Abstract Title: A method of producing pulp-moulded products, a mould for use in such a method and an apparatus for incorporating such a method

A method of forming a pulp-moulded article 106 comprises the step of exciting water molecules in a pulp work piece by subjecting the work piece to a radio frequency (RF) field. The method involves placing the work piece between two electrodes 100 which form mould halves and subjecting the work piece to a radio frequency of between 10-100 MHz such that any water in the work piece is heated and evaporates. The mould halves (202 figure 9) may be maintained above ambient temperature by the use of steam pipes (206 figure 9) in the mould halves. The electrodes may be of a mesh or porous structure (402 figure 11) to act as a passageway for the removal of the gas or steam generated by the heating of the work piece and which may be further assisted by a suction force. A computer controller (128 figure 6) may be used to continuously monitor and control the apparatus (120 figure 6). There are two other embodiments relating to a mould and apparatus for the production of a pulp moulded article.
Virgin Paper + Water

Shredding
Breakup paper into fibre

Fine Craving
Mix fibre with water

Dosing
Add in additives

Cold Pressing
Press water out

Forming
Vacuum forming

Hot Pressing
Evaporate water

Dry Pulp Containers

FIG. 1
FIG. 16
A Method of Producing Pulp-Moulded Products, a Mould for Use in such a Method and an Apparatus incorporating such a Mould

This invention relates to a method of producing pulp-moulded products, a mould for use in such a method, and a machine incorporating such a mould and, in particular, such a method with an improved drying process.

Pulp is nowadays used for the production of many products, including, e.g. food containers, liquid vessels, or packaging materials, mainly for its biodegradable characteristic. There are two main methods of producing such containers, namely the dry 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 integrally with a uniform thickness.

Fig. 1 hereof shows schematically the steps whereby a conventional wet method is carried out to produce pulp-moulded products. Such a 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 wood fibre, bamboo, or cane, are fed into a mixer, which breaks up the paper. In the fine carving stage, the paper broken up in the shredding stage is fed into a processor for further mixing the paper with the water, and allowing the plant fibre to align with one another. 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 plant fibre, and thus the product so manufactured. In the forming stage, the plant fibre is filled into a chamber, and supported by a lower mould half. Water is drawn out from the wet plant fibre by vacuum. The material, which at this stage will be similar to the structure of wet tissue papers, will then, in the cold pressing stage, be pressed between the lower mould half and an upper mould half to further press some of the remaining water. After this stage, the material will be formed into the general shape and configuration of the final product. The cold-pressed product will then be positioned within a mould formed of a pair of mould halves for hot pressing. The product will be heated by the hot mould to
around 150°C to 180°C for about 45 to 60 seconds, to completely dry up the product.

Fig. 2 shows a pair of metal mould halves which are used in a conventional drying process in the wet method for producing pulp-moulded products. As shown in Fig. 2, a wet pulp work piece 10 is sandwiched between metal mould halves 12A, 12B. The metal mould halves 12A, 12B are heated up, e.g. to around 150°C to 180°C by an electric heater or steam pipes 14 within the mould halves 12A, 12B. To allow water in the form of steam to escape from the work piece 10 to the outside environment, the mould halves 12A, 12B may contain some ventilation channels. It generally takes 45 to 60 seconds to complete the drying process.

This conventional drying process however suffers from a number of disadvantages. As heat is conducted from the outside, i.e. the mould, into the interior of the wet pulp work piece, the outer layer of the material will be dried up earlier. This outer layer will act as a barrier, hindering the evaporation of steam from the interior. As heat energy is continuously supplied to dry the pulp work piece, the trapped steam will build up in pressure and may eventually burst through the outer dried layer, thus causing surface cracking, porosity, and uneven solid dispersion. The surface temperature of the metal moulds must therefore be kept at a lower temperature to reduce the heating rate; and this would, unavoidably, result in a long drying time. In addition, even if the heating rate is reduced, problems such as skin on the coatings, surface discoloration, and surface cracking will still often arise. These problems will have a direct impact on the production yield and operation cost of the manufacturing plants.

It is thus an object of the present invention to provide a method of producing pulp-moulded products, a mould for use in such a method, and an apparatus incorporating such a mould, 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 a step of exciting water molecules in a pulp work piece by subjecting said work piece to a radio frequency (RF) field.
According to a second aspect of the present invention, there is provided a mould for the production of a pulp-moulded article, including a first and a second electrically conductive parts which are, when connected to an RF source, adapted to generate an RF field in a space between said electrically conductive parts.

According to a third aspect of the present invention, there is provided an apparatus for the production of a pulp-moulded article, including a mould including at least a first and a second electrically conductive parts which are, when connected to an RF source, adapted to generate an RF field in a space between said electrically conductive parts.

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

Fig. 1 shows schematically the steps whereby a conventional wet method is carried out to produce pulp-moulded products;

Fig. 2 shows a metal mould used in a conventional drying process in the wet method for producing pulp-moulded products;

Fig. 3 shows a mould, according to a first embodiment, used in a drying process of a method for producing pulp-moulded products according to the present invention;

Fig. 4 shows the comparative rate of reduction of moisture (water) from a work piece undergoing conventional heating and RF heating respectively;

Fig. 5 shows schematically the reaction of water (H₂O) molecules to an alternating electric field, as in the case of RF heating;

Fig. 6 shows a schematic drawing of an apparatus incorporated with a mould according to the present invention for working a method according to the present invention;

Fig. 7 shows a piece of pulp sandwiched between a pair of electrodes;

Fig. 8 shows a piece of pulp and an insulator sandwiched between a pair of electrodes;

Fig. 9 shows a mould, according to a second embodiment, used in a drying process of a method for producing pulp-moulded products according to the present invention;

Fig. 10 shows a mould, according to a third embodiment, used in a drying process of a method for producing pulp-moulded products according to the present invention;

Fig. 11 shows a mould, according to a fourth embodiment, used in a drying process of a
method for producing pulp-moulded products according to the present invention;
Fig. 12 shows a mould, according to a fifth embodiment, used in a drying process of a
method for producing pulp-moulded products according to the present invention;
Fig. 13 shows a mould, according to a sixth embodiment, used in a drying process of a
method for producing pulp-moulded products according to the present invention;
Fig. 14 shows a mould, according to a seventh embodiment, used in a drying process of a
method for producing pulp-moulded products according to the present invention;
Fig. 15 shows a mould, according to an eighth embodiment, used in a drying process of a
method for producing pulp-moulded products according to the present invention; and
Fig. 16 shows a mould, according to a ninth embodiment, used in a drying process of a
method for producing pulp-moulded products according to the present invention.

Referring now to Fig. 3, a mould according to a first embodiment of the present
invention, comprising two mould halves 100, used in a drying process of a method for
producing pulp-moulded products according to the present invention, is shown. The mould
halves 100, which are made of a porous metal, are connected to a high voltage radio
frequency (RF) generator 102, so that, during operation, the mould halves 100 act as a pair of
electrodes for generating an RF field between a space 104 between them. A wet pulp work
piece 106 is sandwiched between the mould halves 100, so that it will be subject to the
influence of the RF field in the space 104 between the mould halves 100.

As generally understood, radio frequency ranges from 10 kHz to 100 GHz. It is found
that the present invention may preferably be carried out with a RF field of between 10 to 100
MHz, and more preferably at a frequency of around 27 MHz, e.g. 27.12 MHz.

Conventional heating methods include heating by conduction, convection and radiation.
Such methods heat the material from outside, so that heat energy is first transferred to the
surface of the material, and subsequently conducted to the interior of the material. In the
present case, if the wet pulp work piece is heated by a conventional heating method, the outer
region will be relatively hot and dry whereas the interior part still remains relatively cold and
wet. On the other hand, in RF heating, which is also called dielectric heating, as heating
occurs at the molecular level across the whole of the material, in a manner to be discussed
further below, essentially the whole of the work piece undergoes heating simultaneously.

In the context of the drying of a wet pulp work piece, e.g. a container, as the material with which the work piece is made, e.g. paper, is a poor heat conductor, such cannot be easily dried up totally. A product dried by a conventional heating method will be dry on the outside but remain cold and wet in the interior. The dry outer region acts as a barrier, reducing the rate of transmission of heat energy to the interior of the product, thus increasing the drying time and, therefore, reducing the production speed. When further heat is transferred from the outside to the product, in the hope of also drying its interior, the outer region may be over-heated and cracks may develop.

On the other hand, in the case of RF heating, the heating occurs generally across the whole of the material, so no hot and dry outer layer will develop. In the case of a wet pulp work piece, as the water in the interior of the work piece heats up, it moves towards the outer region.

Fig. 4 shows the comparative rate of reduction of moisture (water) from a work piece undergoing conventional heating and RF heating respectively. It can be seen that it takes a shorter time, \( t_1 \), to reduce the moisture content of the work piece to a specific level, \( m \), by RF heating, than by a conventional heating method, for which a longer time, \( t_2 \), is required.

Because of the characteristics of RF heating, it can provide the following advantages over conventional heating methods:

- In RF heating of wet pulp work pieces, heating occurs selectively in areas where heat is required, because water is much more responsive to RF heating than dried pulp material. Since wetter regions will absorb more RF energy than drier regions, more water will be heated up and removed from the wetter regions, resulting in a more uniform moisture distribution across the whole work piece. In addition, as heating occurs from within the work piece, no dry outer layer will develop, thus providing a more uniform dispersion of sizing and additives through the work piece.

- During RF heating, water moves through the product in the form of a gas instead of by capillary action, and the solids in the work piece cannot so migrate, the problems of
warping, surface discoloration and cracking associated with conventional heating methods can be avoided.

No over-heating of the work piece will occur as RF heating is self-limiting: no heating will occur once the work piece is dry, since no, or next to no, water will remain in the work piece for heating. The quality of the product can therefore be guaranteed.

In conventional heating method, e.g. in the arrangement shown in Fig. 2, discussed above, even if the mould halves 12A are not in operation, it is still necessary to provide heat to them so as to maintain their temperature for subsequent operation. However, in the case of RF heating, the RF field can be generated or removed by a simple “ON”/“OFF” operation, and no warming up/cooling down cycles are involved, thus further reducing the use of energy.

Additionally, as heating begins instantaneously throughout the process, the dwell time in an RF drying system is far less than that in a conventional drying system, thus achieving faster work cycle. Furthermore, as compared with the 45 to 60 seconds required in conventional heating, it takes only about 10 to 20 seconds to complete drying by RF heating, thus further reducing the processing time.

RF heating is an environmentally friendly process as no combustion by-product needs be exhausted.

The basic theory of RF heating is that dielectric materials heat up when placed in a high voltage, high frequency electric field. The best materials for RF heating are those that are neither good electric conductors nor good electric insulators, e.g. water. Fig. 7 shows the reaction of polar molecules, such as water (H₂O) molecules, in a material to a high-frequency high-voltage alternating electric field, as in the case of RF heating. A triode oscillator (RF generator) 110 generates an alternating electric field in the RF range, e.g. 27.12 MHz between two electrodes 112. A wet work piece 114 to be dried is positioned between the electrodes 112, and subject to the influence of the RF field. The RF field causes the polar water molecules (represented in Fig. 7 by spheres with “+” and “-” signs connected by a respective bar) to move so as to seek to orient themselves relative to polarity of the electrodes 112. However, as the RF field alternates at such a high frequency, the movement of the water molecules will continue so long as the RF field is present.
In RF heating, two heating mechanisms are present, namely ionic conduction and dipole rotation. In ionic conduction, charged particles, e.g. ions, always move toward an oppositely charged plate. In the case of the above RF field, the polarity of the respective electrodes 112 alternates at 27.12 MHz, i.e. over twenty-seven million times per second, these ions will constantly be moving and colliding with other particles, creating friction and heat, thus warming up the material 114. The power inputted into the material by ionic conduction depends on the voltage gradient in the material 114 and the conductivity of the material 114. Frequency has no effect on the power in ionic conduction.

As to dipole rotation, as the water molecules rotate to align themselves with the electric field, and as the electric field changes polarity several millions of times per second, the water molecules try to align themselves so rapidly that they generate much heat by rubbing on their neighbouring molecules millions of times per second. The power inputted in the material by dipole rotation can be described by the following general Formula I:

\[ P = 5.5 \times 10^{-13} K \times PF \times f^2 \left( \frac{V}{S} \right)^2 \] ..........................(I)

where
- \( P \) is the power per unit volume of material;
- \( V \) is the voltage across the material;
- \( f \) is the frequency of the electric field;
- \( K \) is the dielectric constant of the material;
- \( S \) is the thickness of the material; and
- \( PF \) is the loss factor of the material.

The relationship among these factors is complicated by the fact that the loss factor (PF) and dielectric constant (K) both vary with frequency, temperature and moisture content. The PF value is a material property that determines how well the material can absorb RF energy. If the material has a high PF value, it will absorb RF energy quickly and thus heats up faster. On the other hand, if a material has a low PF value, it will absorb RF energy slowly and thus heats up slowly. In general, paper tends to have a low PF value and thus does not heat up quickly. Water, on the other hand, has a high PF value, and so it will heat up quickly under an RF field. This explains why RF heating works well with drying wet
pulp moulded products: it heats the water content quickly but does not heat up the paper significantly. In addition, the reduction in loss factor \((PF)\) or receptivity to RF energy as the material continues to dry provides a valuable safeguard against over-heating. RF drying is thus ideal for applications where uniformity of product dryness is an important requirement.

Fig. 6 shows a schematic drawing of an apparatus, generally designated as 120, incorporated with a mould according to the present invention for working a method according to the present invention. The apparatus 120 includes one or more power supplies 122 supplied with AC (50 or 60 Hz) three-phase or single-phase power inputs. The electric power from the power supplies 122 is supplied to an RF generator 124 \emph{via} a high-power cable 126, and to a computer/controller system 128 \emph{via} a low-power cable 130 for powering the computer/controller system 128. The computer/controller system 128 acts to control the operation of the RF generator 124 and also the positions of a tuning capacitor or inductor 131. The RF generator 124, coupled \emph{via} the tuning capacitor or inductor 131, generates a high-voltage radio-frequency (e.g. 27.12 MHz) field across a pair of moulds 132 to excite the water molecules in a load 134, e.g. a wet pulp work piece. This high voltage RF output is continuously adjusted by tuning the capacitor or inductor 131 to match with the power input and RF response of the mould system (i.e. the pair of moulds 132 and the load 134). In order to achieve the above result, a sensor system 136 is connected to the tuning capacitors or inductor 131, the load 134, and the RF generator 124, for sensing the state of operation of the apparatus, and sending feedback signals to the computer/controller system 128, so that the computer/controller system 128 can continuously monitor and adjust the operation of the apparatus 120.

A wet pulp work piece 150 is shown in Fig. 7 as being positioned between a pair of electrodes 152 connected to a high-voltage RF generator 154 for drying. The power dissipation \((PD_{\text{pulp}})\) required to dry the pulp work piece 150 is given by the following Formula II:

\[
PD_{\text{pulp}} = \frac{mC_p\Delta T + mL_w}{t}
\]

\(\text{(II)}\)

where \(m\) is the mass of the water to be heated and evaporated,
\( C_p \) is the specific heat capacity of water, which is 4.184 J\(\text{kg}^{-1}\text{K}^{-1} \);
\( \Delta T \) is the temperature rise;
\( L_w \) is the latent heat of vaporization of water, which is 2,260 kJ/kg; and
\( t \) is the time to finish the heating and evaporating process.

Let us assume that the wet pulp work 150 is at a temperature of 25\(^\circ\)C, contains 35g of water, and of a length of 38 cm, a width of 20 cm and a thickness of 0.1 cm, and that the water is to be totally evaporated (at 100\(^\circ\)C) by RF heating in 10 seconds. Thus, \( m = 0.035 \) kg; \( \Delta T = 75^\circ \text{C} \); and \( t = 10 \) s. The pulp power dissipation \((PD_{pulp})\) in this example is thus 9008 W, and the power dissipation per unit volume of pulp \((P_{pulp})\) is 118.5 W/cm\(^3\).

Rearranging Formula I above, we have the following Formula III:

\[
\frac{V}{S} = \frac{P_{pulp}}{\sqrt{(5.5 \times 10^{-13}) K_{pulp} \times PF_{pulp} \times f}} \quad \text{(III)}
\]

Taking the above example further, and assume that:
- the relative permittivity of pulp \(K_{pulp}\) is 6;
- the power loss factor of pulp \(PF_{pulp}\) is 0.5; and
- the radio frequency applied is 27.12 MHz.

In an ideal situation, i.e. a perfect machine scenario, the electric field strength required, \(E_{pulp}\) (i.e. \(\frac{V}{S}\) in Formula III above), is 1,615 V/cm, and the RF voltage across the pulp \((V_{pulp})\) is 161.5 V, as the pulp is of a thickness of 0.1 cm, as given above.

As water can conduct electricity and has a very low breakdown voltage, electric sparks may pass between the mould halves when the voltage across the pulp work piece increases, thus producing an “arching” effect. Thus, and as shown in Fig. 8, a wet pulp work piece 160 is positioned between a pair of electrodes 162 connected to a high-voltage RF generator 164 for drying. The main difference between this arrangement and the arrangement shown in Fig. 7 is that an electric insulator 166, e.g. a TEFLON plate, is positioned between the pulp
work piece 160 and one of the electrodes 162, with all other parameters remaining as in the
example shown in Fig. 7 and discussed above.

TEFLON is a polytetrafluoroethylene (PTFE), which is a highly stable
tetrafluoroethylene homopolymer or polymer composed of a large number of C\textsubscript{2}F\textsubscript{4} monomer
units linked into very long unbranched chains. This homopolymer is chemically very inert,
and is a good electric insulator in high frequency applications. It should be understood that
TEFLON is used here as the insulating plate for illustration purpose only, and other good
electric insulators may also be used.

Let us assume the following values for the example shown in Fig. 8:
- the thickness of the TEFLON plate (D\textsubscript{f}) is 0.9 cm;
- the loss factor of the TEFLON plate (PF\textsubscript{f}) is 0.0003;
- the dielectric constant of the TEFLON plate (K\textsubscript{f}) is 2.1; and
- the breakdown voltage of the TEFLON plate (V\textsubscript{BWT}) is 80 kV/mm.

As the TEFLON plate and the pulp work piece are perpendicular to the electric field,
there should be no free surface charge between the interface of the TEFLON plate and the
pulp work piece. The electric field strength across the insulating TEFLON plate (E\textsubscript{T}) is thus
given by the following Formula IV:

\[
E_T = \frac{E_{pulp} * K_{pulp}}{K_T} \quad \text{(IV)}
\]

On the above given parameters and given values, E\textsubscript{T} is around 4.62 kV/cm, or 0.462 kV/mm,
which is very much smaller than V\textsubscript{BWT}, and thus no breakdown of the TEFLON plate will
occur, thus avoiding arcing.

The power loss over per unit volume of the TEFLON plate (P\textsubscript{T}) is given by the following
Formula V, which is derived from the general Formula I above:

\[
P_T = 5.5 \times 10^{-13} K_T * PF_T f^* E_T^2 \quad \text{...............(V)}
\]
The value of \( P_T \) in this example is thus 0.203 W/cm\(^3\) and the total power loss over the insulating plate is 138 W.

The overall power required for drying the wet pulp work piece discussed above is the sum total of the power dissipated on heating and drying the pulp work piece itself (i.e. 9,008 W) and the power loss over the insulating plate (i.e. around 138 W), i.e. 9,146 W. If the machine is of an efficiency of 70% for the generation of RF power, the input power required to dry the pulp work piece in 10 seconds would be 13,066 W.

The advantages of using an insulating plate, such as the TEFOLON plate discussed above, include:
- to reduce the tendency of arcing across the mould halves;
- to reduce the sensitivity of the system to the change in moisture content, and thus make it easier to control the working of the system;
- to compensate for small irregularities in the mould surface; and
- to lower the heat loss from the pulp work piece to the mould. The TEFOLON plate thus also acts as a thermal insulator.

It can be seen that the power dissipated (lost) on the TEFOLON plate is only around 1.5% of the total power consumption. Such will be too small an amount to significantly raise the temperature of the TEFOLON plate.

Because of the advantages associated with the inclusion of an electrically insulating layer between the pulp work piece and the electrode(s), further embodiments of the moulds are proposed and will be discussed below.

As shown in Fig. 9, a wet pulp work piece 200 is sandwiched between a pair of metal mould halves 202, to the inner surface of each of which is provided a TEFOLON layer 204. The TEFOLON layers 204 follow the shape and configuration of the pulp-moulded products to be produced. The mould parts 202 are connected to an RF source for generating an RF field for inputting energy to, and thus exciting, the water molecules in the work piece 200. In order to avoid condensation of the heated steam upon contact with the relatively cold mould
halves 202, steam pipes 206 are provided within the mould halves 202 for heating the mould halves 202, e.g. to a temperature above 100°C.

As shown in Fig. 10, provided the TEFLON layer 304 for sandwiching the wet pulp work piece 300 follow the shape and configuration of the finished product, the mould halves 302, which act as the electrodes and are connected to an RF source, can be of various different shapes.

As shown in Fig. 11, a wet pulp work piece 400 is positioned between a pair of porous metal electrodes/mould halves 402, which are connected to an RF source, for RF heating the work piece 400. The porous structure of the mould halves 402 allows easy escape of the steam generated in the heating process from the space between the mould halves 402, and from the mould halves 402 to the outside environment. Moreover, the porous metal electrodes may be replaced by electrodes with other ventilation mechanism (e.g. a mesh network or holes distributes across the electrode surface) to allow evaporation of steam and escape of water from between the moulds during the drying process.

A further embodiment of a pair of moulds is shown in Fig. 12, in which a wet pulp work piece 500 is sandwiched between an upper porous metal mould half 502a and a lower metal mould half 502b installed with steam pipes 506 for maintaining the mould half 502b at an elevated temperature. A layer of TEFLON material 504 is provided on an inner surface of the mould half 502b, so as to be positioned between the work piece 500 and the mould half 502b.

As a further alternative, and as shown in Fig. 13, a pair of metal mould halves 602 are provided. On an inner surface of each metal electrode part 603 is provided an insulating layer, e.g. a TEFLON layer 604, and on an inner surface of each insulating layer 604 is provided an electrically conductive water-ventilation layer 608, which may be of a porous nature. A wet pulp work piece 600 is positioned between the two water-ventilation layers 608. Although each conductive layer 608 is separated from the respective electrode part 603 by an intervening insulating layer 604, charges can still be induced on the conductive layer 608 because it is also inside the alternating electric field of the electrode parts 603.
Thus, the wet pulp work piece 600 can be heated by the RF field generated between the two conductive layers 608, the insulating layers 604 provide a buffer to minimize the chance of arcing, and to reduce the system’s sensitivity to change in moisture content. The conductive water-ventilation layers 608 also provide paths for the escape of steam.

The arrangement in Fig. 8 above is in fact akin to two capacitors, one being the pulp and the other being the TEFLON plate, connected in series with each other. According, therefore, to the same principle, and as shown in Fig. 14, a pair of electrically conducive mould halves 702, between which a pulp work piece 700 is sandwiched, are connected with an RF source 712, and in series with a variable capacitor 710. The variable capacitor 710 serves to reduce the overall capacitance of the mould halves 702 in the RF circuit. Such an arrangement will reduce the chance of arcing occurring between the mould halves 702, and allow the mould halves 702 to work with, or even without, a thin layer of insulating material. As the capacitor 710 is a variable capacitor, the degree to which the overall capacitance of the mould halves 702 in the RF circuit may be reduced may therefore be adjusted.

With a view to enhancing the removal of water, in the form of liquid and/or gas, from the work piece, a further alternative arrangement is proposed and shown in Fig. 15. A work piece 800 is sandwiched between an upper mould halve 802a and a lower mould half 802b. The upper mould half 802 is made of a metal, e.g. aluminum, and coated with a layer of TEFLON material 804. As to the lower mould half 802b, such is also made of a metal, and includes a number of vertical channels 810 leading, on one end, to a surface 812 intended to be in abutment with the work piece 800 during the drying process. Another end of each of the channels 810 is joined with a source of suction force, not shown. By way of such an arrangement, a suction force may be applied through the channels 810 to the work piece 800, to draw out the water in the work piece 800 through the lower mould half 802b, in the direction indicated by the arrows in Fig. 15.

As a further alternative, and as shown in Fig. 16, a work piece 900 is sandwiched between an upper mould half 902a and a lower mould half 902b. As in the case of the embodiment shown in Fig. 15 and discussed above, the lower mould half 902b is provided with a number of channels 910 joined to a source of suction force (not shown) to thereby
enhance the removal of water in the form of gas and/or liquid from the work piece 900. The improvement in this embodiment resides in the fact that the upper mould 902a, which is made of a metal, e.g. aluminum, is also provided with a number of channels 912 joined to a source of suction force, not shown. A layer of TEFLON material 904 is also provided with a number of holes 914 which match and are adjoined with the channels 912, to thereby allow water in the work piece 900 to enter the channels 912, and thus to be removed from the system.

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.

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.
CLAIMS:

1. A method of forming a pulp-moulded article, including a step of exciting water molecules in a pulp work piece by subjecting said work piece to a radio frequency (RF) field.

2. A method according to Claim 1 wherein said water molecules in said work piece is heated by said RF field.

3. A method according to Claim 1 wherein said water molecules in said work piece is evaporated by said RF field.

4. A method according to Claim 1 wherein said RF field is at a frequency of 10 to 100 MHz.

5. A method according to Claim 4 wherein said RF field is at a frequency of substantially 27.12 MHz.

6. A method according to Claim 1 further including a step of positioning said work piece between two electrodes adapted to generate said RF field.

7. A method according to Claim 6 further including a step of heating and maintaining said electrodes at a temperature above the ambient temperature.

8. A method according to Claim 6 further including a step of providing an electrically insulating layer between said work piece and at least one of said electrodes.

9. A method according to Claim 8 wherein further including a step of providing an electrically insulating layer between said work piece and each of said electrodes.

10. A method according to Claim 6 wherein at least one electrode contains at least one passage for removal of a gas or liquid.

11. A method according to Claim 10 wherein both electrodes contain at least one passage for removal of a gas or liquid.

12. A method according to Claim 10 or 11 wherein at least part of said electrode(s) is of a mesh or porous structure.

13. A method according to Claim 12 wherein the whole electrode(s) is of a mesh or porous structure and adapted to act as a homogeneous passageway.

14. A method according to Claim 10 or 11 wherein said gas is steam.

15. A method according to Claim 10 or 11 wherein said liquid is water.

16. A method according to Claim 10 or 11 wherein said gas or liquid is removed by virtue of pressure built up in said work piece.
17. A method according to Claim 10 or 11 further including a step of generating a suction force for removing said gas or liquid.

18. A method according to Claim 8 further including a step of providing an electrically conducting layer on said electrically insulating layer.

19. A method according to Claim 9 further including a step of providing an electrically conducting layer on each of said electrically insulating layers.

20. A method according to Claim 6 further including a step of electrically connecting said electrodes with a capacitor.

21. A method according to Claim 20 wherein said capacitor is a variable capacitor.

22. A mould for the production of a pulp-moulded article, including a first and a second electrically conductive parts which are, when connected to an RF source, adapted to generate an RF field in a space between said electrically conductive parts.

23. A mould according to Claim 22 wherein a layer of an electrically insulating material is provided on a surface of at least one said electrically conductive part.

24. A mould according to Claim 23 wherein said layer of an electrically insulating material is, in operation, positioned adjacent a work piece to be formed into a pulp-moulded article.

25. A mould according to Claim 23 wherein a layer of an electrically insulating layer is provided on a respective surface of each of said electrically conductive parts.

26. A mould according to any one of Claims 23 to 25 wherein said electrically insulating layer is made up of a polytetrafluoroethylene.

27. A mould according to Claim 23 wherein a layer of an electrically conducting material is provided on said layer of an electrically insulating material.

28. A mould according to Claim 25 wherein a layer of an electrically conducting material is provided on each of said layers of an electrically insulating material.

29. A mould according to Claim 27 or 28 wherein said layer of an electrically conducting material is a layer of metal of a porous or mesh structure.

30. A mould according to Claim 22 wherein said electrically conductive part includes at least one passageway for removal of a gas or liquid.

31. A mould according to any one of Claims 23 to 25 wherein each said electrically conductive part and the layer of electrically insulating material thereon includes at least one passageway which join with each other for removal of a gas or liquid.
32. A mould according to Claim 22 wherein said electrically conductive part is of a porous or mesh structure allowing the passage of a gas or a liquid.

33. A mould according to Claim 30 wherein said gas is steam.

34. A mould according to Claim 30 wherein said liquid is water.

35. An apparatus for the production of a pulp-moulded article, including a mould including at least a first and a second electrically conductive parts which are, when connected to an RF source, adapted to generate an RF field in a space between said electrically conductive parts.

36. An apparatus according to Claim 35 wherein a layer of an electrically insulating material is provided on a surface of at least one said electrically conductive part.

37. An apparatus according to Claim 36 wherein said layer of an electrically insulating material is, in operation, positioned adjacent a work piece to be formed into a pulp-moulded article.

38. An apparatus according to Claim 36 wherein a layer of an electrically insulating layer is provided on a respective surface of each of said electrically conductive parts.

39. An apparatus according to any one of Claims 36 to 38 wherein said electrically insulating layer is made up of a polytetrafluoroethylene.

40. An apparatus according to Claim 36 wherein a layer of an electrically conducting material is provided on said layer of an electrically insulating material.

41. An apparatus according to Claim 38 wherein a layer of an electrically conducting material is provided on each of said layers of an electrically insulating material.

42. An apparatus according to Claim 38 or 41 wherein said layer of an electrically conducting material is a layer of metal of a porous or mesh structure.

43. An apparatus according to Claim 35 wherein said electrically conductive part is of a porous or mesh structure allowing the passage of a gas or a liquid.

44. An apparatus according to Claim 43 wherein said gas is steam.

45. An apparatus according to Claim 43 wherein said liquid is water.

46. An apparatus according to Claim 35 wherein said electrically conductive parts are electrically connected to a variable capacitor.

47. A method of forming a pulp-moulded article substantially as herein described and with reference to the accompanying drawings.

48. A mould for the production of a pulp-moulded article substantially as herein described.
and with reference to any one of Figs. 3 and 9-16 of the accompanying drawings.

49. An apparatus for the production of a pulp-moulded article substantially as herein described and with reference to any one of Figs. 3 and 9-16 of the accompanying drawings.
Amendments to the claims have been filed as follows

CLAIMS:

1. A method of forming a pulp-moulded article, including the steps of (a) exciting water molecules in a pulp work piece by subjecting said work piece to a radio frequency (RF) field; (b) positioning said work piece between two electrodes adapted to generate said RF field; and (c) providing an electrically insulating layer between said work piece and at least one of said electrodes.

2. A method according to Claim 1 wherein said water molecules in said work piece is heated by said RF field.

3. A method according to Claim 1 wherein said water molecules in said work piece is evaporated by said RF field.

4. A method according to Claim 1 wherein said RF field is at a frequency of 10 to 100 MHz.

5. A method according to Claim 4 wherein said RF field is at a frequency of substantially 27.12 MHz.

6. A method according to Claim 1 further including a step of heating and maintaining said electrodes at a temperature above the ambient temperature.

7. A method according to Claim 1 wherein further including a step of providing an electrically insulating layer between said work piece and each of said electrodes.

8. A method according to Claim 1 wherein at least one electrode contains at least one passage for removal of a gas or liquid.

9. A method according to Claim 8 wherein both electrodes contain at least one passage for removal of a gas or liquid.

10. A method according to Claim 8 or 9 wherein at least part of said electrode(s) is of a mesh or porous structure.

11. A method according to Claim 10 wherein the whole electrode(s) is of a mesh or porous structure and adapted to act as a homogeneous passageway.

12. A method according to Claim 9 or 10 wherein said gas is steam.

13. A method according to Claim 9 or 10 wherein said liquid is water.

14. A method according to Claim 9 or 10 wherein said gas or liquid is removed by virtue of pressure built up in said work piece.

15. A method according to Claim 9 or 10 further including a step of generating a suction force for removing said gas or liquid.
16. A method according to Claim 1 further including a step of providing an electrically conducting layer on said electrically insulating layer.

17. A method according to Claim 7 further including a step of providing an electrically conducting layer on each of said electrically insulating layers.

18. A method according to Claim 1 further including a step of electrically connecting said electrodes with a capacitor.

19. A method according to Claim 18 wherein said capacitor is a variable capacitor.

20. A mould for the production of a pulp-moulded article, including a first and a second electrically conductive parts which are, when connected to an RF source, adapted to generate an RF field in a space between said electrically conductive parts, wherein a layer of an electrically insulating material is provided on a surface of at least one said electrically conductive part.

21. A mould according to Claim 20 wherein said layer of an electrically insulating material is, in operation, positioned adjacent a work piece to be formed into a pulp-moulded article.

22. A mould according to Claim 20 wherein a layer of an electrically insulating layer is provided on a respective surface of each of said electrically conductive parts.

23. A mould according to any one of Claims 20 to 22 wherein said electrically insulating layer is made up of polytetrafluoroethylene.

24. A mould according to Claim 20 wherein a layer of an electrically conducting material is provided on said layer of an electrically insulating material.

25. A mould according to Claim 22 wherein a layer of an electrically conducting material is provided on each of said layers of an electrically insulating material.

26. A mould according to Claim 24 or 25 wherein said layer of an electrically conducting material is a layer of metal of a porous or mesh structure.

27. A mould according to Claim 20 wherein said electrically conductive part includes at least one passageway for removal of a gas or liquid.

28. A mould according to any one of Claims 20 to 22 wherein each said electrically conductive part and the layer of electrically insulating material thereon includes at least one passageway which join with each other for removal of a gas or liquid.

29. A mould according to Claim 20 wherein said electrically conductive part is of a porous or mesh structure allowing the passage of a gas or a liquid.
30. A mould according to Claim 27 wherein said gas is steam.

31. A mould according to Claim 27 wherein said liquid is water.

32. An apparatus for the production of a pulp-moulded article, including a mould including at least a first and a second electrically conductive parts which are, when connected to an RF source, adapted to generate an RF field in a space between said electrically conductive parts, wherein a layer of an electrically insulating material is provided on a surface of at least one said electrically conductive part.

33. An apparatus according to Claim 32 wherein said layer of an electrically insulating material is, in operation, positioned adjacent a work piece to be formed into a pulp-moulded article.

34. An apparatus according to Claim 32 wherein a layer of an electrically insulating layer is provided on a respective surface of each of said electrically conductive parts.

35. An apparatus according to any one of Claims 32 to 34 wherein said electrically insulating layer is made up of a polytetrafluoroethylene.

36. An apparatus according to Claim 32 wherein a layer of an electrically conducting material is provided on said layer of an electrically insulating material.

37. An apparatus according to Claim 34 wherein a layer of an electrically conducting material is provided on each of said layers of an electrically insulating material.

38. An apparatus according to Claim 34 or 37 wherein said layer of an electrically conducting material is a layer of metal of a porous or mesh structure.

39. An apparatus according to Claim 32 wherein said electrically conductive part is of a porous or mesh structure allowing the passage of a gas or a liquid.

40. An apparatus according to Claim 39 wherein said gas is steam.

41. An apparatus according to Claim 39 wherein said liquid is water.

42. An apparatus according to Claim 32 wherein said electrically conductive parts are electrically connected to a variable capacitor.

43. A method of forming a pulp-moulded article substantially as herein described and with reference to the accompanying drawings.

44. A mould for the production of a pulp-moulded article substantially as herein described and with reference to any one of Figs. 9-16 of the accompanying drawings.

45. An apparatus for the production of a pulp-moulded article substantially as herein described and with reference to any one of Figs. 9-16 of the accompanying drawings.
Application No: GB0408785.4
Claims searched: 1-21
Examiner: Mr Haydn Gupwell
Date of search: 6 July 2004

Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

<table>
<thead>
<tr>
<th>Category</th>
<th>Relevant to claims</th>
<th>Identity of document and passage or figure of particular reference</th>
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<tr>
<td>X</td>
<td>1-3, 6, 22 &amp; 35</td>
<td>JP 06049800 A (UTSUI) see abstract.</td>
</tr>
<tr>
<td>X</td>
<td>1-3, 6, 22 &amp; 35</td>
<td>JP 05076095 A (FOSTER) see abstract.</td>
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<tr>
<td>X</td>
<td>1-4</td>
<td>US 5611882 A (RIEBEL et al) see lines 6-13 column 1, 14-20 column 3, 36-49 column 10 and 28-65 column 11.</td>
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Categories:

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| A        | Document indicating technological background and/or state of the art |
| P        | Document published on or after the declared priority date but before the filing date of this invention |
| E        | Patent document published on or after, but with priority date earlier than, the filing date of this application |

Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC:\(^W\) :

B5A; F4G

Worldwide search of patent documents classified in the following areas of the IPC\(^07\) :

B29C; F26B

The following online and other databases have been used in the preparation of this search report:

EPODOC, WPI, JAPIO.