

An Apparatus and a Method of Producing Pulp-Moulded Products

This invention relates to an apparatus and a method of producing pulp-moulded products, and, in particular, such an apparatus and a method for carrying out an improved
5 forming/formation stage in the pulp-moulding process.

Pulp is nowadays used for the production of many products, for example food containers, liquid vessels, or packaging materials, mainly for its decomposable characteristic. There are two main methods of producing such products, namely the dry
10 method and the wet method. In the dry method, the containers are manufactured by folding and joining various adjacent flaps from a piece of flat dry board paper. Such a method is both cumbersome and expensive. The resultant product is also not leak-proof. As to the wet method, wet pulp is shaped to the contour of the final product, and is subsequently dried to form the final product. The resultant product is thus formed
15 integrally with a generally uniform thickness.

A conventional wet method may typically be divided into six main steps, namely shredding, fine carving, dosing, forming, cold pressing and hot pressing. In the shredding stage, water and pieces of virgin paper, which may be made from such plant fibre as
20 wood fibre, bamboo, or cane, are fed into a mixer, which breaks up the paper. In the fine carving stage, the fibre broken up in the shredding stage is fed into a processor for further mixing the fibre with the water, and allowing the plant fibre to orient freely in a dilute slurry. The content is then fed, in the dosing stage, to a second mixer in which additives, e.g. water sealants, oil sealants, etc., are added, so as to modify the characteristics of the
25 plant fibre, and thus the product so manufactured. In the forming stage, also called formation stage, the plant fibre and additive slurry is introduced into a chamber, and supported by a lower mould with a formed mesh on top of it. Water is drawn out from the wet plant fibre by vacuum applied from below the mesh. The material, which at this stage will be similar to the structure of wet tissue papers, will then, in the subsequent cold
30 pressing stage, be pressed between the lower mould and an upper mould to further press out some of the remaining water. After this stage, the material will be formed into the

shape and configuration of the final product. The cold-pressed product will then be positioned between a pair of hot moulds for hot pressing. The product will be heated by the hot moulds to around 150°C to 180°C for about 45 to 60 seconds, to completely dry up the product.

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It is found in practice that irrespective of the type of machine used for producing pulp-moulded products, i.e. be it a continuous type or a batch process machine, the production throughput depends very much on the time spent in the formation stage. Depending on the contour of the products, the formation stage in a batch process machine may take from 20 to 80 seconds. In a continuous type, although the formation stage is faster than in a batch process type, the formation stage is still the step which takes the longest time than any of the rest of the stages in the machine. For a typical 600 ml food container produced in a batch system, the formation stage will usually take around 45 seconds.

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During the formation stage, and as shown in Fig. 1, diluted fibre slurry in the form of a suspension is poured into a container with a mesh or porous material at its bottom. Air is then introduced into the container for stirring up the slurry. The slurry is then allowed to be settled. Upon the application of a vacuum suction force from below the mesh, water will be drawn out of the slurry *via* the mesh, and initial layers of fibre will settle and deposit on the mesh, creating a wet layer of fibre mat. This fibre mat, after the formation process, will be subsequently cold-pressed to form the initial pulp shape before final hot press.

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The use of vacuum suffers from the following shortcomings:

- (i) The maximum difference in pressure that can be created for sucking water out of the slurry via the mesh is limited to negative 1 bar (i.e. 1 kg/cm²).
- (ii) A suction pump and a vacuum tank are mostly required.
- (iii) The vacuum tank has to be replenished within the vacuum tank at a regular interval because of the intake of water in order to maintain the suction performance. Such requires either a down time period within which (a) the

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vacuum is stopped, (b) the water is drained out of the tank, and (c) the vacuum is re-applied. Alternatively, a further pump is installed for continuously drawing out water from the tank. For the former method, the system will be idle during the down time, thus affecting the throughput. For the latter method, the complexity and cost of the system will be increased

- (iv) As the fibre precipitates on top of the mesh, a vacuum decay, as shown in Fig 2, will develop in which the suction force drops over time, thus lengthening the time required for the formation process. It is also noteworthy that with repeated use of the mesh in the formation process some of the pores of the mesh may be clogged up with fibre. Thus the performance of the vacuum will also deteriorate over time, as the pores in the mesh may be so clogged up that very little water can pass through.
- v) In view of the problem discussed in (iv) above, the mesh will require regular preventive maintenance and servicing to keep up the quality of the products and productivity of the machine.

It is thus an object of the present invention to provide an apparatus and a method of producing pulp-moulded products in which the aforesaid shortcomings are mitigated, or at least to provide a useful alternative to the public.

According to a first aspect of the present invention, there is provided a method of forming a pulp-moulded article, including the steps of (a) providing a container with at least one liquid permeable end; (b) introducing a slurry containing a fibre and a liquid into said container; and (c) applying a positive gauge pressure on said slurry to force at least part of said liquid in said slurry out of said chamber via said liquid permeable end, and thereby to form layers of said fibre on said liquid permeable end.

According to a second aspect of the present invention, there is provided an apparatus for forming pulp-moulded products, including a container for containing a slurry containing a fibre and a liquid, said container having at least one liquid permeable end, and means for applying a positive gauge pressure on said slurry in said container to

force at least part of said liquid in said slurry out of said chamber *via* said liquid permeable end, and thereby to form layers of said fibre an said liquid permeable end.

Embodiments of the present invention will now be described by way of examples
 5 only, by reference to the accompanying drawings, in which:

Fig. 1 shows steps in a conventional formation process for the production of pulp-moulded products;

Fig. 2 shows the variation (decay) of the vacuum force of a vacuum tank, during a cycle
 10 of a conventional formation process;

Fig. 3 shows a schematic sectional view of an apparatus according to a first embodiment of the present invention;

Fig. 4A shows the drainage of fibre *via* a mesh in case of an initial high water flow rate;

Fig. 4B shows the settling of fibre on a mesh in case of an initial low water flow rate;

15 Fig. 5A is a cross-sectional image of a pulp-moulded product produced according to the conventional formation process, taken by a scanning electron microscope;

Fig. 5B is a cross-sectional image of a pulp-moulded product produced according to a formation process according to the present invention, taken by a scanning electron microscope of the same magnification as in Fig. 5A;

20 Fig. 6 shows a possible profile of variation of the pressure applied by the compressed air in the apparatus shown in Fig. 3 onto the slurry over time, set against the variation (decay) of suction force over time in a conventional vacuum forming process;

Fig. 7 shows a schematic sectional view of an apparatus according to a second embodiment of the present invention;

25 Fig. 8 shows a schematic sectional view of an apparatus according to a third embodiment of the present invention;

Fig. 9 shows a schematic sectional view of an apparatus according to a fourth embodiment the present invention;

Fig.10 shows a schematic sectional view of an apparatus according to a fifth embodiment
 30 of the present invention; and

Fig. 11 shows a hot press apparatus used in a pulp-moulding process.

Referring now to Fig. 3, an apparatus according to a first embodiment of this invention is shown as generally designated as (100), which makes use of a "Time-Pressure" forming process. The apparatus (100) includes a pressure chamber (102) with a conduit (104) on its upper end and a wire mesh or porous material (106) on its lower end. Below the mesh (106) is a formation mould (108) (which may be made of metal), which is porous in structure or is provided with channels, thus allowing liquid, e.g. water, from the chamber (102) to pass through. The conduit (104) is connected to a source of high pressure, e.g. compressed air (110), for applying a gauge pressure on a fibre-containing water in the form of slurry (112) contained in the chamber (102).

To carry out the formation process according to the present invention, slurry (112) is introduced into the chamber (102), e.g. *via* an inlet (not shown) on a side wall of the chamber (102). The source of compressed air (110) is then activated, releasing compressed air, e.g. at a gauge pressure of up to 10 kg/cm², into the chamber (102) *via* the conduit (104), thus applying a positive gauge pressure on the slurry (112). The positive gauge pressure will force water in the slurry (112) out of the apparatus (100), through the mesh (106) and subsequently through the mould (108). During the course of out-flowing of the water from the chamber (102), the fibre in the slurry (112) will settle and deposit on the mesh (106) to form layers of fibre for subsequent cold-pressing

There are three parameters which can be adjusted for controlling the forming process, namely (a) the pressure of the compressed air, (b) the time period for which the pressure is applied, and (c) the rate of flow of the compressed air into the chamber (102). The rate of flow of the compressed air is a function of the magnitude of the pressure applied and the overall system resistance. The overall system resistance depends at least partly on the geometry of the mesh, e.g. pore size and the number of pores of the mesh. The rate of outflow of water, and thus the overall formation time, can be controlled by adjustment of one or more of these three parameters. In this connection, while it is relatively easy to control and adjust parameters (a) and (b) above, parameter (c) can also be adjusted and controlled, though to a lesser degree. This is in clear contrast to the

conventional method of applying a vacuum to the slurry, in which not much control can be exercised except to apply the vacuum, and to wait until the formation process concludes.

5 It is known that three types of water removal mechanisms may operate on and around the mesh (106). In filtration type, fibre in the slurry (112) are free to move around the slurry (112). In thickening type, fibre in the slurry (112) form a coherent network which is compressed and collapses as drainage of wafer proceeds. Finally, in turbulent thickening, a combination of the previous two types of mechanisms occurs.

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 In the conventional vacuum formation process, and as shown in Fig. 4A, a strong vacuum is initially applied, which which will bring about turbulent thickening of fibre (150) in the slurry (152) and a high initial rate of outflow of water through the mesh (154) The fibre (150) will therefore have no sufficient time to orient themselves
15 horizontally, and thus many of the tiny fibre (150) will be lost to drainage through pores (153) of the mesh (154), as shown in Fig. 4A. In the use of additive, the loss of fibre and additive will be significant in case of a high initial flow rate of water. With a view to mitigating such a problem, chemical retention aids are used for avoiding the increase of fibre and fines in the drained water in case of a high initial flow rate. On the other hand,
20 in a method according to the present invention, the positive pressure applied on the slurry may be set to be relatively small initially, so as to induce a relatively low Initial flow rate of water out from the slurry, as shown in Fig. 4B. A low Initial flow rate will reduce the chance of non-horizontally oriented fibre being lost through drainage.

25 In the conventional vacuum formation process, when initial layers of fibre are formed on the mesh or porous material, they act as a resistance which water in the slurry has to pass through subsequently before drainage. As the number, and thus thickness, of the layers of fibre increases, the effective suction force (i.e. the so called vacuum) will drop, and thus the compression force on the top layers of fibre will decrease gradually.

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Fig. 5A shows a cross-sectional image of a pulp-mould product produced according to the conventional vacuum formation process, taken by a scanning electron microscope (SEM). It can be seen clearly that the lower layers are more compressed than the upper layers. Such a structure is not suitable for products which are intended to be water-proof, as water can penetrate the top layers and, due to osmotic pressure, can pass through the lower layers, thus causing failure. With sudden changes of the vacuum suction force, the density of the upper layers follow an random pattern.

On the other hand, Fig SB shows an image of a cross-section of a pulp-moulded product produced according to a formation process according to the present invention, taken by a scanning electron microscope of the same magnification as that shown in Fig. 5A. This product was formed by applying a pressure profile with an approximate maximum gauge pressure of 4 bars. It can be seen that all the fibre layers are formed with essentially the same degree of compression from upper layers down to lower layers. The thickness of the two pulp-moulded products as shown in Figs. 5A and 5B should also be noted. The amount of fibre used in the production of these two products, and their final weight, are very much the same, However, it can be clearly seen that with the same magnitude of magnification, the product formed under the conventional vacuum suction forming process is almost 10-15% thicker than that produced under the forming process according to the present invention. Such concludes that the use of a positive gauge pressure makes a more uniform and compact finished product. A product with a generally uniform degree of compression, which may be used as water-proof purpose, can thus be formed by a method and an apparatus according to the present invention.

In particular, and as mentioned above, in the apparatus (100), the pressure of the compressed air, the time period for which the pressure is applied and the rate of flow of the compressed air into the chamber (102) may all be adjusted independently. A possible processing pressure profile as shown in Fig. 6 may be pre-set. The profile indicates that a relatively small gauge pressure, e.g. significantly less than 1 bar, is applied initially for one second, thus bringing about a low initial flow rate of water out of the slurry (122) *via* the mesh (106). This would reduce the loss of fibre and clogging up during the initial

forming stage. This also allows sufficient time for the fibre to orient horizontally to form good initial layers. Once such initial layers are formed, a higher gauge pressure, e.g. of up to 3 bars, may be applied for one second to expedite the outflow of water *via* the mesh (106). The application of higher gauge pressure on the slurry (122) will also produce top
 5 layers of fibre which are more compressed, as compared to products manufactured under the conventional vacuum forming process. Subsequently, lower gauge pressure, e.g. of 2 bars, or 1 bar, may then be applied, for 1/2 second and 1/4 second respectively. It can also be seen that the time required for completing the forming process according to the present invention considerably less than that required under the conventional method.

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It should be emphasized that the present invention may be used in combination with the application of a vacuum, to help to achieve higher compactness, shorter formation time and more uniform layers of the resultant product. For example, if a total gauge pressure of 4 bars is to be applied for the formation process, such may be applied
 15 solely by the application of pressure by compressed air. However, such would require a rather strong chamber with good sealing to withstand such a high pressure. As an alternative it is also possible to apply a gauge pressure of 3 bars by the compressed air and simultaneously apply a suction vacuum of 1 bar. In this case, instead of having to withstand a gauge pressure of 4 bars, the chamber needs now only have to withstand a
 20 gauge pressure of 3 bars.

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Referring now to Fig. 7, an apparatus according to a second embodiment of this invention is shown as generally designated as (200), which makes use of a "Displacement Volumetric" forming process, also called a "Positive Displacement" forming method. In
 25 this apparatus (200), a piston (202) is provided in a slurry-containing chamber (204). The piston (202) is operatively associated with a motor and screw assembly (206), which may be activated to push the piston (202) to press onto the slurry (208) to force the water in the slurry (208) out *via* a mesh or porous material (210) supported by a lower metallic mould (212) of a porous structure. The movement of the piston (202) can be preset, e.g.
 30 by a microprocessor, to which the motor and screw assembly (206) is connected, so as to produce a pre-defined pressure variation or pressure profile during the formation stage. It

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is thus possible to preset the magnitude of the gauge pressure to be applied on the slurry and the time for which such a gauge pressure is to be applied. It is of course also possible to pre-set the variation of the magnitude of the gauge pressure to be applied, and the time for which each such magnitude of the gauge pressure is to be applied, on the slurry during
 5 the course of the formation stage. This pressure profile may also be tailored to the process requirements on a trial and error basis.

An apparatus according to a third embodiment of the present invention is shown in Fig. 8, and generally designated as (300). This apparatus (300) is similar to the
 10 apparatus (100) discussed above, except that a feedback-response mechanism is provided. In particular, a first process valve (302) is provided downstream a mesh (304). The first process valve (302) can detect the rate of water flow and transmit control feedback signals to a second process valve (306) downstream the source of compressed air (308). Thus, by way of such an arrangement, if the rate of water flow through the first process
 15 valve (302) is too low, the second process valve (306) will be activated to allow more compressed air from the source (308) to pass through, so as to apply a higher gauge pressure on the slurry (310) in the chamber (312), thus increasing the rate of outflow of water through the mesh (304). This may also have the effect of forcing cleaning some of the blockage in the mesh (304). Conversely, in case the water flow rate through the first
 20 process valve (302) is too high, the second process valve (306) will be controlled to allow less compressed air from the source (308) to pass through, so as to apply a lower gauge pressure on the slurry (310) in the chamber (312), thus decreasing the rate of outflow of water through the mesh (304).

25 An apparatus according to a fourth embodiment of the present invention is shown in Fig. 9, and generally designated as (400). This apparatus (400) is similar to the apparatus (200) discussed above, except that, as in the case of the apparatus (300) discussed above, a feedback-response mechanism is provided. In particular, a process valve (402) is provided downstream a mesh (404). The process valve (402) can detect the
 30 rate of water flow and transmit control feedback signals to control the operation of the motor and screw assembly (408). Thus, by way of such an arrangement, if the rate of

flow of water through the process valve (402) is too low, the motor and screw assembly (406) will be controlled to move a piston (408) toward the mesh (404) faster, so as to apply a higher gauge pressure on the slurry (412) in the chamber (410), thus increasing the rate of outflow of water through the mesh (404). Conversely, in case the water flow rate through the process valve (402) is too high, the motor and screw assembly (408) will be controlled to move the piston (408) more slowly in the chamber (410), so as to apply a lower gauge pressure on the slurry (412) in the chamber (410), thus decreasing the rate of outflow of water through the mesh (404).

In a conventional method of forming pulp-moulded products, once the formation stage is concluded, the wire mesh and the fibre layers formed on it are transferred to a cold press machine, comprising an upper mould and a lower mould. The cold press is then pressed onto the fibre layers to further reduce the water content in the fibre layers. An apparatus for carrying out the "Positive Displacement" forming method may be further modified to be capable of also carrying out the cold-press stage. Such an apparatus, as shown in Fig. 10 and generally designated as (500), is similar to the apparatus (200) and (400) discussed above. A lower end (501) of a piston (502) is formed of a contour matching or corresponding to the upper contour of the product to be ultimately formed. As in the case of the apparatus (100), (200), (300) and (400) discussed above, the mesh or porous material (504) and a lower mould (510) (which may be made of metal) are also formed of a contour matching or corresponding to the lower contour of the product to be ultimately formed. This piston (502) may thus move downward to press on slurry (507) in a formation chamber (508) to carry out the formation stage. After the formation stage, the motor and screw assembly (506) may continue to move the piston (502) further downwardly to carry out the cold-press process. Thus, one stage in the conventional pulp moulding process is eliminated, and with it a set of mould is also saved. After the combined formation and cold-press stage, and as shown in Fig. 11, the cold-pressed fibers as supported by the mesh (504) and the mould (510) will be hot-pressed by an upper mould (520) for completing the pulp moulding process.

It should be understood that the above only illustrates examples whereby the present invention may be carried out, and that various modifications and/or alterations may be made thereto without departing from the spirit of the invention.

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It should also be understood that certain features of the invention, which are, for clarity, described in the context of separate embodiments, may be provided in combination in a single embodiment. Conversely, various features of the invention which are, for brevity, described in the context of a single embodiment, may also be provided separately or in any appropriate sub-combinations.

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CLAIMS:-

1. A method of forming a pulp-moulded article, including the steps of:
 - (a) providing a container with at least one liquid permeable end;
 - 15 (b) introducing a slurry of a fibre and a liquid into said container; and
 - (c) applying a positive gauge pressure on said slurry to force at least part of said liquid in said slurry out of said chamber *via* said liquid permeable end, and thereby to form layers of said fibre on said liquid permeable end.
2. A method according to Claim 1 wherein said gauge pressure is applied by a compressed gas.
- 20 3. A method according to Claim 2 wherein said gas is air.
4. A method according to Claim 1 wherein said positive gauge pressure is above the atmospheric pressure.

5. A method according to Claim I wherein said liquid permeable end includes a porous member.
6. A method according to Claim 5 wherein said porous member includes a mesh,
7. A method according to Claim 1 including the steps of:
 - 5 (a) applying gauge pressure of a first magnitude on said slurry; and
 - (b) subsequently applying gauge pressure of a second magnitude, which is different from said gauge pressure of said first magnitude, on said slurry.
8. A method according to Claim 1 wherein said gauge pressure of said first magnitude is applied on said slurry for a first period of time, and said gauge pressure of said second magnitude is applied on said slurry for a second period of time which is different from said first period of time.
- 10 9. A method according to Claim 7 further including a step (f) of subsequently applying gauge pressure of a third magnitude, which is different from said gauge pressure of said second magnitude, on said slurry.
- 15 10. A method according to Claim I further including a step (g) of detecting the rate of flow of said liquid out of said chamber *via* said liquid permeable end.
11. A method according to Claim 9 further including a step (h) of varying the magnitude of gauge pressure applied on said slurry in response to the rate of flow of said liquid out of said chamber *via* said liquid permeable end.
- 20 12. A method according to Claim 1 wherein said gauge pressure is applied by a piston

member.

13. A method according to Claim 12 further including a step (i) of forming the contour of *a* lower end of said piston member to correspond generally to an upper contour of said article,
- 5 14. A method according to Claim 13 further including a step (j) *of* pressing said piston member on said layers of said fibre on said liquid permeable end.
15. A method according to Claim 1 further including a step (k) of pre-setting the magnitude of the gauge pressure to be applied on said slurry,
- 10 16. A method according to Claim 1 further including a step (l) of pre-setting the time for which the gauge pressure is to be applied on said slurry.
17. A method according, to Claim 1 further including a step (m) of applying a suction force from below said liquid permeable end to draw at least part of said liquid in said slurry out of said chamber *via* said liquid permeable end.
- 15 18. An apparatus for forming pulp-moulded products, including a container for containing a slurry of a fibre and a liquid, said container having at least one liquid permeable end, and means for applying a positive gauge pressure on said slurry in said container to force at least part of said liquid in said slurry out of said chamber *via* said liquid permeable end, and thereby to form layers of said fibre on said liquid permeable end.
- 20 19. An apparatus according to Claim 18 further including a conduit adapted to be connected to a source of compressed gas.
20. An apparatus according to Claim 19 wherein said gas is air.

21. An apparatus according to Claim 18 wherein said gauge pressure is above 1 kg/cm².
22. An apparatus according to Claim 18 wherein said liquid permeable end includes a porous member
- 5 23. An apparatus according to Claim 22 wherein said porous member includes a mesh.
24. An apparatus according to Claim 18 wherein said pressure applying means is adapted to apply gauge pressure of a first magnitude on said slurry and to subsequently apply gauge pressure of a second magnitude, which is different from
10 said gauge pressure of said first magnitude onto said slurry.
25. An apparatus according to Claim 24 wherein said pressure applying means is adapted to apply gauge pressure of said first magnitude for a first period of time, and to apply gauge pressure of said second magnitude for a second period of time which is different from said first period of time.
- 15 26. An apparatus according to Claim 24 wherein said pressure applying means is adapted to subsequently apply gauge pressure of a third magnitude, which is different from said pressure of said second magnitude.
27. An apparatus according to Claim 18 further including means for detecting the rate of flow of said liquid out of said chamber *via* said liquid permeable end.
- 20 28. An apparatus according to Claim 27 further including means for varying the magnitude of gauge pressure applied on said slurry in response to the rate of flow of said liquid out of said chamber *via* said liquid permeable end detected by said detecting means.

29. An apparatus according to Claim 18 further including a piston member.
30. An apparatus according to Claim 29 wherein the contour of a lower end of said piston member corresponds generally to an upper contour of said article.
31. An apparatus according to Claim 30 wherein said piston member is movable to
5 press on said layers of said fibre on said liquid permeable end.
32. An apparatus according to Claim 18 including means for applying a suction force from below said liquid permeable end to draw at least part of said liquid in said slurry out of said chamber *via* said liquid permeable end.
33. A method of forming a pulp-moulded article substantially as herein described and
10 with reference to Figs, 3, 4B, and 6 to 10 of the accompanying drawings.
34. An apparatus for forming pulp-moulded products substantially as herein described and with reference to Figs. 3, 4B, and 6 to 10 of the accompanying drawings.