Processes for molding pulp paper containers and lids

A process for molding recyclable, compostable, and disposable containers made of pulp paper is disclosed herein. The process includes disposing a wet pulp layer on a male or female mold, mating the mold with its counterpart, and applying a force on the pulp layer to remove moisture and thin the pulp. The process continues by applying a vacuum to either the male or female mold to hold the pulp layer, and removing the other mold. The process further comprises sequentially mating male and female molds until the pulp layer is the desired thickness and shape of the container. Embodiments of the process may include molding pulp containers to include pleats, stability features, reverse draft features, and puffed pulp configurations.
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TECHNICAL FIELD

[0001] The present invention relates to containers made of paper, and more specifically to molding pulp or forming paper to form paper containers.

BACKGROUND

[0002] Paper tubs, containers, and cups are made out of pulp, which is inherently fragile when wet, and, accordingly, the standard methods of manufacturing paper containers begin with dry sheets of finished paper. Using a paper cup as an example, paper sheets are first die cut into specific shapes and then wound onto a mandrel. A cylindrical shape is formed, and the pulp paper cup is then glued or sealed at a seam. Next, a base of the cup is die cut and glued or sealed at a base seam adjacent to the cylindrical portion of the cup. Most paper cups and other paper containers have a top edge portion that requires an additional manufacturing step, e.g., creating a lip roll, which provides the container with circumferential strength. In addition, since paper is water permeable, the paper used in containers must be pre-printed and laminated with a water resistant layer, either before or after manufacturing, to ensure the containers are capable of holding food and beverages. Furthermore, paper containers, especially cups, made with this standard manufacturing method often necessitate the use of thermal insulating sleeves to prevent a user from being burned by the hot contents of the container. Manufacturing thermal insulating sleeves requires an additional manufacturing step and additional machining tools. Therefore, the standard method of manufacturing paper containers requires numerous processes and numerous machine tools.

[0003] Molding plastic is a less complex method of manufacturing containers. The elasticity of plastic simplifies manufacturing to the following steps: pouring heated plastic into a mold having a desired container shape, allowing the plastic to harden, and removing the hardened plastic from the mold. More complex shapes may also be made during thermo forming of plastics since the elasticity of plastic
allows it to bend in different directions and resiliently recover when drawn from a mold. Unfortunately, molding techniques used for plastic containers are generally incompatible with pulp paper because wet pulp is inelastic and fragile. Applying standard molding techniques causes the pulp to tear. Additionally, pulp molding is less capable of attaining complex shapes, e.g., reverse drafts on surfaces, since it cannot elastically recover when drawn from molds. Therefore, it is desirable to have a less complex method for manufacturing paper containers that accommodates the material characteristics of pulp.

SUMMARY

[0004] The present disclosure is directed to a process for molding a pulp container that overcomes problems experienced in the prior art. The present disclosure is further directed to a method of molding a container that is made of recyclable, disposable, and/or compostable cellulose fiber materials. A generally accepted definition of compostable is a material that is able to break down into carbon dioxide, water and biomass at the same rate as paper. Compostable material also does not produce toxic material and is generally able to support plant life.

[0005] A container made in accordance with at least one embodiment of the present disclosure may be made from renewable resources that may include recycled materials, biodegradable materials, compostable materials, and organics, e.g., cellulose fiber, tapioca, wood, agricultural recycled crop materials, and plastics, e.g., PLA. The container may also be made from materials including non-organics, e.g., clay, metals, and petro plastics, e.g., silicone, PVC’s, and PET styrene. An embodiment in accordance with the present disclosure includes molding a container made of pulp.

[0006] Embodiments of the present disclosure include processes for forming molded pulp containers, such as cups and/or lids. Some embodiments may include using molds having greater draft angles than typical molding to accommodate for the fragility of wet pulp. The processes disclosed herein may also result in greater insulation because the resulting pulp container has a less densely formed substrate due to the forming and pressing processes associated with embodiments of the
invention. Molded containers manufactured with this process can include a variety of homogeneous and non-homogeneous shapes.

[0007] Embodiments in accordance with the present disclosure provide a process for molding containers that include a pleat. Pleats are advantageous since they allow containers to be molded with larger draft angles for easy removal from molds. The pleats are subsequently folded, thereby forming a seam and a container having a smaller draft angle, a smaller diameter, and a greater height than the mold.

[0008] Another embodiment of the present disclosure is drawn to processes that include containers having specially shaped edges. For example, cups may include a top edge having a contoured lip or roll. This forms a more desirable drinking surface and makes it easier to connect the cup to a lid.

[0009] Still other embodiments in accordance with the present disclosure provide a process for molding a container including a reverse draft feature. For example, lids include reverse draft features to securely connect to containers. Containers themselves also have reverse draft features. Embodiments in accordance with this process include first molding pulp along a horizontal axis to include pleat configurations, gradually bending the pulp to a reverse draft angle using sequential molds, removing the molds, and collapsing the pleats on the pulp to form the reverse draft feature.

20 BRIEF DESCRIPTION OF THE DRAWINGS

[0010] In the drawings, the sizes and relative positions of the elements in the drawings are not necessarily drawn to scale. For example, the shapes of the various elements and angles are not drawn to scale, and some of these elements are arbitrarily enlarged and positioned to improve drawing legibility. Further, the particular shapes of the elements as drawn are not intended to convey any information regarding the actual shape of the particular elements, and have been solely selected for ease of recognition in the drawings. Understanding that these drawings depict only one embodiment of the disclosure and are not therefore to be considered as limiting of its scope, the disclosure will be described and explained with additional specificity and detail through the use of the accompanying drawings.
[0011] Figures 1A-H are schematic cross-sectional views illustrating a number of stages of a process for molding a pulp paper cup in accordance with an embodiment of the invention.

[0012] Figures 2A and 2B are schematic cross-sectional views of a pulp layer between male and female molds of an alternate embodiment.

[0013] Figures 3A-3C are schematic cross-sectional views of a pulp layer between male and female molds of another alternate embodiment.

[0014] Figure 4A and 4B are schematic cross-sectional views of a pulp layer between male and female molds of another alternate embodiment.

[0015] Figure 5A is a perspective view of a molded pulp paper cup having a pleat in accordance with an embodiment of the invention.

[0016] Figure 5B is a top view of a molded pulp paper cup having a pleat in accordance with an embodiment of the invention.

[0017] Figure 6 is a front view of a molded pulp paper cup having an angular base in accordance with an embodiment of the invention.

[0018] Figure 7 is a perspective view of a molded pulp paper cup having fins in accordance with an embodiment of the invention.

[0019] Figures 8A-F are schematic cross-sectional views illustrating a number of stages of a process for molding an upper edge of a pulp paper cup in accordance with an embodiment of the invention.

[0020] Figures 9A-F are cross-sectional and perspective views illustrating a number of stages of a process for molding a reverse draft feature on a pulp paper lid in accordance with an embodiment of the invention.

[0021] Figures 10A-D are schematic cross-sectional views illustrating a number of stages of a process for molding a puffed pulp construction in accordance with an embodiment of the invention.

[0022] Figure 11 is a cross-sectional view of a molded pulp paper cup and lid assembly having a reverse draft feature with a puffed pulp construction in accordance with an embodiment of the invention.
[0023] Appendix A includes prospective views of other molded pulp paper containers in accordance with embodiments of the invention.

[0024] From the foregoing, it will be appreciated that specific embodiments of the invention have been described herein for purposes of illustration, but that various modifications may be made without deviating from the spirit and scope of the invention. Accordingly, the invention is not limited except as by the appended claims.

DETAILED DESCRIPTION

[0025] The following describes embodiments of a process for molding a pulp container in accordance with the present disclosure. Embodiments in accordance with the present disclosure are set forth hereinafter to provide a thorough understanding and enabling description of a number of particular embodiments. Several specific details of the disclosure are set forth in the following description and in Figures 1-7 to provide a thorough understanding of certain embodiments of the disclosure. For example, Figures 1-7 illustrate a pulp container as a cup and/or a lid. However, it should be noted that the process described below can be used to make any suitable container or insulating sleeve made of pulp paper. A cup and lid are only one embodiment of a molded pulp container made by the disclosed process. Appendix A illustrates other suitable shapes in accordance with the invention. One skilled in the art, however, will understand that the present disclosure may have additional embodiments, and that other embodiments of the disclosure may be practiced without several of the specific features described below.

[0026] Embodiments of processes in accordance with the present disclosure may include molds having tapered surfaces that form a draft angle between the mold and the parting line of the molded material. Draft angles allow for easy removal of the formed container for the mold. For example, Figure 1A illustrates a pulp layer 1 positioned between a male mold 2 and a female mold 3. The pulp layer is held against the male mold 2 using a vacuum and the female mold 3 is removed. The angle θ is the draft angle between pulp layer 1 and male mold 2 that simplifies removal of the female mold 3. Features that are not positioned in the same direction
as the mold is removed, i.e., the draw of the mold, are said to have reverse draft or be positioned on a negative draft angle.

[0027] Figures 1B-1H illustrate sequential stages of an embodiment of a process for forming a molded pulp cup in accordance with the disclosure. Figure 1B, more specifically, is a cross-sectional view at the initial stage of the process in which a wet, pulp layer 101 is held against the exterior surface of a male forming mold 102. The pulp layer 101 is formed on the male forming mold 102 using any suitable method, e.g., positioning the male forming mold 102 in a slurry of wet pulp and drawing a vacuum (i.e., a negative pressure) through the mold surface to draw the pulp onto the mold until a sufficient amount of pulp covers the mold.

[0028] Figure 1C illustrates a subsequent stage of the process that includes axially mating a first female mold 103 with the layer of pulp on the male forming mold 102, thereby sandwiching the pulp layer 101 between the female and male molds. During this first molding process, the layer of wet pulp is substantially compressed, thereby squeezing or otherwise removing a substantial amount of water out of the pulp layer. The distance between the two molds is known as an offset 110. The offset of the initial mold set in one embodiment is approximately 3mm-5mm and becomes sequentially smaller as the molding process continues in subsequent molds, so as to incrementally compress and thin the pulp without tearing. The male forming mold 102 and the first female mold 102 have a cross-section shape including a lower portion with a first draft angle and a splayed upper portion with a second draft angle greater than the first draft angle. This general shape, optionally including a large draft angle, helps to insure that the layer of fragile wet pulp does not tear during insertion or removal from a mold.

[0029] In the subsequent stage of the process illustrated in Figure 1D, the male forming mold 102 is removed from the first female mold 103. The pulp layer 101 is held to the interior surface of the first female mold 103 by applying a vacuum to the first female mold, between the mold surface and the pulp. Additionally, pressurized air may be forced through the male forming mold 102 to assist in removal and work in conjunction with the vacuum to hold the pulp layer 101 against the first female mold 103.
[0030] In another embodiment in accordance with the present disclosure, the pulp layer 101 is formed directly on the first female mold 103 using with a process similar to the process discussed above. For example, the wet pulp can be initially coated or otherwise disposed on the interior surface of the female mold 103 and a vacuum can be drawn through the mold surface to hold the layer of pulp 101 against the first female mold 103. In this embodiment, the process begins at Figure 1D. It is noted for the reader that the draft angle at the upper portion of the first female mold 103 is shown in an exaggerated manner to visually illustrate the difference in the draft angle of the upper portion relative to the lower portion of the female mold and to the draft angle of the male mold. In at least one embodiment, the draft angle of the lower portion of the female mold and the male mold is approximately 1°-7°, and the offset therebetween is approximately 0.01mm – 5mm. The draft angle of the upper portion of the female mold is approximately 2°-14°, and the offset increases to approximately 4mm - 6mm, depending upon the depth of mold draw. In one embodiment provided as an example, the draft of the lower portion of the molds is approximately 5°, and the draft of the upper portion of the molds is approximately 8°. Other embodiments can use other mold configurations.

[0031] Figure 1E illustrates the subsequent stage of the process for molding a cup that includes mating a first male mold 104 with the first female mold 103. In this step illustrated in Figure 1E, the molds 103 and 104 apply a force on the pulp layer 101 due to the wedging of the male mold against the female mold to provide compression from the molds against the pulp layer 101. The compressive force squeezes excess moisture (e.g., water) from the pulp, causing the pulp layer 101 to thin. In Figure 1E, the offset upper portion of the first female mold 103 may be smaller at the lower region than the upper region.

[0032] The subsequent stages of the process are shown in Figures 1F and 1G, in which a vacuum is applied through the first male mold 104, thereby drawing the pulp layer 101 away from the first female mold 103 and holding the pulp layer 101 against male mold 104. Additionally, pressurized air may be applied to the first female mold 103 in accordance with the direction of the arrows in Figure 1G. The additional pressurized airflow acts in conjunction with the vacuum to smoothly remove the pulp off the female mold 103 and firmly hold the pulp layer 101 against the male mold 103. Once the pulp layer is held against the surface of the male mold
104 as illustrated in Figure 1G, the first female mold 103 is removed and moved away from male mold 104 and the pulp layer 101. As described above, the upper portion of the first female mold 103 may have a larger draft angle than subsequent female molds so as not to tear the pulp layer 101 while it is most fragile during the initial molding steps of the process.

[0033] In accordance with the subsequent stage of the process shown in Figure 1H, a second female mold 105 mates with the male mold 104 that carries the pulp layer 101 thereon. This combination of the second female mold 105 and the first male mold 104 has a smaller offset than first female mold 103 in combination with the male mold 104. Upon pressing the male mold 104 and the pulp layer into the second female mold 105, wedging and compressive forces are applied to pulp layer 101 to squeeze out additional moisture and to further thin the pulp layer 101. Additionally, the second female mold 105 can be configured to provide an offset relative to the male mold 104 that is smaller at the upper region of the molds 104 and 105 than the offset between the lower region of the molds 104 and 105. This variation in the offset between the mating molds results in the molds exerting more force on the upper portion of pulp layer 101 than on the lower portion during this stage of the molding process. One of the benefits of this varied offset is that it minimized the risk of damage to the pulp layer when separating the male and female molds. It also provides a varied wedging forces to different portions of the pulp layer during different sequential molding steps.

[0034] In the next step of the process, the second female mold 105 is removed from the pulp layer 101, which remains on the male mold. This process is similar to that described above with reference to Figures 1F and 1G wherein a vacuum is drawn through the male mold 104, and, optionally, pressurized air is applied inwardly from the second female mold 105 so that pulp layer 101 is held against male mold 104 and the second female mold can be easily and safely removed without damaging the pulp layer 101.

[0035] In accordance with embodiments of the disclosure, the process includes mating additional female molds with the pulp layer on the male mold 104 until the pulp layer 101 is the desired shape and thickness of the cup. The process of mating an additional female mold is similar to the sequence of stages described above with
reference to Figures 1E-H. Each subsequent female mold has a decreased offset relative to the male mold to apply compressive forces to the pulp layer 101 to squeeze out additional moisture and to sequentially thin the pulp layer 101 until a desired thickness of the pulp layer is achieved. The offsets created by each subsequent female molds may also vary within individual female molds in a manner that is essentially opposite from the previous female mold. For example, the offset between the female and male molds discussed above included a slightly greater offset at the lower region of the molds than at the upper regions of the mold. This provides greater compression and thinning of the upper portion of the pulp layer during this step of the molding process.

[0036] The next female mold can be configured so that, when combined with the male mold, the molds will have an offset A at the lower portion of the mold that is slightly less than the an offset B at the upper portion molds. This provides greater compression and thinning of the lower portion of the pulp layer during this step of the molding process. The subsequent female molds, when combined with the male mold, may have alternating variations of the offsets A' and B' at the lower and upper portions of the mold, respectively. Varying the offsets within individual molds and alternating the position of the varied offset of subsequent molds decreases the defects on the completed pulp paper container since the pulp is not continuously compressed against the same portions of the male mold. In the illustrated embodiment, the final pair of female and male molds will have a selected offset, uniform or varied, that provides the desired thickness of the pulp layer for the final product. For example, if the final product is designed to have a uniform thickness, the offset between the final set of female and male molds will have a uniform offset.

[0037] Figures 2A and 2B illustrate an alternate embodiment wherein the pulp layer 101 is retained female mold 203, and the male mold 204 is inserted into the female mold 203 to compress and thin the pulp layer. The male mold is configured with different draft angles relative such that the offset between the lower portion 206 of the female and male molds 203 and 204 is greater than the offset between the upper portion 208 of the female and male molds.

[0038] In accordance with embodiments of the present disclosure, the process may also include a varying number of molding steps for molding the pulp layer.
between selected sequential sets of male and female molds depending upon the desired thickness and shape of the container. For example, one embodiment forms the molded pulp product using three molding steps with three sets of sequential pairs of molds, each having increasingly smaller offsets. Other embodiments can include five to seven sequential molding steps with the selected pairs of male and female molds. Additional embodiments in accordance the present disclosure may include more or less repetitions. In some embodiments, the use of a greater number of molding steps can provide for better throughput in the molding process to provide a greater number of molded pulp products in a selected time period.

[0039] The molding process described above with reference to Figures 1E-H includes sequential mating of multiple female molds with one male mold 104 (which that retains the pulp layer on it throughout the molding process. In an alternate embodiment, the molding process can include sequential mating of multiple male molds with one female mold that retains the pulp layer therein throughout the molding process. For example, this embodiment of the process included holding a pulp layer against a female mold having the desired exterior diameter of the container with a vacuum. A first male mold is then mated with the female mold, applying a wedging and compressive force on the pulp layer, thereby removing excess moisture from the pulp and thinning the pulp layer. Next, a vacuum is drawn the female mold to hold the pulp layer against the female mold. Additionally, pressurized air may be blown radially from the first male mold to act in conjunction with the vacuum, holding the pulp layer on the female mold and helping remove the first male mold. In the next step of the process, a second male mold is mated with the female mold, wherein this second set of molds has a smaller offset compared to the offset of the first pair of molds. The reduced offset removes additional moisture and further thins the pulp layer.

[0040] In accordance with this embodiment of the process, each subsequent male mold has a greater diameter than the previous male mold so as to decrease the offset between the molds, and the number of male molds may vary depending upon the desired thickness and shape of the resulting molded pulp product. Additionally, as described above with reference to female molds, the male molds can be configured to provide varied offsets between different portions of a set of male
and female molds, i.e., the lower portion compared to the upper portion of the mold. The positions of the varied offset may alternate between subsequent male molds.

[0041] Still further embodiments in accordance with the present disclosure can include alternating the vacuumed surface between male and female molds so that the pulp layer 101 is retained on a male mold at one molding station and then on the female mold at the next molding station. For example, as illustrated in Figures 3A-3C, a layer of pulp 101 may first be held against a first female mold 303, and a first male mold 304 may be mated with the first female mold, exerting a compressive force on the pulp layer to remove excess moisture and thin the pulp layer. The illustrated first male mold 304 has variable draft angles. A vacuum is then drawn through the first male mold 304 to hold the pulp layer against it and pressurized air may be forced through the first female mold 303 to work in conjunction with the vacuum, holding the layer of pulp against the first male mold and aiding in the removal of the first female mold. A second female mold 306 (Figure 3B) is then mated with the first male mold 304, decreasing the offset and exerting a compressive force on the pulp layer 101 to remove excess moisture and further thin the pulp. Next, a vacuum is drawn through the second female mold 306, thereby holding the pulp layer 101 against it, and the first male mold 304 is removed. A second male mold 308 is then mated with the second female mold 306. This process may be repeated until the pulp layer is the desired thickness and shape. With each repetition, the offset is decreased. Additionally, in some embodiments the offset may be varied within the molds and alternated as described above. Switching the mold on which the pulp layer is held allows the pulp to "paddy-cake" between the male and female molds, and further decreases any defects transferred to the inner and outer surfaces of the pulp layer since the pulp layer is not retained on the same male or female mold during the molding process. In an additional embodiment, the pulp may first be vacuumed to the female mold, subsequently vacuumed onto the male mold, and continue with the "paddy-cake" sequence described above.

[0042] Figures 4A and 4B are schematic cross-sectional views of an alternate embodiment having male and female molds used to mold a pulp layer 101 into a selected molded pulp product. In the illustrated embodiment, the female mold 403 is similar to the female molds discussed above. The male mold 404 is a multi-segmented partially conical shaped mold assembly that includes a plurality of
shaped mold segments 406. In the illustrated embodiment the mold segments 406 are carried by a central shaft 408. The mold segments 406 are axially moveable on the central shaft 408 so the segments can be spaced apart from each other to form an initial molding position as shown in Figure 4A. The mold segments can be moved relative the shaft to a final mold position wherein the mold segments are stacked upon each other. Accordingly, the draft angle of the male mold when in the initial position is less than the draft angle of the male mold when in the final mold position.

[0043] In operation of one embodiment, the pulp layer 101 is carried by the female mold 403 as discussed above. The male mold 404 is in the initial molding position with the mold segments 406 spaced apart before the male mold is inserted into the female mold. When the male mold 404 is axially inserted into the female mold 403 to compress the pulp layer, the first (bottom mold) segment 410 pressed into the bottom portion of the pulp layer to compress the pulp layer against the female mold. In this position, when the mold segments are still in the initial position, which defined the first draft angle, the mold segments provide some compressive forces against the pulp layer. The remaining mold segments 412-420 are then moved axially along the central shaft until the segments are stacked upon each other and in the final mold position. As the mold segments are moving to the final mold position, the effective draft angle of the male mold increases and the segments provide increased wedging and compression forces against the pulp layer that drives moisture from the pulp layer 101 and further thins the pulp layer. In one embodiment, the mold segments 412-420 can all be substantially simultaneously moved into the final mold position. In another embodiment, the mold segments can be moved sequentially into their respective final mold positions. Although the illustrated embodiment shows male and female molds with a cup shape, other embodiments can provide molds for forming molded pulp containers with other shapes.

[0044] As shown in Figures 5A and 5B, additional embodiments in accordance with the present disclosure include processes for forming a pulp cup 500 having a pleat 501. Pulp is molded in accordance with any of the processes described above, except the male and female molds each have an indentation configured to form a pleat similar to pleat 501 on cup 500. After the molding process is completed, the molded product has the pleat in an expanded, unfolded position. The pleat can then
be folded to a collapsed position so as to decrease the diameter and the draft angle of the molded product. The folded pleat will appear to be a vertical seam on the sidewall of the molded pulp cup. Embodiments in accordance with the present disclosure may include more than one pleat positioned around the circumference of the cup or other container. Molds including an indentation configured to form a pleat have the advantage of permitting the use of a greater draft angle, thereby decreasing the difficulty of removing the fragile pulp layers from the molds, especially during the initial molding steps. This results in a reduced risk of tears or defects within the pulp layer during the molding process.

Additional embodiments in accordance with the present disclosure include processes for molding pulp products having non-cylindrical features. For example, Figures 6 and 7 illustrate different shapes or features that may be included in the pulp molding processes disclosed above. Figure 6 illustrates a cup 600 that has an angular sections 601 on the lower portion of the cup that provide stability and greater surface area through which heat may dissipate. Additionally, the shape of cup 600 permits the use of greater draft angles for easier removal of pulp from the molds. In further embodiments of containers made in accordance with the process of the present disclosure, Figure 7 illustrates a cup 700 that has fins 701 protruding from the base of the cup 702. These fins 701 provide greater stability. The pulp molding process used to form cup 600 and cup 700 may include any of the molding processes described above, except that the male and female molds include the desired features of the cups 600 and 700. It should be noted that non-cylindrical cup features are not limited to the structures shown in Figures 6 and 7. These are merely an illustration of some features that may be included in pulp molding.

Each of the above embodiments may further include a process for forming an upper edge feature on a container. Figures 8A-F illustrate stages of an embodiment of a process for forming an edge on a molded pulp cup in accordance with the disclosure. More specifically, Figure 8A is a cross-sectional view at the initial stage of forming an edge wherein a pulp layer 101 is held against a first female mold 803, the pulp layer 101 extending beyond the first female mold 803. In the subsequent stage of the process illustrated in Figure 8B, a first male mold 802 is mated with the female mold 803. The first male mold 802 has an upper portion 802a that pushes vertically down on the portion pulp layer 101 extending beyond the first
female mold 803 and causes the pulp layer 801 to bend outwardly over edge of the first female mold 803.

[0047] Figures 8C and 8E illustrate the next sequential steps in the process in accordance with the disclosure. As described above, a vacuum is applied to the first male mold 802 and pressurized air may be blown radially inward from the first female mold 803 to hold the pulp layer on the first male mold 802 and remove the first female mold 803. The pulp 101 is held against the first male mold 802 as illustrated in Figure 8C. Next, a second female mold 804 is mated with the first male mold 802, the second female mold having an upper edge angled downward as shown in Figure 8D. The first male mold 802 is then removed from the pulp layer 101 by using the vacuum and optional pressurized air process described above, leaving the pulp layer 101 held against the second female mold 804 as shown in Figure 8E. Subsequently, a second male mold 805 is mated with the second female mold 804, as illustrated in Figure 8F. The second male mold has edges angled downward, similar to the second female mold separated by an offset, that force pulp layer 101 to curl downward as shown in Figure 8F. As discussed above with reference to molding the cup 100 in Figures 1A-H, the process of mating male and female molds to create an edge may be repeated as many or as few times to obtain the appropriate edge shape and thickness. Additionally, as described above, each additional mold set may decrease the offset between the molds to thin the edge and to remove excess moisture from the pulp. As also described above, the process may include varying offset within individual mold sets and alternating offset between subsequent mold sets to decrease defects. It should be noted that the shape of the edge formed in Figures 8A-8F is only an example of one shape of an edge that can be formed. Any suitable edge to a cup or container may be formed using the above process, including, but not limited to an inward edge, an angular edge, and a stepped edge. Moreover, an edge may be formed simultaneous to molding the cup, rather than after the cup is molded. This can decrease manufacturing time.

[0048] Still other embodiments of the present disclosure include processes for forming a container with a reverse draft. As described above, a reverse draft feature is one whose angle runs against the draw of the mold. Figures 9A-F illustrate a reverse draft feature molded on a cup lid. However, it should be noted that the
process for molding a reverse draft feature may apply to any paper container feature having a negative draft angle.

[0049] Figures 9A-C illustrate sequential steps of an embodiment of a process for forming a molded pulp lid with a reverse draft. Figure 9A, more specifically, is a schematic cross-sectional view of the first stage of the process of forming a lid 900 with a flange 911 that will include reverse draft features (discussed in greater detail below). A wet pulp layer 901 is held against a first male mold 902 using a vacuum. A first female mold 903 is mated with the first male mold 902, the two molds having an offset. The first male and female molds 902 and 903 begin the molding of the flange 911 on the horizontal axis.

[0050] Figures 9B and 9C illustrate the next steps of the molding process in which the flange 911 is pressed from the horizontal axis to the vertical axis. The first male and female molds are removed from the pulp layer 901 in any one of the processes described above for forming a cup, i.e., vacuuming the pulp layer to one mold and concurrently applying pressurized air from the mated mold while it is removed. Next, as shown in Figure 9B, a second male mold 904 and second female mold 905, having a smaller offset than the first molds 902 and 903, are mated around the pulp layer 901. The second molds 904 and 905 include portions angled between the horizontal and vertical axis to bend the flange 911 to an intermediate position between the horizontal orientation and vertical orientation. During the next sequential step shown in Figure 9C, the second male and female molds 904 and 905 are removed using any of the methods described above and a third male mold 906 and third female mold 907 are mated around the pulp layer 901, the third molds having a smaller offset than the second molds. The third molds further move and bend the flange 911 into the vertical orientation. The molds are then removed from the pulp layer 901. Again, removal of the molds may include anything in accordance with the methods described above.

[0051] As shown in Figure 9D, the flange 911 connects to the body of the lid at a radially inward portion forming an intersection. The sequential bending of the flange 911 at this intersection from the horizontal orientation to the vertical orientation compresses the pulp material on the underside of the flange at the intersection, which causes the fibers of the pulp to bunch together, forming a
projection, such as a bump 910, that extends radially inwardly to create a reverse draft feature. Figure 9D is a cross-sectional view of the pulp layer during stages of the molding process including a magnified view of the corner portion of the reverse draft feature. The magnified image illustrates the bump 910, caused by the bunching of pulp at the flange intersection while forming the reverse draft feature 911 (Figures 9A-C). The bump 910 creates the reverse draft that allows a molded pulp lid to connect or snap onto a lip area of container, e.g., a rolled rim of cup.

[0052] In the process described above, three sequential male and female molds move the reverse draft feature from a horizontal plane to the vertical plane, thereby creating the bump 910 at a negative draft angle. However, it should be noted that more or less pairs of molds may be used to create a reverse draft feature. For example, each sequential pair of molds may change the angle of a pulp layer only a few degrees until the desired reverse draft feature is obtained. As discussed above, each additional mold set decreases offset to apply force to the pulp and extract excess moisture. Additionally, the offset may be varied within individual molds and alternate between sequential molds in order to decrease the defects transferred to the pulp.

[0053] In additional embodiments illustrated in Figures 9E and 9F, the flange 911 is molded to provide additional reverse draft features, which are illustrated as a plurality of pleats 912 and/or protrusions 913. When the flange is in the horizontal position, the pleats 912 are generally in an open configuration with a generally V-shape cross-section described above may include pleats. During the sequential bending of the flange 911 from the horizontal orientation to the vertical orientation described above, the pleats 912 pinch together from the open V-shaped configuration to a closed orientation. Figure 9F illustrates a perspective view of the lid 900 after the final stage of molding, wherein the pleats 912 are collapsed so as to extend radially inwardly to form reverse draft features. The molded pleats 912 create a reverse draft, so as to supplement the bump 910 created during compression of the pulp as discussed above, so that it may firmly attached to the container and remain firmly in position during use. When the lid 900 is in a relaxed position (i.e., not yet snapped onto the lip of the cup), the flange 911 (in the vertical orientation) lid has a reduced circumference or diameter. When the lid is snapped onto the rim of the cup, the molded pleats allow the flange to radially expand to a
slightly larger circumference or diameter to fit over the rim of the cup (or other selected container). Once, the lid has been fully snapped onto the rim of the cup, the molded pleats return toward the relaxed position, with the flange in the vertical orientation so that the flange fits over and is positioned with the reverse draft features at least partially radially inward of the rim of the cup, firmly securing the lid onto the rim of the cup. Additionally, the pleats 912 facilitate removal of the male and female molds from the pulp layer because they can expand in response to any force exerted on the reverse draft feature. The memory of the pleats causes the circumference of the lid to collapse back into the desire reverse draft shape after the molds are removed.

[0054] An additional embodiment in accordance with the present disclosure includes a process for forming a pulp product or a portion of a pulp product with a less dense construction, referred to as a puffed pulp construction. In some embodiments, this puffed pulp construction can be used to form portions that will elevate a reverse draft feature, such as on a container or a lid. Figures 10A-D are schematic cross-sectional views showing an embodiment of forming the puffed pulp construction. More specifically, Figure 10A illustrates the first stage of the process of forming a puffed pulp construction. A male forming tool 1002 is submerged into a pulp slurry 1000. A vacuum is applied to the male forming tool 1002 to attach a layer of pulp 1004 to the male forming tool 1004. A female pressing tool 1006, positioned above the pulp slurry 1000 and can apply pressurized air.

[0055] Figures 11B-C illustrate removal of the pulp layer 1004 from the pulp slurry 1000. Male forming tool 1002 is lifted above the pulp slurry 1000, e.g., manually or mechanically. Pressurized air can be applied to male forming tool 1002 while a vacuum is applied to the female pressing tool 1006. This holds the pulp layer 10004 against the female pressing tool 1006, so that the male forming tool 1002 can be removed. As shown in Figure 10C, once the male forming tool 1002 is removed, a male pressing tool 1008 is introduced to the process.

[0056] As illustrated in Figure 10D, in the subsequent step, the male pressing tool 1008 is mated with the female pressing tool 1006. Both the female and male pressing tools 1006 and 1008 include a portion with an expanded region, i.e., greater offset D, that forms the puffed pulp construction. A vacuum is applied to both the
male and female pressing tools 1006 and 1008, thereby creating a less dense pulp in the expanded region. Heat can also be added to one or both of the pressing tools during the formation of the less dense pulp. After formation, the less dense and, consequently, softer puffed pulp configuration facilitates removal from the pressing tools while retaining enough memory to create an engaging force having a reverse draft.

[0057] This process of molding a pulp product with the puffed pulp process can be used to provide a wide range of products, including containers with or without lids. For example, the puffed pulp configuration can be used when forming a lid to provide a reverse draft feature that can engage a rim of a cup or other container. Figure 11 shows a cross-sectional view of a puffed pulp reverse draft feature 1111 in accordance with an embodiment of the disclosure. The advantage of the puffed feature is that it allows a container part, e.g., a lid, to snap onto an adjoining rim of a container, e.g., a cup. This puffed pulp construction may be formed in conjunction with any of the processes described above.

[0058] All of the above processes may include heating the male and/or female mold. Heating the molds during the vacuum and the pressurized air application stages of the process facilitates a more rapid removal of the moisture from the pulp by turning it into steam. Adding heat is also advantageous in containers having a reverse draft feature as described above because it increases the memory of the pulp, thereby making it easier for the pulp layer to collapse from its horizontal orientation to its desired position after removal from the molds.

[0059] In each of the above embodiments, subsequent processes may be applied to the molded containers. For example, the containers may be printed, coated with a waterproof coating, and die cut. A coating may be applied to the containers while a vacuum holds a pulp layer against either the male or female mold. This has the additional advantage of assisting the coating in adhering to the container because the vacuum operates through the pours of the pulp paper container. The processes may further include applying a smooth and pleasing surface by using heat and press-in-place techniques. In additional embodiments, other surfaces and/or textures can be added to the container.
[0060] Each of the pulp molding processes described above may be performed by machines. These machines may include linear distribution lines wherein pulp layers are molded between male and female molds along an assembly line. The machines may also include circular revolving molds. It should be noted that any suitable machine for sequentially molding pulp into a container may be used to accelerate the process.

[0061] From the foregoing, it will be appreciated that specific embodiments of the disclosure have been described herein for purposes of illustration, but that various modifications may be made without deviating from the disclosure. Furthermore, aspects of the disclosure described in the context of particular embodiments may be combined or eliminated in other embodiments. Further, while features and characteristics associated with certain embodiments of the disclosure have been described in the context of those embodiments, other embodiments may also exhibit such features and characteristics, and not all embodiments need necessarily exhibit such features and characteristics to fall within the scope of the disclosure. Accordingly, the disclosure is not limited, except as by the appended claims.
CLAIMS

I/We claim:

1. A process for making a molded pulp container comprising:
   disposing a pulp layer on a first mold;
   mating a second male mold with the first mold, the first and second molds
   being separated by a first offset and configured to exert a compressive
   force on the pulp layer to remove moisture and thin the pulp layer;
   drawing a vacuum through the second mold, the vacuum being configured to
   hold the pulp layer against the second mold;
   removing the first mold from the second mold and the pulp layer;
   mating a third mold with the second mold, the second and third molds being
   separated by a second offset, less than the first offset and configured
   to exert a compressive force on the pulp layer to further thin the pulp
   layer;
   drawing a vacuum through one of the second and third molds, the vacuum
   being configured to hold the pulp layer against the one of the second
   and third molds; and
   removing the other one of the second and third molds from the one of the
   second and third molds with the pulp layer thereon.

2. The process of claim 1 wherein the pulp layer is first disposed on a
   forming mold, mated with the first mold, and the forming mold is removed by drawing
   at least one of a vacuum through the first mold and pressurized air through the
   forming mold.

3. The process of claim 1, further comprising:
   applying pressurized air through at least one of the first and third molds when
   they are removed from the second mold.
4. The process of claim 1 wherein the first offset is greater in upper portions of the first and second molds and smaller in lower portions of the first and second molds, the process further comprising:

varying the portions of subsequent male and female molds having a greater offset; and

decreasing the size of subsequent offsets.

5. The process of claim 1, further comprising:
repeating the mating and removing of subsequent molds until the container is a desired thickness and shape.

6. The process of claim 1, further comprising:
repeating the mating and removing of subsequent molds;
alternating the mold on which the vacuum operates to hold the pulp layer.

7. The process of claim 1, further comprising:
mating a fourth mold with the second mold, the pulp layer having a portion extending beyond the fourth mold;
drawing a vacuum through the fourth mold, the vacuum being configured to hold the pulp layer against the fourth mold;
removing the second mold;
mating a fifth mold with the fourth mold, the fifth mold having an upper portion configured to mold the portion of the pulp layer extending beyond the fourth mold at least partially against the fourth mold; and
repeating the mating and removal of subsequent mating molds configured to mold the portion of the pulp extending beyond the fourth mold at least partially against the subsequent mating molds.

8. The process of claim 1 wherein first, second and third molds each have a draft angle, the draft angle configured to prevent the pulp layer from tearing when it is removed from at least one of the first, second and third molds.
9. The process of claim 1 wherein first, second and third molds have at least one indentation configured to form at least one pleat on the container.

10. The process of claim 1 wherein the first, second and third molds have a plurality of indentations configured to form a plurality of pleats on a circumference of the pulp layer, the process further comprising:
    molding a plurality of pleats about a circumferential portion of the pulp layer, wherein at least a portion of the pleats provides a reverse draft feature positioned at a negative draft angle.

11. The process of claim 10 wherein at least one of the first, second and third molds has a reverse draft portion with a greater porosity and a greater offset than the remainder of the mold, the reverse draft portion being configured to create a less dense pulp portion.

12. The process of claim 1 wherein the first, second and third molds are configured to imprint a pattern onto the pulp layer.

13. The process of claim 1 wherein first, second and third molds include angular lower portions, the angular lower portions configured to form stability features on the paper container.

14. The process of claim 1, further comprising: heating at least one of the first, second and third molds during mating.

15. The process of claim 1, further comprising: heating at least one of the first, second and third molds while a vacuum is applied to hold the pulp layer against it; and applying a coating to the pulp layer.

16. A method of manufacturing a pulp paper cup, the method comprising:
    disposing a pulp layer on a female mold;
mating a male mold with the female mold, the female mold and the male mold having a first offset, wherein the first offset is the distance between the male and the first female mold and the first offset is non-homogeneous and is configured to apply a greater force on a first portion of the pulp layer;

applying a vacuum to the male mold, the vacuum being configured to hold the pulp layer against the first male mold;

removing the female mold, the female mold and male mold having a draft angle positioned between them and configured to prevent tearing of the pulp layer during removal of the female mold;

mating a second female mold with the male mold, the second female mold creating a second offset, less than the first offset, the second offset is non-homogenous and is configured to apply a greater force on a second portion of the pulp layer, different than the first portion of the pulp layer; and

removing the pulp layer from the male mold and the second female mold.

17. The method of claim 16, further comprising:
providing a straight assembly line of sequential female molds; and
repeating the mating of subsequent female molds with the male mold along the straight assembly line until the pulp layer is the desired thickness and shape.

18. The method of claim 16, further comprising:
providing a circular manufacturing tool comprising male and female molds with sequentially smaller offsets; and
repeating the mating of subsequent male and female molds until the pulp layer is the desired thickness and shape.

19. A process for manufacturing a molded pulp paper container having a reverse draft feature, the process comprising:
   disposing a pulp layer on a first female mold;
mating a first male mold with the first female molds, the first male and female molds being separated by a first offset and having reverse draft portions with plurality of indentations configured to form a plurality of pleats on the pulp layer;

5 applying a vacuum to the first male mold, the vacuum being configured to hold the pulp layer against the first female mold;
removing the first female mold;
mating a second female mold with the first male mold;
applying a vacuum to the second female mold, the vacuum being configured to hold the pulp layer against the second female mold;
removing the first male mold;
mating a second male mold with the first female molds, the second male and female molds separated by an offset, smaller than the first offset, and having reverse draft portions configured an angular distance away from the draft;
repeating the mating and removal of subsequent male and female molds until a portion of the pulp layer has a reverse draft feature, positioned at a negative draft angle;
removing final male and female molds, wherein removing the molds expands the circumference of the paper container; and
20 collapsing the paper container at the pleats to form the reverse draft feature.
INTERNATIONAL SEARCH REPORT

International application No. PCT/US 10/32461

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - D21J 1/04 (2010.01)
USPC - 162/227

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC(8) - D21J 1/04 (2010.01)
USPC - 162/227

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

IPC(8) - D21F$; D21J$; D21US (2010.01)
USPC - 162/218, 227, 220, 362

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

PubWest (PGPB,USPTO,USOC,EPAB,JPAB); USPTO; Espacenet; Google Patents; Google Scholar; Google -- please see extra sheet

C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<th>Category*</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
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<tr>
<td>Y</td>
<td>WO 2006/057609 A1 (Nilsson et al.) 01 June 2006 (01.06.2006) Figs 1-3; page 1, In 5-9; page 8, In 18-25; page 16, In 12-30</td>
<td>1-19</td>
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<td>Y</td>
<td>US 2004/0013830 A1 (Nonomura et al.) 22 January 2004 (22.01.2004) Figs 5(a) through 5(f); para [0151]; [0154] to [0157]; [0160]; [0162]; [0163]</td>
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<td>US 5,127,815 A (Yalta et al.) 07 July 1992 (07.07.1992) Fig 2; Fig 5; Figs 10-12; col 3, In 41-48; col 6, In 26-28; col 7, In 41-60</td>
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Further documents are listed in the continuation of Box C.

* Special categories of cited documents:
  "A" document defining the general state of the art which is not considered to be of particular relevance
  "E" earlier application or patent but published on or after the international filing date
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  "&" document member of the same patent family

Date of the actual completion of the international search
21 SEPTEMBER 2010 (21.09.2010)

Date of mailing of the international search report
05 OCT 2010

Name and mailing address of the ISA/US
Mail Stop PCT, Attn: ISA/US, Commissioner for Patents
P.O. Box 1450, Alexandria, Virginia 22313-1450
Facsimile No. 571-273-3201

Authorized officer:
Lee W. Young
PCT Hq: 571-272-4300
PCT DSP: 571-272-7774

Form PCT/ISA/210 (second sheet) (July 2009)
### DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
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<td>US 2005/0035495 A1 (Baker et al.) 17 February 2005 (17.02.2005) Fig 1; Fig 2; Fig 4; para [0004]; [0005]</td>
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<td>US 4,096,986 A (Florian) 27 June 1978 (27.06.1978) Fig 1; Fig 2; Fig 3; col 5, ln 50-63</td>
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<td>US 6,451,235 B1 (Owens) 17 September 2002 (17.09.2002) Fig 7; Fig 8; abstract</td>
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<td>A</td>
<td>US 4,284,226 A (Herbst) 18 August 1981 (18.08.1981) Figs 2-5; abstract</td>
<td>9, 10, 13, 19</td>
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Search Terms Used:
ANGLE BASE BOTTOM CELLULOSE CONTAINER CUP CYCLE DENSE DENSITY DRAFT EMBOSSED FEMALE FIBER FIN FINNED IMPRINTS MALE MOLD PLEATS PRESSURE PULP REINFORCED REPEETITIVE REVERSE RIB RIBBED SEQUENCE SEQUENTIALS STABILITY STABLE TEAR TEARING TEXTURE THICKNESS THIN THINNESS VACUUM SLURRY WALL-THICKNESS WALL WOOD REVERSE DRAFT NEGATIVE DRAFT FLUTE FOLD