

CLAIMS:

1. A method of forming an article, the method comprising:
 - (a) providing a mould having a first mould part and a second mould part, the first and second mould parts having respective first and second cavity-forming surfaces;
 - (b) closing the mould thereby defining a cavity between the first and second cavity-forming surfaces;
 - (c) injecting a molten plastic composition comprising a polymer and a physical blowing agent into the cavity, wherein the physical blowing agent is a gas dissolved in the polymer, the molten plastic composition being injected at an injection pressure, wherein during or after the injecting step (c), the injected plastic composition in contact with the first and second cavity-forming surfaces is cooled to form first and second solid skins respectively adjacent to and in contact with the first and second cavity-forming surfaces, whereby in at least one region of the cavity is respectively located at least one portion of the plastic composition in which portion at least some of the plastic composition between the first and second solid skins remains molten, wherein the thickness of the respective portion is constant within a tolerance of $\pm 0.5\%$ based on a nominal thickness of the respective portion;
 - (d) opening the mould before the molten plastic composition between the first and second solid skins has solidified in the at least one portion, so as to expose the molten plastic composition of the respective portion to an external pressure lower than the injection pressure thereby allowing the molten plastic composition between the first and second solid skins of the respective portion to expand by foaming to form an expanded cellular foam as a result of the molten plastic composition beneath the first solid skin expanding outwardly away from the second solid skin which stretches the first solid skin in the respective portion, wherein the opening step comprises removing the first mould part so that the first solid skin is no longer in contact with the first cavity-forming surface; and
 - (e) cooling the expanded cellular foam to cause the molten plastic composition between the first and second solid skins of the respective portion to solidify and to form in the article at least one first wall part comprising a core layer of cellular foam between the first and second solid skins,
wherein after the cooling step (e) the length of the first solid skin in the respective portion has stretched, as compared to the first solid skin present prior to the opening step (d), by a stretch ratio of from 0.5 to up to 3%, wherein the stretch ratio is the ratio of the increase

in the length of the first solid skin after cooling step (e) based on length of the first solid skin before the opening step (d).

2. The method of claim 1, wherein the thickness of the respective portion is constant within a tolerance of $\pm 0.2\%$ based on a nominal thickness of the respective portion.

3. The method of claim 2, wherein after the cooling step (e) the length of the first solid skin in the respective portion has stretched, as compared to the first solid skin present prior to the opening step (d), by a stretch ratio of from 2 to 3%, optionally from 2.25 to 2.75%, further optionally from 2.4 to 2.6%, yet further optionally about 2.5%.

4. The method of any one of claims 1 to 3, wherein prior to the opening step (d), the at least one portion has a thickness of from greater than 0.5 mm to up to 1 mm.

5. The method of any one of claims 1 to 4, wherein after the cooling step (e), the at least one wall part has a thickness of from 1 to 2 mm.

6. The method of any one of claims 1 to 5, wherein from the opening step (d) to the cooling step (e), the at least one first portion has increased in thickness by from 1 to 1.5 mm to form the at least one wall part.

7. The method of any one of claims 1 to 6, wherein the article is a hollow container and the first and second parts have respective first and second annular cavity-forming surfaces and in step (b) the cavity is an annular cavity between the first and second annular cavity-forming surfaces.

8. The method of claim 7, wherein the first and second mould parts are, respectively, outer and inner mould parts forming outer and inner surfaces of the hollow container.

9. The method of claim 7 or claim 8, wherein the hollow container has an annular sidewall, and the wall part is comprised in the annular sidewall and is both continuous and annular.

10. The method of claim 9, wherein prior to the opening step (d), in the at least one portion the first and second solid skins are curved and parallel.
11. The method of claim 10, wherein after the cooling step (e), in the at least one wall part the first and second solid skins are curved and parallel.
12. The method of claim 7 or claim 8, wherein the article is a hollow container having an annular sidewall and an integral base, wherein at least one region of at least one, or both, of the annular sidewall and the base is respectively comprised by the at least one wall part.
13. The method of claim 12, wherein a regular array of a plurality of the wall parts is comprised in at least one, or both, of the annular sidewall and the integral base, each of the wall parts being spaced from one or more adjacent wall parts by an area of the plastic composition comprising a core layer of expanded cellular foam having a lower expansion than the wall parts or by an area of the plastic composition which is unexpanded.
14. The method of claim 12 or claim 13, wherein prior to the opening step (d), in the at least one portion the first and second solid skins are planar and parallel.
15. The method of claim 14, wherein after the cooling step (e), in the at least one wall part the first solid skin is curved and the second solid skin is planar.
16. The method of claim 13, wherein prior to the opening step (d), the at least one portion comprises a regular array of a plurality of the portions, each of the portions comprising a central layer of the molten plastic composition between the opposed first and second solid skins consisting of a three-dimensionally shaped part of the first solid skin defining an outwardly extending convex surface formed by the first cavity-forming surface and a substantially smooth part of the second solid skin formed by the second cavity-forming surface.
17. The method of claim 16, wherein prior to the opening step (d), each portion of the regular array of the plurality of the portions comprises a central convex peak.

18. The method of claim 16 or claim 17, wherein prior to the opening step (d), the outwardly extending convex surfaces of the portions are spaced from the adjacent outwardly extending convex surfaces of the portions by an area of the plastic composition which is a solid layer of the plastic composition extending between, and contacting, the first and second cavity-forming surfaces.

19. The method of any one of claims 16 to 18, wherein during the opening step (d), each portion of the regular array of the plurality of the portions expands to stretch the first solid skin whereby after the cooling step (e) there is formed a regular array of a plurality of the wall parts, each wall part being formed from a respective portion.

20. The method of claim 19, wherein the regular array of the plurality of the wall parts comprises an array of substantially pyramidal, conical or part-spherical convex wall parts, each of the convex wall parts comprising a core layer of expanded cellular foam between opposed skin layers consisting of a three-dimensionally shaped first solid skin part defining the convex surface of the convex wall part and a substantially smooth second solid skin part.

21. The method of claim 20, wherein the convex wall parts are spaced from the adjacent convex wall parts by an area of the plastic composition which is unexpanded.

22. The method of any one of claims 12 to 21, wherein the annular sidewall has an upper annular end remote from the base and a lower annular end adjacent to the base, the upper end has a larger circumference than the lower end, and the sidewall is curved in a longitudinal cross-section, wherein the stretch ratio is higher at the upper annular end than at the lower annular end.

23. The method of any one of claims 1 to 22, wherein after injecting step (c) and before opening step (d), the plastic composition forms a moulded intermediate article within the cavity, and in an initial phase of the opening step (d) the removal of the first mould part so that the first solid skin is no longer in contact with the first cavity-forming surface exposes a first end part of the intermediate article whereas an opposite second end part of the intermediate article remains in contact with the first and second cavity-forming surfaces.

24. The method of claim 23, wherein after the start of the initial phase the first solid skin at the first end part of the intermediate article is exposed for a greater time period than the first solid skin at the second end part of the intermediate article whereby after the cooling step (e) the length of the first solid skin at the first end part of the final expanded and moulded article has stretched by a greater stretch ratio than the length of the first solid skin at the second end part of the final expanded and moulded article.

25. The method of claim 24, wherein the first end part of the intermediate article has a smaller wall thickness than the second end part of the intermediate article to at least partly compensate for the greater stretch ratio for the length of the first solid skin at the first end part of the intermediate article as compared to the second end part of the intermediate article.

26. The method of claim 25, wherein the wall thickness of the first end part of the intermediate article is from 5 to 15% smaller than the wall thickness of the second end part of the intermediate article.

27. The method of claim 25 or claim 26, wherein the first and second end parts of the intermediate article form respective first and second wall portions of the final expanded and moulded article and wherein the first and second wall portions have the same thickness within a tolerance of $\pm 0.5\%$ based on a nominal thickness of the respective wall portions.

28. The method of any one of claims 25 to 27, wherein the wall thickness of the intermediate article progressively tapers in increasing thickness in a direction from the first end part of the intermediate article to the second end part of the intermediate article.

29. The method of any one of claims 1 to 28, wherein the polymer is polypropylene.

30. The method of any one of claims 1 to 29, wherein the blowing agent is carbon dioxide.

31. The method of any one of claims 1 to 30, wherein during the injecting step (c) the injection pressure is at least 150 bar.

32. The method of any one of claims 1 to 31, wherein at the end of the injecting step (c) a packing pressure of at least 150 bar is applied to the plastic composition in the cavity.
33. The method of any one of claims 1 to 32, wherein during the opening step (d) the first solid skin is exposed to the atmosphere and the external pressure is atmospheric pressure.
34. The method of any one of claims 1 to 33, wherein the first and second mould parts are, respectively, outer and inner mould parts forming outer and inner surfaces of the article, and further comprising the step, before injecting step (b), of providing an in-mould label at least partly surrounding the cavity, the in-mould label being located adjacent to the first cavity-forming surface, and wherein after the opening step (d) the in-mould label restricts stretching of the first solid skin formed adjacent thereto.
35. The method of claim 34, wherein the in-mould label is annular and entirely surrounds the cavity.
36. The method of claim 35, wherein the in-mould label is composed of a length of a polymer layer which has opposed ends which are joined together at a seam to form an annular shape.
37. The method of any one of claims 1 to 36, further comprising the step, between opening step (d) and cooling step (e), of disposing the moulded article into a second mould having a third mould part, the third mould part having a moulding surface, wherein the first solid skin is in contact with the moulding surface, and wherein after the opening step (d) the moulding surface restricts stretching of the first solid skin in contact therewith.
38. The method of claim 37, wherein during the disposing step the moulding surface compresses the at least one wall part to reduce the thickness of the core layer of cellular foam between the first and second solid skins and shrink the length of the first solid skin in the at least one wall part.

39. The method of claim 37 or claim 38, wherein the third mould part is hollow and the moulding surface defines a hollow cavity with a tapered surface, and during the disposing step the moulding surface is progressively urged against the first solid skin.
40. The method of any one of claims 37 to 39, wherein the third mould part is at a lower temperature than the first mould part so that the first solid skin is cooled upon contact with the third mould part.
41. The method of any one of claims 1 to 40, wherein the first mould part is at a lower temperature than the second mould part.
42. The method of any one of claims 1 to 41, further comprising the step, prior to solidification of the foamed molten plastic composition between the first and second solid skins in the cooling step (e), of pressing an embossing tool against the first solid skin to impress an inwardly oriented image into the first solid skin by stretching the first solid skin inwardly against the expanded cellular foam.
43. The method of any one of claims 1 to 42, wherein the article is a cup, mug, bottle, basin, bowl, tray, container or vessel for containing a liquid or a food.