Title: PREFORM FOR OBTAINING CONTAINERS

Abstract: A preform obtained by compression moulding comprises a side wall (2) extending around an axis (Z) and a bottom wall (4) extending transversely to said axis (Z), at least a portion (13, 14) of said side wall (2) having a thickness (S1) that is less than 2 mm.
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Preform for obtaining containers

The invention relates to a compression-moulded preform, particularly for obtaining a container, for example a bottle, by stretch blow-moulding or blow-moulding with single-stage or two-stage technology.

Preforms for obtaining bottles normally comprises a side wall with a substantially cylindrical shape and a concave bottom wall that closes an end of the preform. Known preforms can be obtained by injection moulding, inside a mould comprising a punch that reproduces the internal shape of the preform and a die suitable for shaping the preform externally. The punch and the die are mutually movable between a closed position and an open position. In the closed position, between the punch and the die a forming chamber is defined in which the preform can be shaped, whilst in the open position the punch and the die are spaced apart from one another so that the preform can be extracted from the mould.

The die comprises an injecting conduit through which, in the closed position, the plastics that are intended to constitute the preform are injected into the mould. The injecting conduit leads into the forming chamber at an injection point arranged in a central region of the concave bottom wall.

In order to obtain a preform, the punch and the die first have to be arranged in the closed position. Subsequently, plastics are introduced into the mould through the injecting conduit until the forming chamber is filled completely. At this point, the injecting of plastics is stopped and the preform is cooled inside the mould arranged in a closed position. After a suitable cooling time, during which the shape of the preform stabilises, the mould can be opened and the preform that has just been formed can be removed.

If the mould is opened before the preform has cooled sufficiently, the latter may be deformed and damaged when
the punch and the die move in relation to one another to reach the open position. 
Further, if the preform is extracted from the mould before having cooled sufficiently, it may be damaged during possible subsequent steps of conveying, handling and storing. 
The cooling time of the preform is relevant with respect to the production time of the preform. It is therefore desirable to reduce cooling time. 
In the bottling industry, the need is increasingly felt to reduce the quantity of plastics used for forming a container, for example a bottle having a preset capacity. For this purpose, it has been devised to reduce the thickness of the walls of the preform, in particular of the side wall, which entails a consequent reduction in the thickness of the walls of the container, i.e. less consumption of plastics. 
Nevertheless, in preforms obtained by injection moulding there is a lower limit below which the thickness of the walls cannot fall. In order to reduce the thickness of the walls, it is necessary to reduce the distance between the punch and the die in the closed position. By so doing, the plastics that, during injection, fill the forming chamber after being fed into the injection point have to pass through passage zones that are very narrow that are defined between the punch and the die. 
Whilst the plastics pass through these passage zones they are subject to very high shear stress, due to which the molecules of the plastics tend to become orientated parallel to one another. Undesired crystalline zones may thus form that have the appearance of clearly distinguishable opaque zones in the normally transparent preform. This phenomenon is commonly denoted by the expression "stress whitening". 
Further, the crystalline zones may cause several drawbacks and in particular be zones of initial breakage during the
subsequent forming of the bottle by stretch blow-moulding or blow-moulding.

Further, during injection, the plastics, in particular if they have a high intrinsic viscosity value, are highly stressed mechanically and may release undesired substances, for example acetaldehyde. Acetaldehyde is a gaseous substance having a characteristic odour, which may contaminate the product with which the bottle is filled.

When the thickness of the walls of the preforms decreases, the pressure increases that is necessary for filling the forming chamber and consequently the power, dimensions and cost of the injection moulding machines and the energy necessary for producing the preforms increase.

For the reasons set out above, the thickness of the side wall of the preforms that have been injection-moulded and are intended to form containers cannot be less than 2 millimetres.

An object of the invention is to improve existing preforms and the containers obtained therefrom.

Another object is to decrease the cooling time during which it is necessary to wait before opening the mould in order not to damage the preform.

A further object is to decrease the quantity of plastics necessary for manufacturing a container having a preset capacity.

According to the invention, there is provided a preform obtained by compression moulding, comprising a side wall extending around an axis and a bottom wall extending transversely to said axis, characterised in that at least a portion of said side wall has a thickness that is less than 2 mm.

Owing to the invention, it is possible to form containers that, for the same capacity, enable material to be saved compared with containers obtained from injection-moulded preforms. In fact, the preforms according to the invention have a side wall that is much thinner than known preforms.
obtained by injection moulding. In particular, the side wall of the preforms according to the invention may have a thickness of about 1 mm, which is a value that is not obtainable in injection-moulded preforms.

This occurs because the compression moulding provides methods of introducing plastics into the mould that are intended to constitute the preform, the methods being different from those provided in injection moulding. Further, by reducing the thickness of the side wall, it is possible to reduce significantly the cooling time that has to elapse before extracting the preforms from the mould without damaging the preforms.

The invention can be better understood and implemented with reference to the attached drawings, which illustrate some embodiments thereof by way of non-limiting example, in which:

Figure 1 is a section taken along a longitudinal plane of a preform according to the prior art;
Figure 2 is a section taken along a longitudinal plane of a preform for bottles according to an embodiment of the invention;
Figure 3 is a schematic section of a mould for obtaining the preform in Figure 2, in an open position;
Figure 4 is a section like the one in Figure 3, showing the mould in an intermediate position;
Figure 5 is a section like the one in Figure 3, showing the mould in a closed position;
Figures 6 to 8 are sections like the one in Figure 2, showing alternative embodiments of the preform;
Figure 9 is a table showing the variation in cooling time in relation to the decrease in the thickness of a preform according to the invention;
Figure 10 is a graph showing how the stress varies in function of deformation by various plastics;
Figure 11 is a graph like the one in Figure 10, referring to two different types of PET.
Figure 1 shows a preform 101 according to the prior art, comprising a side wall 102, with a substantially cylindrical shape, that extends around a longitudinal axis Z1. The preform 101 is provided, at one end thereof, with a mouth 103 also called a "finish", that is suitable for engaging with a cap of a container, which is not shown. At a further end of the preform 101 opposite the mouth 103 there is provided a bottom wall 104 that extends transversely to the longitudinal axis Z1 and is concave towards the inside of the preform 101.

The side wall 102 has a thickness S1 of 3.1 mm, whilst the bottom wall 104 has a slightly lower thickness that is variable between 2 mm and 2.8 mm.

The preforms 101 obtained by injection moulding are easily recognisable because on the external surface of the bottom wall 104 a riser 112 is visible.

The riser 112 indicates an injection point through which, during injection moulding, a closed forming chamber, defined by a punch and by a die, was filled with plastics.

Figure 2 shows a preform 1 according to the invention, usable for obtaining a container such as, for example, a bottle by means of a subsequent stretch blow-moulding or blow-moulding process with two-stage and single-stage technology.

In the stretch blow-moulding process, a stretching element is arranged inside a preform, that has a suitable temperature, and stretches the preform along a longitudinal direction. Subsequently, or simultaneously, air is blown inside the preform, so that the latter can be enlarged radially until it takes on the shape of a mould inside which it is enclosed.

The blow-moulding process obtains the container from the preform only through the action of the air blown inside the preform and having a suitable temperature.

The two-stage technology lets a moulded preform cool down to ambient temperature, and subsequently subjects the moulded
preform to heating and stretch blow-moulding or blow-moulding to obtain a container therefrom. In two-stage technology, moulding of the preform and stretch blow-moulding or blow-moulding of the container are performed by two different machines. Between moulding of the preform and stretch blow-moulding or blow-moulding of the container even several days may elapse. Further, stretch blow-moulding or blow-moulding of the container can be performed by a person other than the one who has moulded the preform, for example if the preforms are sold to a manufacturer of containers.

On the other hand, in one-stage technology only a few seconds elapse between moulding of the preform and blow-moulding or stretch blow-moulding thereof. Immediately after being compression-moulded, in fact, the preform is blow-moulded or stretch blow-moulded in the same machine to obtain the container, without being cooled to ambient temperature.

The preform 1 is made of plastics, for example polyethylene terephthalate (PET), polypropylene (PP), polyvinyl chloride (PVC), high-density polyethylene (HDPE) or polyethylene naphthalate (PEN).

The preform 1 comprises a side wall 2 that extends around a longitudinal axis Z. The side wall 2 may comprise a substantially cylindrical portion 13 and a slightly frustum conical portion 14 arranged in sequence along the longitudinal axis Z. Near the slightly frustum conical portion 14, the preform 1 is provided with a mouth 3 comprising a threaded portion 15, an annular projection 16 and a collar 17. The mouth 3 is also called "finish" and does not undergo substantial variations during the stretch blow-moulding or blow-moulding process by means of which the container is obtained from the preform 1. The mouth 3 is suitable for engaging, at the threaded portion 15, a cap that closes the container.

An end of the preform 3 opposite the mouth 3 comprises a bottom wall 4 that extends transversely to the longitudinal
axis Z. The bottom wall 4 has the shape of a dome, i.e. it is concave with the concavity facing inside the preform 1. The bottom wall 4 can also be substantially flat, or concave with concavity facing the outside of the preform 1, or may have other non regular shapes.

The bottom wall 4 may have a constant thickness, or a thickness that decreases gradually or in an irregular manner as the longitudinal axis Z is approached from the side wall 2.

The side wall 2 has, in a region thereof comprised between the mouth 3 and the bottom wall 4, a thickness S1 that is less than 2 mm, in this case equal to approximately 1.9 mm. In particular, the thickness S1 is measured at the substantially cylindrical portion 13. The latter has an approximately constant thickness. Also the substantially frustum conical portion 14 may have a thickness that is less than 2 mm, which may be constant.

The thickness of the bottom wall 4 varies gradually from the value S1 to a further value S2 reached in a central region 5 arranged near the longitudinal axis Z. Also the further thickness value S2 is less than 2 mm and in this particular case is approximately 1.5 mm.

The side wall 2 and possibly the bottom wall 4 can have such small thicknesses because the preform 1 is not obtained by injection moulding but by compression moulding. This can easily be recognised because the bottom wall 4 is bounded by a substantially smooth external surface 18, also near the longitudinal axis Z.

In other words, the bottom wall 4 does not have the riser that can be seen in the injection-moulded preforms in the region into which the injecting conduit leads.

Figures 3 to 5 show a mould 6 that can be used for forming the preform 1 in Figure 2. The mould 6 comprises a die 7 provided with a cavity 19 in which the side wall 2 and the bottom wall 4 can be externally shaped. The mould 6 further comprises a punch 8 for internally shaping the preform 1 and
a pair of movable elements 20 for externally shaping the mouth 3. A sleeve 21 interacts with the movable elements 20 to maintain the movable elements 20 alongside one another. As shown in Figure 3, the mould 6 is initially in an open position, in which the die 7 is spaced away from the punch 8, so that it is possible to deposit in the cavity 19 a dose 22 of melted plastics, by means of a transferring device that is not shown. Subsequently, the die 7 is moved towards the punch 8 and reaches an intermediate position, shown in Figure 4, in which the die 7 abuts on the movable elements 20. In this configuration, the punch 8 has already started to interact with the plastics constituting the dose 22. The die 7 continues to move to the punch 8 together with the movable elements 20 until a closed position, shown in Figure 5, is reached in which between the die 7 and the punch 8 there is defined a forming chamber 9 having a shape corresponding to the preform 1. The mould 6 remains in the closed position for the cooling time that is necessary for sufficiently cooling the preform 1.

In order to ensure that the preform 1 cools rapidly, cooling devices are generally provided for cooling the punch 8 and the die 7 that are not shown in the Figures. Subsequently, the mould 6 is opened so that the preform 1 that has just been formed can be extracted and it is possible to start a new moulding cycle.

In injection moulding all the plastics constituting the preform, after leading the extruder, have to follow a long and tortuous path before entering the forming chamber through an injection point arranged in a zone of the forming chamber in which the bottom wall is formed. The plastics intended for forming the side wall and the mouth further have to flow through a further zone of the forming chamber, defined between a side surface of the punch and a corresponding side surface of the die and extending substantially along the longitudinal axis.
The narrower the aforesaid zones, the greater the stress, for example shear stress, to which the plastics are subjected. On the other hand, during compression moulding, the plastics that constitute the dose 22 are subject to stress that is significantly less than that which occurs in injection moulding.

This is because, in compression moulding, the dose 22 is inserted into the mould 6 arranged in the open position and is shaped so as to obtain the preform 1 whilst the mould 6 reaches the closed position. Plastics can thus reach the portions of the forming chamber 9 that are further from the region in which the dose 22 was deposited, passing through passage zones that are wider than the final thickness of the preform. On the other hand, as in injection moulding plastics are injected into the forming chamber when the mould is already shut, they always flow through passage zones having the final thickness of the preform.

Further, in order to fill the forming chamber in compression moulding, the plastics flow along shorter paths than occurs in injection moulding.

For these reasons, in compression moulding plastics are not subject to particularly great stress.

This is reflected in the dimensions and power of the machines for compression moulding. In fact, by stressing the plastics less intensely during forming of the preform, the pressure is limited that it is necessary to apply to the plastics to fill the forming chamber entirely. This enables machines to be used that are less powerful and costly than the machines used for injection moulding and enables significant savings both in plant costs and energy costs of such machines to be obtained.

Owing to the reduced stress applied during compression moulding, it is possible to increase the diameter of the punch 8 and/or to decrease the diameter of the cavity 19 to
reduce the thickness of the side wall 2 without causing serious defects on the preform 1.

Further, in the closed position the punch 8 can be positioned at a distance from the die 7 that is less than 2 mm without causing significant defects on the preform 1.

This enables the side wall 2 to be thinned at will, and possibly the bottom wall 4 of the preform 1, as compatible with the resistance limits of the container obtained by the aforesaid preform.

In this way, it is possible to reduce the quantity of plastics that is necessary to manufacture the preform 1, and thus to manufacture the container obtained therefrom, with the same container capacity. For example, whilst the preforms 101 according to the prior art shown in Figure 1 weighed 23 grams, the preform 1 according to the invention weighs 18 grams.

By using compression moulding it is possible to obtain preforms 201, 301, shown respectively in Figures 6 and 7, having a shape that is substantially similar to the preform 1 of Figure 2, but provided with thicknesses that are even more reduced.

In particular, Figure 6 shows a preform 201 having a thickness S1 of the side wall 2 equal to approximately 1.5 mm and a thickness S2 of the bottom wall 4 equal to approximately 1 mm. This preform weighs 16 grams.

Figure 7 shows a preform 301 having a thickness S1 of the side wall 2 equal to approximately 1 mm and a thickness S2 of the bottom wall 4 equal to approximately 0.5 mm. The preform 301 weighs 13 grams. The preform 301 enables a significant quantity of plastics to be saved and is particularly suitable for forming bottles intended for being filled with liquids such as still water, milk or fruit juice that, being substantially devoid of dissolved gases, do not generate great pressure inside the bottle.

Owing to the reduced thickness, for containers produced with the same capacity, the preforms 1, 201 and 301 can be cooled
more quickly than the preform 101 according to the prior art. As will be explained in detail below, cooling time depends in a non-linear manner on the thickness of the walls of the preform. By shortening cooling time, it is possible to decrease the duration of the forming cycle of the preforms and thus increase productivity.

Figure 8 shows a preform 401 according to an alternative embodiment. The preform 401 has the same weight as the preform 1 shown in Figure 2 and can be stretch blow-moulded or blow-moulded so as to produce a container having dimensional features that are substantially similar to those of the container obtained by the preform 1. Nevertheless, the preform 401 has a maximum dimension H along the longitudinal axis Z that is greater than the corresponding maximum dimension of the preform 1. In fact, the preform 401 has a maximum dimension H equal to approximately 110 mm, whilst the preform 1 has a corresponding maximum dimension equal to approximately 100 mm.

Whilst the mouth 3 of the preform 401 has substantially the same dimensions as the mouth 3 of the preform 1, the preform 401 has a thickness S1 of the side wall 2 equal to approximately 1.5 mm and a thickness S2 of the bottom wall 4 equal to approximately 1 mm, i.e. it has thicknesses that are less than the corresponding thicknesses of the preform 1.

As a result, the preform 401 has a cooling time that is less than the preform 1, although being usable to form a container that is completely similar to the one that is obtainable from the preform 1.

It should be noted that, by decreasing the thickness of the walls of the preform even by a few tenths of a millimetre, it is possible to obtain a significant reduction in cooling time.

Figure 9 is a table showing the decrease, in percentage terms, of cooling time in relation to the decrease in the thickness of the walls. In particular, it should be noted
that if the thickness of the side wall decreases by a third, from 3 mm to 2 mm, cooling time decreases by at least 55%, from 4 seconds to no more than 1.8 seconds. If, on the other hand, the thickness of the side wall is reduced by half, from 3 mm to 1.5 mm, cooling time decreases by at least 75%, i.e. from 4 seconds to no more than 1 second. This proves that cooling time decreases in percentage terms more rapidly than the thickness.

Although the obtained container has same geometry of, the preform 401 shown in Figure 8 is stretched less than the preform 1 shown in Figure 2. This can be quantified by the stretch ratio, which defines the amount of the deformation undergone by the plastics when the latter is stretched. If the preforms are made of polyethylene terephthalate (PET) it is possible, in order to increase the mechanical performance of the produced container, to use a typical PET phenomenon commonly known as "strain hardening". In fact, if the PET is deformed beyond the so-called natural stretch ratio (NSR) the polymer chains thereof form particular transparent crystalline structures that considerably increase the mechanical performance of the plastics, also by 500%.

Other plastics, such as polypropylene (PP) or polyvinyl chloride (PVC), do not enjoy the same properties.

Figure 10 is a graph showing qualitatively how the stress varies in function of the deformation of PET, PP and PVC. It can be noted how once PET has been deformed beyond a value corresponding to the natural stretch ratio, the mechanical features of PET increase, i.e. it is able to withstand greater stress. On the other hand, PP and PVC, as they are deformed, are able to tolerate, after a maximum peak, less and less stress. Usually, the preforms in PET are stretched so that the PET is deformed beyond the natural stretch ratio, so that the mechanical performance of the finished container increases significantly.
If, in order to decrease cooling time, preforms are used having a maximum dimension H that is relatively great with respect to the corresponding dimension of the finished container, like the preform 401, the stretch ratio may decrease considerably and during stretch blow-moulding the PET may not be deformed beyond the natural stretch ratio. In this case, in the stretch blow-moulded container an increase in mechanical performance does not occur. In order to overcome this drawback it is possible to use a type of PET having a relatively high intrinsic viscosity. In fact, when the intrinsic viscosity of the PET increases, the natural stretch ratio decreases and the consequent increase in mechanical performance occurs with lower deformation values.

Figure 11 is a graph showing how stress varies in function of deformation for two types of PET having a different intrinsic viscosity (IV). It can be noted how the value of the natural stretch ratio of the PET having greater intrinsic viscosity is less than the corresponding value for PET having a lower intrinsic viscosity.

Usually, the preforms produced by injection moulding are made by using PET that has intrinsic viscosity comprised between 0.71 and 0.8. Using types of PET having greater intrinsic viscosity is not advisable in injection moulding, inasmuch as if intrinsic viscosity increases greater stress is generated from which phenomena of "stress whitening" and the formation of acetaldehyde arise.

Compression moulding, which stresses the plastics less intensely, enables preforms to be made with PET that have intrinsic viscosity that is greater than 0.8. It is for example possible to use PET having intrinsic viscosity of 0.84 or even of 0.87. More in general, intrinsic viscosity can be comprised between 0.84 and 1.1. In this way the natural stretch ratio of the PET decreases, which enables the benefit of "Strain Hardening" to be obtained also starting with preforms that are relatively
long or wide compared with the desired container. By so doing, cooling time can be significantly reduced without compromising the performance of the finished container. It should be noted that it is possible to benefit from “Strain Hardening” during stretch blow-moulding or blow-moulding of relatively long or wide preforms also by intervening on the process parameters, for example by decreasing the temperature at which the preforms are deformed to obtain the corresponding containers therefrom. In fact, the natural stretch ratio of plastics decreases as the temperature decreases at which the plastics are processed. Decreasing the temperature at which the preforms are stretch blow-moulded or blow-moulded also enables the natural stretch ratio to be exceeded even when relatively low stretch ratios are used.

In compression moulding, the types of PET having relatively high intrinsic viscosity, i.e. greater than 0.8, can also be used to produce preforms of the type shown in Figures 2, 6 and 7, the maximum dimension H of which is not modified with respect to the prior art, but the side walls of which are thinner than the known preforms. In this way the mechanical performance of the corresponding container improves, making the corresponding container particularly strong or suitable for containing liquids having dissolved gases, such as gaseous drinks, inside which great pressure is generated.

Lastly, it should be noted that the preforms according to the invention may also have side walls with a different shape from the represented shapes, for example they may have cylindrical side walls (i.e. devoid of the slightly frustum conical portion 14) or prismatic side walls, i.e. provided with a cross section with a polygonal shape with three or more sides.
CLAIMS

1. Preform obtained by compression moulding, comprising a side wall (2) extending around an axis (Z) and a bottom wall (4) extending transversely to said axis (Z), characterised in that at least a portion (13, 14) of said side wall (2) has a thickness (S1) that is less than 2 mm.

2. Preform according to claim 1, wherein said at least a portion (13, 14) has a thickness (S1) comprised between 1 mm and 2 mm.

3. Preform according to claim 1, wherein said at least a portion (13, 14) has a thickness (S1) that is less than, or equal to, 1 mm.

4. Preform according to any preceding claim, wherein said at least a portion (13, 14) has a substantially constant thickness (S1).

5. Preform according to any preceding claim, wherein said at least a portion (13, 14) defines a significant part of said side wall (2) along said axis (Z).

6. Preform according to any preceding claim, wherein said at least a portion (13, 14) extends from said bottom wall (4) to a "finish" (3) of said preform (201; 301; 401).

7. Preform according to claim 6, wherein said "finish" (3) is provided with removable fixing means that is suitable for engaging a cap for closing a container obtainable from said preform (201; 301; 401).

8. Preform according to any preceding claim, wherein said side wall (2) has a substantially cylindrical hollow shape.

9. Preform according to any one of claims 1 to 7, wherein said side wall (2) has a substantially prismatic hollow shape.

10. Preform according to any preceding claim, wherein said bottom wall (4) has a thickness (S2) that is less than 2 mm.
11. Preform according to any preceding claim, wherein said bottom wall (4) becomes progressively thinner from said side wall (2) to said axis (Z).

12. Preform according to any one of claims 1 to 10, wherein said bottom wall (4) comprises a central region (5) having a substantially constant thickness.

13. Preform according to any preceding claim, wherein said bottom wall (4) is bounded by a substantially smooth external surface (18).

14. Preform according to any preceding claim, wherein said bottom wall (4) has a concave shape with a concavity facing inside said side wall (2).

15. Preform according to any one of claims 1 to 13, wherein said bottom wall (4) has a convex shape with a convexity facing inside said side wall (2).

16. Preform according to any one of claims 1 to 13, wherein said bottom wall (4) has a substantially flat shape.

17. Preform according to any preceding claim, and made of polyethylene terephthalate (PET) having an intrinsic viscosity that is greater than 0.71.

18. Preform according to claim 17, wherein said intrinsic viscosity is greater than, or equal to, 0.80.

19. Preform according to claim 18, wherein said intrinsic viscosity is variable between 0.84 and 1.1.

20. Preform according to any preceding claim, usable for forming a container by means of stretch blow-moulding.

21. Preform according to any one of claims 1 to 19, usable for forming a container by means of blow-moulding.

22. Preform according to any preceding claim, at ambient temperature.
Fig. 10

Fig. 11