comparison with the three-fold shear viscosity (see Fig. 1). The plastics materials in which the stretching viscosities do not increase greatly in comparison with the three-fold shear viscosity (see Fig. 2) are less suitable or unsuitable for producing water bottles.

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The melts of the polycarbonates which are not advantageous for producing water bottles, may to an extent not deform at high total elongations ($\epsilon > 2,5$) as the samples constrict and/or fail.

- 25 The measured results of the uniaxial stretching viscosity can depend heavily on the correct test procedure. With an incorrect test procedure, greatly increased stretching viscosities can be measured which are not real. To ascertain correct measuring values an adequate test procedure and evaluation is to be observed (cf. Th. Schweizer, Rheol. Acta 39 (2000) 5, pages 428 to 443; J. S. Schulze et al., Rheol.

Acta 40 (2001) pages 457 to 466; and V. C. Barroso, J. A. Covas, J. M. Maia Rheol. Acta 41 (2002) pages 154 to 161).

Fig. 1 and 2 will be described hereinafter.

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Fig. 1 shows the uniaxial stretching viscosity $\eta_E(t, \dot{\epsilon})$ and the three-fold shear viscosity $3\eta(t)$ for a polycarbonate which is advantageous for producing water bottles by extrusion blow moulding (produced in accordance with the example according to the invention). The three-fold shear viscosity $3\eta(t)$ is shown as a solid line. The uniaxial stretching viscosities $\eta_E(t, \dot{\epsilon})$ for three different elongation rates $\dot{\epsilon}$ of 0.1 and 0.03 and 0.01 (unit: 1 divided by seconds) are shown as lines with symbols. It can be seen that for all elongation rates the stretching viscosities increase greatly with increasing time and come to lie above the three-fold shear viscosity.

15 Fig. 2 shows the uniaxial stretching viscosity $\eta_E(t, \dot{\epsilon})$ and the three-fold shear viscosity $3\eta(t)$ for a polycarbonate which is not advantageous for producing water bottles by extrusion blow moulding (produced in accordance with the comparison example). The three-fold shear viscosity $3\eta(t)$ is shown as a solid line. The uniaxial stretching viscosities $\eta_E(t, \dot{\epsilon})$ for three different elongation rates $\dot{\epsilon}$ of 0.2 and 0.1 and 0.05 (unit: 1 divided by seconds) are shown as lines with symbols. It can be seen that for all elongation rates the stretching viscosities do not increase greatly with increasing time and come to lie in the region of the three-fold shear viscosity.

25 In Fig. 1 and 2, the time axis t for a curve with a specific Hencky elongation rate $\dot{\epsilon}$ may be converted into the Hencky elongation ϵ as:

Hencky elongation ϵ = Hencky elongation rate $\dot{\epsilon}$ multiplied by time t

applies.

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Fig. 3 shows the bottles produced in the examples. The dimensions thereof are given in millimetres (mm).

Fig. 4 shows the position of the measuring points on the bottles at which the wall
5 thickness was measured in the examples.

Fig. 5 shows the course of the wall thickness reproduced in Table 2, in a graph. The wall thickness in mm is plotted against the measuring points 1 to 46. The bottle made of polycarbonate in accordance with the example shows a regular course (square symbols).
10 The bottle made of polycarbonate in accordance with the comparison example shows an irregular course (triangular symbols).

Examples

A polycarbonate was produced with the rheological stretching properties in accordance with the example. Water bottles with a volume of 5 gallons were subsequently produced
5 from the plastic granules and the wall thickness distribution measured. The same process was carried out with a comparison product which had the rheological stretching properties in accordance with comparison example.

Water bottles with a homogeneous wall thickness distribution were obtained from the
10 polycarbonate according to the example but not from the polycarbonate according to the comparison example.

1. Producing the polycarbonates

15 Example:

5515.7 g (24.16 mol) bisphenol A and 31.10 g isatinbiscresol were dissolved in 33.40 kg 6.5% sodium hydroxide solution in a nitrogen atmosphere while stirring. A mixture of 70.6 g phenol and 36.03 kg methylene chloride was added to this solution. 2967.6 g
20 phosgene were then introduced within 30 minutes at 20 to 25°C and a pH of 13, maintained by adding further sodium hydroxide solution, while stirring intensively. After this introduction, 28.3 g N-ethylpiperidine were added and the solution stirred for 45 minutes at a pH of 13.

25 The alkali phase was separated from the organic phase. The organic phase was adjusted with diluted phosphoric acid or hydrochloric acid to a pH of 1. The phase was then washed free of electrolytes with deionised water. After exchanging the methylene chloride for chlorobenzene the polycarbonate was isolated in a known manner via a stripping extruder.

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The polycarbonate thus obtained had a relative solution viscosity, measured at a concentration of 0.5 g polycarbonate in 100 ml methylene chloride at 25°C, of 1.325.

Comparison example:

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6.91 g isatinbiscresol and 78.4 g phenol were used as in the above example. A polycarbonate with a relative solution viscosity of 1.305 was obtained. Isatinbiscresol is commercially obtainable and has the correct name 3,3-bis-(3-methyl-4-hydroxyphenyl)-2-oxo-2,3-dihydroindol.

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2. Description of the production of 5 gallon water bottles made of polycarbonate by extrusion blow moulding

The bottles were produced using an extrusion blow moulding machine KBS 2-20 from
15 SIG Blowtec with the following machine requirements. An extruder with a screw 100 mm in diameter and a length of 25 D was used, which introduced little frictional heat into the material at relatively low screw speeds. The plasticising capacity was between about 145 and 190 kg/h at a bottle weight of about 750 g net and a piece number of 130 to 144 bottles/hour. The plasticising cylinder was equipped with regulated heating zones
20 and fans guaranteeing exact and constant temperature control. The drive was provided by a thyristor-controlled d.c. unit which provided for uniform conveying of material and a constant torque. The parison die consisted of a fifo accumulator head (fifo = first in – first out) with 3.5 litre storage volume and overlapping heart-shaped grooves. The double heart-shaped grooves offset by 180° produced an inner and an outer parison and
25 convey the flow of melt into the accumulator chamber. Mandrel and die in the parison die were conical in design. The mandrel was displaced axially with respect to the conical die via a wall thickness control programme. Consequently, it was possible to optimise the weight of the bottle and adapt the wall thicknesses in the corresponding wall regions, for example in the base region.

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The extruder temperatures were 110°C in the feed zone and between 245°C and 265°C in the individual heating zones. The die head temperatures were 245°C to 250°C and the die temperature 275°C. The mass temperature ascertained was 267°C. The mean cycle time was ± 0.2 s at 25.8 s, with an ejection time of the parison of 5.3 s, corresponding to a piece number of 138 to 140 bottles per hour. A conventional vertical wall thickness profile for 5 gallon polycarbonate bottles was used to control the wall thickness. The bottles produced had a net weight of 750 g to 850 g and were immediately adjusted in temperature by means of infrared radiation. The temperature control served to rapidly relax the material and to relax the process-induced internal stress associated therewith.

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10 A Protherm 850-3 model, Serial No.: KRK 7110, infrared radiation oven from Process Dynamics Inc., USA was used. The adjustable temperatures of the seven heating zones present were selected such that a surface temperature of the bottles of $130^{\circ}\text{C} \pm 2^{\circ}\text{C}$ was ensured.

Table 1**Bottle geometry and weight of the water bottle example/comparison example:**

Example	Average wall thickness [mm]	Area [cm ²]	Volume [cm ³]	Calculated weight [g]
Neck	2.35	129.53	30.440	36.53
Shoulder	2.01	642.44	129.130	154.96
Body	1.30	2747.82	357.217	428.66
Base	2.14	547.11	117.082	140.50
Total		4066.90	633.87	760.65

5

Comparison Example	Average wall thickness [mm]	Area [cm ²]	Volume [cm ³]	Calculated weight [g]
Neck	2.75	129.53	35.588	42.71
Shoulder	2.30	642.44	147.681	177.22
Body	1.35	2747.82	369.696	443.64
Base	2.23	547.11	122.224	146.67
Total		4066.90	675.19	810.23

3. Description of the wall thickness measurement of the water bottles:

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The wall thicknesses were ascertained using an ultrasonic wall thickness measuring apparatus from Krautkrämer GmbH & Co, Hürth, Germany of the CL3 DL type. This apparatus operates by the impulse-echo principle. Measurement of the time covered by the pulse in the material starts with the entry echo produced when a portion of the ultrasonic pulse is reflected from the boundary face between advance section and the surface of the material to be measured. Depending on the thickness of the material the

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CL3 DL automatically decides on a measurement from the entry echo to the first slap-back (interface-to-first modes) or on a measurement between successive slap-back echoes (multi-echo-modes). An ultrasonic advance probe specifically for plastics materials called ALPHA DFR-P and with a nominal frequency of 22 MHz and a
 5 connecting face of 6.4 mm was used for a measuring range of 0.125 mm to 3.8 mm. The wall thickness measurements were made at 46 measuring points (see Fig. 4) directly on the bottle using an ultrasonic coupling means.

Table 2

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Wall thickness of the measuring point

Measuring point	Measuring region	Wall thickness [mm] Example	Wall thickness [mm] Comparison example
1	Neck	2.47	2.57
2	Neck	2.42	2.92
3	Shoulder	2.28	2.78
4	Shoulder	2.14	2.66
5	Shoulder	1.88	2.39
6	Shoulder	1.72	1.92
7	Body	1.53	1.63
8	Body	1.36	1.36
9	Body	1.22	1.14
10	Body	1.16	1.45
11	Body	1.14	1.08
12	Body	1.16	1.32
13	Body	1.19	1.17
14	Body	1.24	1.78
15	Body	1.3	1.86
16	Body	1.38	1.96
17	Body	1.45	1.76
18	Body	1.57	1.89
19	Base	1.72	1.78

Measuring point	Measuring region	Wall thickness [mm] Example	Wall thickness [mm] Comparison example
20	Base	1.94	2.28
21	Base	2.16	2.56
22	Base	2.33	2.73
23	Base	2.46	2.53
24	Base	2.45	2.39
25	Base	2.35	2.48
26	Base	2.19	2.29
27	Base	2.02	1.94
28	Base	1.76	1.36
29	Body	1.58	1.21
30	Body	1.45	1.09
31	Body	1.35	1.37
32	Body	1.29	1.43
33	Body	1.25	1.34
34	Body	1.19	0.94
35	Body	1.16	1.18
36	Body	1.15	0.96
37	Body	1.14	1.27
38	Body	1.22	0.94
39	Body	1.33	1.03
40	Body	1.48	1.13
41	Shoulder	1.68	1.35
42	Shoulder	1.92	2.09
43	Shoulder	2.12	2.51
44	Shoulder	2.3	2.69
45	Neck	2.45	2.86
46	Neck	2.25	2.64

Claims

1. A container containing plastics material, wherein at its thickest point the regular container wall is at most three times as thick as at its thinnest point.
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2. The container according to claim 1, wherein at its thickest point the regular container wall is at most 2.6 times as thick as at its thinnest point.
3. The container according to claim 1, wherein at its thickest point the regular
10 container wall is at most 2.2 times as thick as at its thinnest point.
4. The container according to any of claims 1 to 3, wherein the container is a bottle.
- 15 5. The container according to claim 4, wherein the container is a water bottle.
6. The container according to any of claims 1 to 5, wherein the plastics material is polycarbonate.
- 20 7. A process for producing the container according to any of claims 1 to 6 by extrusion blow moulding or by injection stretch blow moulding.