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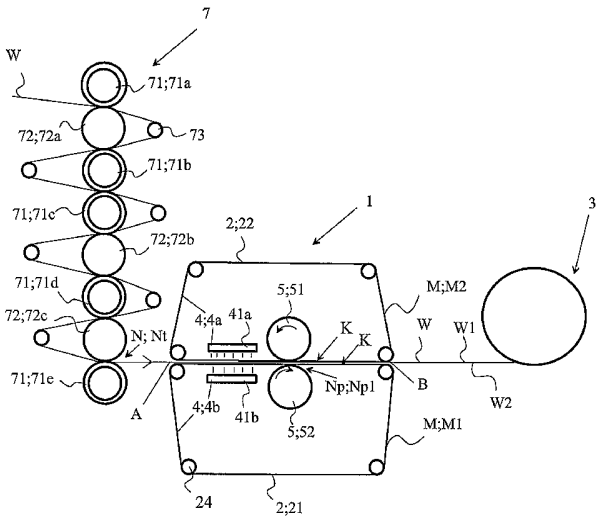
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(54) **Title:** METHOD AND ARRANGEMENT FOR COOLING A FIBROUS WEB



(57) **Abstract:** The invention relates to a method for cooling a fibrous web (W) in the contact region (K) between the fibrous web and a cooling surface, the fibrous web being supported by at least one supporting surface (M) in the said contact region (K), whereby the fibrous web is cooled so that the cooling capacity is mainly transferred to the fibrous web by conduction. In the method, at least one supporting surface (M) and the surface of the fibrous web (W) and at least one cooling surface and the surface of the fibrous web (W) are arranged in a mutual contact in at least a portion of the contact region (K) by pressing the supporting surface/surfaces (M) and the fibrous web (W) and the cooling surface and the fibrous web (W) towards each other at such a compression pressure (P) that the evaporation temperature of the water in the fibrous web rises and that the effective contact area between the fibrous web (W) and the surface that is intended to cool the same becomes sufficient for the cooling capacity.

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Method and arrangement for cooling a fibrous web

The invention relates to a method according to the preamble of Claim 1, for example, for cooling a fibrous web.

The invention also relates to an arrangement according to the preamble of Claim 8, for example, for cooling the fibrous web.

When calendering a paper web before winding the fibrous web onto machine rolls, the final moisture of the web should be about 5%. Furthermore, from the point of view of the rollability, the temperature of the fibrous web should be less than 50°C. An excessively high winding temperature and a low moisture cause winding problems, which are visible as roughness of the tension profile of the machine roll in the lateral direction (CD direction, cross machine direction) and the longitudinal direction (MD direction, machine direction) of the fibrous web. An uneven/poor tension profile of the wound machine roll causes, among others, folding of the fibrous web that is taken from the machine roll, instability of the web, breaks in the web, an uneven quality of the edges, etc.

In calendering, high temperatures of a thermo roll are often used to provide a desired paper quality. In multi-roll calenders, in particular, the fibrous web easily dries to less than 5% of the moisture level, which is ideal for winding, due to the high temperature of the thermo rolls and the open web transfer between the roll nips. The temperature of the fibrous web leaving the multi-roll calender is often 80 to 90°C after the last roll nip of the calender, i.e., considerably higher than what would be desirable for the winding (less than 50°C). Therefore, the fibrous web must be cooled before winding onto a machine roll. It is well-known to cool the paper web by cooling cylinders. However, the cooling capacity of the cooling cylinders is relatively low, which is why several cooling cylinders are generally used, whereby the fibrous web must be conveyed by an open transfer over long distances. In a test that was conducted on different web velocities, it was observed that the fibrous web dries about 1 to 1.5% in a free web transfer after the last calendering nip before arrival at the reel-up station. Because of the drying of the fibrous web, it has been necessary to increase the calendering moisture in multi-roll calenders, in particular. However, the high calendering moisture causes so-called calender blackening. The available calendering window will narrow, if the loss of moisture caused by drying is not compensated for.

In the method known from published patent application DE 102 17 910 and in the arrangement used therein, efforts have been made to prevent the drying of the fibrous web leaving the calender by adding water vapour to the surface of the fibrous web before cooling and during cooling. In the method in question, the surface of the fibrous web is cooled by cooling cylinders. Furthermore, in the method known from the said publication, the fibrous web is conveyed between the cooling cylinders so that it is partly supported by wires, the purpose being to decrease the evaporation of water vapour from the surface of the fibrous web. However, such a cooling method of the fibrous web is relatively ineffective due to the fact that the contact between the fibrous web and the surface of the cooling cylinder that is formed is relatively weak, even if the web was tightened against the cooling surface by means of backing wires, for example. In addition, in the arrangement presented, the fibrous web must be moistened because the fibrous web still dries too much.

The purpose of the invention is to eliminate the problems in the prior art presented above. Accordingly, the first object of the invention is to provide a cooling method and a cooling arrangement used therein, which can be used to effectively prevent the drying of the fibrous web between the calendering unit and the reel-up station. Another object of the invention is to provide a cooling method and an arrangement used therein, which can be used to effectively cool the fibrous web to the desired final moisture.

The above objects are achieved, for example, by the method according to Claim 1 and, for example, the arrangement according to Claim 8.

The invention is based on the fact that the evaporation of moisture from the surface of the fibrous web is prevented by one or preferably two steam-proof supporting surfaces and, simultaneously, by creating a sufficient compression pressure between the fibrous web and the supporting surface, for its part preventing the evaporation of water vapour from the surface of the fibrous web. The compression pressure is provided between the cooling device and the fibrous web, improving the heat transfer by conduction between the hard surface of the cooling device and the fibrous web by increasing the heat transfer surface area on the interface thereof. The fibrous web is either cooled by a conventional cooling cylinder or using, both as the cooling device and the supporting surface of the fibrous web, a material that is good in conducting heat and which is cooled by an external cooler.

In the method according to the invention for cooling the fibrous web in the contact region K between the fibrous web and a cooling surface, with the fibrous web being supported by at least one supporting surface in the said contact region, the fibrous web is cooled so that the cooling capacity is mainly transferred onto the fibrous web by conduction. In the method, at least one supporting surface and the surface of the fibrous web and at least one cooling surface and the surface of the fibrous web are arranged into a mutual contact along at least a portion of the contact region by pressing the supporting surface/surfaces and the fibrous web and the cooling surface and the fibrous web towards each other by such a compression pressure that the temperature of evaporation of the water in the fibrous web increases and that the effective contact area between the fibrous web and the surface intended to cool the same becomes sufficient from the point of view of the cooling capacity.

The contact region herein refers to the interface between the fibrous web and the surface that cools the fibrous web, wherein heat can transfer from one surface to another.

One advantage of such a method compared, for example, with the above-mentioned method, which is known from the published patent application DE 10217910, is that now a sufficiently large effective contact surface area is formed between the fibrous web and the hard cooling surface of the cooling device, having a sufficient heat transfer area and a good cooling capacity. The supporting surface and the fibrous web are preferably pressed against one another by such a force that the compression pressure (P) between the two is at least 0.1 MPa to 15 MPa, preferably 0.5 MPa to 15 MPa. The compression pressure (P) is further preferably dimensioned so that the effective contact surface area between the fibrous web and the surface intended to cool the same is at least 15% from the total contact surface area between the two.

The arrangement according to the invention in turn includes a pressure apparatus, which can be used to arrange at least one supporting surface and the fibrous web and the fibrous web and the surface of the cooling device in such a mutual contact along at least a portion of the contact region, that a compression pressure can be provided between the supporting surface/surfaces and the fibrous web (W) and the cooling surface of the cooling device and the fibrous web (W), by means of which the evaporation temperature of the water in the fibrous web (W) increases and the effective contact area between the fibrous web (W) and the surface of the

cooling device intended to cool the same becomes sufficient from the point of view of the cooling capacity.

The sufficient compression pressure (P) is preferably provided by a pressure apparatus consisting of two roll members, between which a compression nip can be formed.

In a preferred embodiment of the invention, the fibrous web is arranged in a mutual contact with the supporting surfaces in the contact region, and the cooling of the fibrous web is carried out by cooling both supporting surfaces by similar or different cooling capacities. In this way, cooling and a supported transfer is arranged for the fibrous web between closed surfaces, whereby moisture will not evaporate from the fibrous web and the contact region between the fibrous web and the cooled supporting surface becomes good.

In another preferred embodiment of the invention, the supporting surface that cools the fibrous web is cooled by spraying fluid or gas onto the supporting surface. The supporting surface is preferably an endless belt, such as a metal belt, which is impermeable to liquid, flexible, inelastic, and heat conductive. When the supporting surface conducts heat well and does not permeate water vapour, the advantage is achieved that the convection of steam through the same is effectively prevented and, at the same time, the supporting surfaces can be cooled on the other side by a suitable cooler. When so desired, the supporting surfaces located on different sides of the fibrous web can also be cooled by coolers having a different cooling capacity.

The other advantages provided by the invention include the following:

The calendering process can be dimensioned better on the basis of the nip process without needing to take into consideration the drying effect of the cooling process after the calender on the quality of the fibrous web to be wound. No water evaporates from the fibrous web in the cooling process, whereby lower inlet moistures of the fibrous web can be used in calendering, avoiding calender blackening, among others. The advantage is considerable for smooth printing paper (SC), among others, the finishing of which is carried out by multi-roll calenders. Also post-graining is reduced. As no energy is consumed for unnecessary heating and evaporation of water, the temperature of the thermo rolls in calendering can be reduced. A supported web transfer from calendering to the winding stage improves/ensures the runnability. Using the method, the energy balance of the cool-

ing process and the calendering improves, as no energy is wasted and it does not stress the air conditioning of the factory hall.

The other advantages provided by the invention and its features will be apparent from the appended detailed description of the invention and the dependent claims.

In the following, the invention is described in more detail with reference to the appended drawings.

Fig. 1 shows an arrangement according to the invention, which is viewed directly at one end of the cooling arrangement, when the arrangement is applied to the cooling of a paper web after a multi-roll calender.

Fig. 2 shows an alternative embodiment of the cooling arrangement according to the invention, which is also viewed at the one end of the arrangement.

Fig. 3 shows in more detail a portion of the contact region K in the cooling arrangement of Fig. 1.

Figs. 4A to 4C illustrate the preheating and cooling device used in connection with the cooling arrangement according to the invention, which is viewed directly at the end of the equipment.

In the following, the structures and functions presented in Figs. 1 to 3 are generally dealt with first.

Fig. 1 shows a cooling arrangement 1 according to the invention, which is located right after the last roll nip N; Nt of a multi-roll calender 7 but before a reel-up 3, which is used to wind up the paper web W to form machine rolls. The cooling arrangement 1 includes two cooling devices 4; 4a and 4; 4b, which are used to cool the upper and lower surfaces of the fibrous web W in the contact region K. The cooling devices 4 include the metal belts M; M1, M2 of endless metal belts 2; 22, 21 that support the fibrous web and, for example, corresponding fluid coolers 41b and 41a that cool the outer surface of each belt. The outer surface of the belt M refers to the side of the said belt, which is turned away from the fibrous web that is supported by the belt. The metal belts M; M2 and M; M1 of the endless metal belts 2, which support the fibrous web on both sides, travel on both sides of the fibrous web W, closing the fibrous web W between them in the contact region K.

In the contact region K, the fibrous web W travels through a roll-nip (compression nip) Np; Np1 between two rider rolls 5; 51 and 5; 52 that are located opposite to each other and used as a pressure apparatus 5, the rider rolls being used to rise the compression pressure P, which is provided by the compression force F that presses the rolls together between the metal belts M and the fibrous web W travelling between them, to the desired level (the effects of the power are presented in Fig. 3 in more detail).

Fig. 2 presents the cooling arrangement 1 according to the invention, which can be located immediately after the multi-roll calender or another calender. In this cooling arrangement 1, the fibrous web W is also cooled on both sides. The first or the upper side W1 of the fibrous web W is cooled by a cooling device 4; 4c, comprising a cooling cylinder 4; 43, and the other or the lower side W2 of the fibrous web is cooled by a cooling device 4; 4d comprising the metal belt M; M3 of the endless metal belt 2; 23, which is cooled, for example, by a gas cooler 41c. The rider roll 5 is located opposite to the cooling cylinder 43, and the fibrous web W travels between the roll-nip Np; Np2 between the cooling cylinder 43 and the rider roll 5, whereby a sufficiently high compression pressure P can be generated between the fibrous web W and the cooling cylinder 43 (= the roll arranged to be cooled), on the one hand, and, between the fibrous web W and the metal belt M3, on the other hand.

Fig. 3 shows a portion of the interface between the fibrous web W and the metal belts M; M1, M2 of the cooling arrangement according to Fig. 1 in the contact region K. In the contact region K between the fibrous web and the metal belts M that cool the same, the fibrous web and the cooled metal belts that travel on both sides of the web are pressed against each other in the compression nip Np between the rider rolls 5; 51 and 5; 52 by the force $\sum F=Fa + Fb$.

Figs. 4A to 4C show the heat transfer equipment 6 that is used for example in connection with multi-roll calendering to cool or heat one or more fibrous webs.

Fig. 4A shows the heating and the cooling of the fibrous web W, which arrives at the multi-roll calender 7 and leaves the same, by means of the heat transfer equipment 6. The heat transfer equipment consists of a roll 6a that is used as a heat exchanger and guides 6b of the fibrous web.

The heat transfer equipment 6 of the fibrous web shown Fig. 4B differs from that in Fig. 4A mainly in that the heat exchanger, which is used in the equipment, in-

cludes, in addition to the heat exchange roll 6a, also an endless metal belt 6c and guides 6b of the fibrous web. The heat transfer equipment according to Fig. 4b can be used in connection with both calendering and the other unit processes of the paper machine, where the fibrous web must be heated and/or cooled.

Fig. 4C illustrates the heat transfer equipment 6 that is used in connection with the multi-roll calender 7, for example. Now, the heat exchanger comprises a pair of rolls 61 that is provided with a drive, the endless metal belt M being fitted around the pair of rolls.

In the following, the invention is described in more detail with reference to Figs. 1 to 4 and the general description of the figures presented above.

The exemplary embodiment of the invention shown in Figs. 1 and 2 illustrate the cooling arrangement 1 according to the invention, where in the contact region K, cooling is arranged for the fibrous web W, as well as supported transfer by one or two metal belts M that are used as a closed supporting surface M. The closed supporting surface refers to a surface that supports the fibrous web on its upper or lower side, the admission of water vapour being prevented through the surface. The evaporation of water vapour from the upper or lower surface of the fibrous web W is also partly prevented by generating a positive pressure between the fibrous web W and the metal belt M by means of a pressure apparatus 5, which consists of two opposite rolls, between which a compression nip (roll-nip) Np is formed. In the roll-nip Np, the fibrous web and the metal belt are pressed towards each other by a compression pressure P of over 0.5 MPa (cf. Fig. 3, where the total pressure P in the roll-nip is Pa+Pb). By means of measurements of the contact surface area, the applicant has observed that the effective contact area between a hard cooling surface, such as the metal surface 43a of the roll, and the surface W1 of the fibrous web W that is pressed against it is highly dependent on the compression pressure P between the cooling surface and the fibrous web. At low compression pressures P (less than 0.5 MPa), only about 5 to 15% of the surface area of the fibrous web in the contact region K are in an effective contact with the cooling surface.

In Fig. 1, the paper web W arrives at the cooling arrangement 1 from the multi-roll calender 7 on the left in the figure. The multi-roll calender 7 is shown schematically and it includes 8 main rolls, of which the rolls 72; 72a...72c are heated metal-coated thermo rolls and the rolls 71; 71a...71c are polymer rolls, which have a wa-

ter circulation, for example, to balance the inner temperature of the rolls. The set of rolls includes a so-called reverse nip comprising two polymer rolls 71b and 71c opposite to each other, the roll-nip enabling similar calendering on both sides of the paper web. The travel of the fibrous web from one roll-nip to another is guided by fly rolls 73. Regarding a more detailed structure and functioning of the multi-roll calender, reference is made to the known technology in the field. The temperature of the fibrous web W leaving the last roll-nip N; Nt is 80 to 90°C, which is why it must be cooled before reeling up the paper web W to form machine rolls in the reeling station 3 shown furthest on the right. The paper web W is cooled by the cooling arrangement 1 according to the invention to less than 50°C, preferably to about room temperature. The paper web W travels through the contact region K of the cooling arrangement shown in Fig. 1 so that its upper and lower surfaces W1 and W2 are supported by the cooled metal belts M; M2, M1.

The contact region refers to the calculated contact surface area between the surface of the fibrous web and the cooling surface that is in contact with it. In Fig. 1, the metal belts M2 and M1 of the endless metal belts 22 and 21 meet the upper and lower surfaces W1 and W2 of the fibrous web W coming from the multi-roll calender 7 in about the same point A. The metal belts M of the endless metal belts diverge from the upper and lower surfaces of the fibrous web in about the same point B. In that case, both the contact region between the metal belt M2 that circulates above the level of the fibrous web's contact region and the upper surface W1 of the fibrous web, and that between the metal belt M1 circulating below the level of the fibrous web and the lower surface W1 of the fibrous web are approximately the same K.

The metal belts M have good heat conductivity and they do not permeate liquid. Because of their structures, the metal belts M are rigid and inelastic, but sufficiently flexible so that their circulation in the contact region and away from there can be guided by means of guide rolls 24. Because of its structure that is impervious to liquid, the surface of the metal belt M can be cooled by a suitable fluid cooler, such as a water cooler, without the risk of the fibrous web below it becoming wet. In this connection, it should be mentioned that the invention namely tries to avoid wetting the fibrous web after calendering, in contrast to the method described in the published patent application DE 102 17 910. In Fig. 1, the coolers 41; 41a, 41b are located in close proximity to the outer surfaces of the metal belts M at a vertical distance from them above and below the contact region. The outer surface of the metal belt herein refers to the side of the metal belt M, which in the

contact region K is turned away from the fibrous web W. The cooling surface of each cooler 41; 41a, 41b is approximately parallel to the plane that travels via the metal belts M, and the coolers are located at the same horizontal distance from the set of rolls 7 opposite to each other above and below the forward end of the contact region K. The metal belts M; M2, M1 travelling above W1 and below W2 of the fibrous web W are pressed towards the upper and lower surfaces W1, W2 of the fibrous web by a pair of rolls 5 that is used as the pressure apparatus 5 and located approximately above and below the middle point of the contact region, the pair of rolls 5 consisting of two pressing rolls 51, 52. In that case, a compression pressure P; Pb or P; Pa of over 0.1 MPa, preferably over 0.5 MPa (Fig. 3) is generated between the surface of each metal belt M2 or M1 that is turned towards the paper web W and the surface W1 or W2 of the paper web opposite to the same. The metal belts have tight structures, whereby the compression pressure Pb or Pa, which is generated between the fibrous web W and the metal belts M; M1, M2, rises the temperature of the water evaporating from the fibrous web, thus preventing the evaporation of water from the surface of the fibrous web. The metal belts M are preferably slightly wider than the paper web W, whereby their edges preferably extend slightly outside the edges of the paper web, whereby the upper and lower surfaces W1 and W2 of the paper web W travel in the contact region in a space, where their edges are closed, it being possible to create the desired pressure P in this space. The compression pressure P also increases the effective contact area between the surfaces W1 and W2 of the fibrous web W and the surfaces of the metal belts M2 and M1 travelling above and below the fibrous web and, thus, also the heat transfer area between them on the interface of the said surfaces. In that case, heat is effectively transferred by conduction from the fibrous web W to the cooled metal belt M of the cooling device 4. To provide a sufficient compression pressure P in the space between the fibrous web W and the metal belts M, which is closed at its edges but open at its ends, the metal belts M should be tight enough. The cooling arrangement 1 described above, wherein the fibrous web W is supported on its upper and lower sides by the metal belts M, can be used to cool the different sides of the web by the same or a different cooling power. If the average compression pressure P in the contact region K is arranged to be at 0.1 to 15MPa, the cooling time should be at least 50ms, preferably at least 150ms, to ensure a sufficient cooling power.

The cooling arrangement 1 that is connected with the multi-roll calender 7 shown in Fig. 1 provides a great advantage, for example, for smooth printing papers (SC), as the moisture of the fibrous web W at the calendering stage can be dimensioned

solely on the basis of the calendering techniques without needing to be concerned about the drying of the fibrous web before reeling up the fibrous web. In that case, the temperature of the thermo rolls in the multi-roll calender 7 can be set lower than normal, as no excess moisture needs to be evaporated from the fibrous web during calendering.

A slightly different kind of a cooling arrangement 1 is shown in Fig. 2, however, using the same basic idea as the exemplary application of Fig. 1. The cooling arrangement 1 shown in Fig. 2 can be used in connection with the multi-roll calender, or soft, shoe or metal belt calenders, for example. In the arrangement, there are two cooling devices 4, the surfaces of which are used to cool the different sides of the fibrous web. The first cooling arrangement 4; 4c includes a cooling drum or a cooling cylinder 43 that has a cooling surface 43a. The structure of the cooling cylinder 43 is conventional in the field and it is used to cool the upper side W1 of the fibrous web. Another cooling device 4; 4d, in turn, is used to cool the lower side W2 of the fibrous web, consisting of a metal belt M; M3 and a cooler 41c that cools the surface of the metal belt; gas, such as air, being used as the cooling agent in the cooler 41c. The cooling surface of the cooling device 4; 4d in the contact region K; K2 of the metal belt consists of a surface Mb, which is turned towards the fibrous web and which is cooled right before the metal belt M3 arrives at the contact region K; K2. If the fibrous web were to be cooled by a cooler that uses fluid for cooling, it would be more advantageous to cool the side Ma of the metal belt M3 that is turned away from the fibrous web in the contact region K2. The functional properties of the metal belt are similar to those of the metal belts M; M1 and M; M2 illustrated in Fig. 1.

The fibrous web W arrives at the arrangement 1 from a calender (not shown) and travels through the contact region K, supported by the endless metal belt M; M3. The contact region K consists of two separate portions of the contact region. The first portion of the contact region is the contact region K; K2 between the surface Mb of the metal belt M; M3 and the lower surface W2 of the fibrous web W, starting from point C, where the metal belt is guided by the guide roll 24 of the endless metal belt 2; 23 to support from below the fibrous web W coming from calendering, and the contact region K2 ends at point D, where the metal belt is guided by the guide roll 24 of the endless metal belt 2 away from supporting the fibrous web. The other portion K1 of the contact region K comprises the interface between the hard metal jacket 43a of the rotatable cooling cylinder 43 and the upper surface W1 of

the fibrous web W. In the endless metal belt 2, the metal belt 23 is conveyed clockwise by means of the guide rolls 24.

Opposite to the cooling cylinder 43, there is the rider roll 5 that is rotatable anti-clockwise, whereby a compression nip Np; Np2 is formed between the cooling cylinder 43 that is rotatable clockwise and the rider roll, the fibrous web W travelling through the compression nip jointly with the metal belt M3 that supports it from below. The upper side W1 of the fibrous web W is pressed by the rider roll 5, which is used as the pressure apparatus 5, against the surface 43; 43a of the cooling cylinder. Pressing the fibrous web W towards the surface 43a of the cooling cylinder 43 in the contact region K ensures a sufficient effective contact area in the portion K1 of the contact region K between the surface 43a of the cooling cylinder and the upper surface W1 of the paper web, on the one hand, and in the portion K2 of the contact region K between the supporting surface Mb of the metal belt M; M3, which is against the fibrous web, and the lower surface W2 of the fibrous web, on the other hand. In the compression nip Np2, a compression pressure is formed between the cooling cylinder 43, which is used as the cooling device 4; 4c that cools the upper surface of the fibrous web, and the fibrous web W, on the one hand, and between the fibrous web W and the metal belt M3 that belongs to the cooling device 4; 4d that cools the lower surface of the fibrous web, on the other hand, increasing the heat transfer area both between the paper web and the surface 43a of the cooling cylinder and that between the paper web and the surface of the metal belt. Thus, the power of both the surface 43a of the cooling cylinder and that of the metal belt M3, which cools the upper and lower surfaces W1, W2 of the fibrous web W, becomes sufficient. The said increase in the compression pressure also rises the evaporation temperature of the water, decreasing the evaporation of water from the surface of the fibrous web W. Because of the tight metal belt M3 that supports the fibrous web from below, the water vapour is not allowed to evaporate from below the fibrous web; and the cooling cylinder 43, in turn, prevents the water vapour from evaporating from above the fibrous web.

In a preferred embodiment of the invention, the upper surface W1 of the fibrous web after the cooling cylinder 3 is supported from above by an endless belt, wherein the belt is a wire or a metal belt, for example. In this way, the water vapour is also prevented from escaping from above the fibrous web.

In another preferred embodiment of the invention, the cooling arrangement 1 of the fibrous web is integrated in conjunction with the calender; in the multi-roll calender, for example, with the last roll-nip.

In a preferred embodiment of the invention, the fibrous web leaving the calender is cooled by a high cooling capacity essentially in the contact region that forms the closed space, so that moisture is not allowed to evaporate from the surface of the fibrous web W. The contact region is formed by two long supporting surfaces that are fitted on both sides of the fibrous web, the fibrous web being taken between the surfaces. The supporting surfaces can be formed simply by a cooling roll and an endless belt. The endless belt is pressed against the cooling roll over a certain distance s, whereby a closed contact region is formed between the belt and the cooling roll, the contact region having a length s and the fibrous web being cooled in the said region. The length s of the contact region is relatively short, whereby the fibrous web stays in the cooling region (= contact region) for a relatively short time. In that case, a relatively great temperature gradient, i.e. high cooling capacity, can be used for the cooling. A particularly good means for providing the great temperature gradient is a cooling roll, wherein cooling is provided by evaporating liquid, such as water, in under pressure and wherein the evaporated liquid is condensed in a heat exchanger. Such a cooling roll is known from the patent application FI 20040195, for example. The belt that is pressed against the roll is, for example, a polymer or metal belt, whereby the latter can also be cooled, when desired, by a separate cooling arrangement. The closed contact region can also be formed by two endless belts, between which the fibrous web is conveyed. The endless belts are preferably metal belts. When the belt, which forms the closed contact region and which is used as the supporting surface, is pressed towards the supporting surface on the opposite side of the fibrous web by a pressure of 0.05 to 0.5 MPa, a good pressing contact is provided between the belt and the web, and the transfer of heat is effective. The fibrous web cools in the closed, steam-proof contact region, whereby moisture does not evaporate and calendering can be carried out to provide lower moisture of the fibrous web. In this way, the operating window of the calender extends and the need for extra moistening decreases.

When the high temperature gradient is used in cooling, moisture may condensate on the cold surface. In that case, the supporting surface, such as a belt or the surface of a cooling roll can be made of water-repellent material or it can be coated with the water-repellent material. Such materials/coatings include Teflon, diamond coating etc.

Typically, a cooling arrangement that has such a high cooling capacity uses cooling capacity of 50 to 300 kW/m, which cools the fibrous web by 30 to 80°C. The moisture of the fibrous web exiting the cooling arrangement thus changes by -1.0...+0.5 percentage units in relation to the moisture of the fibrous web arriving at the cooling arrangement. Hence, the temperature and the moisture of the fibrous web coming from the cooling arrangement to the reel-up are approximately the same as in the final storage temperature and moisture; a typical temperature of the fibrous web after the cooling treatment is 20 to 40°C and the moisture 4 to 6%.

Figs. 4A to 4C illustrate a further aspect of the invention, namely the cooling and heating of two or more fibrous webs that are at different temperatures, such as one or more paper or board webs, indirectly by means of a roll apparatus that is used as a heat exchanger.

The roll apparatus consists of one or more rolls 6a, which may also have endless metal belts that are used as supporting surfaces of the fibrous web, arranged in connection therewith. The endless metal belt is used to improve the heat transfer between the roll apparatus and the fibrous web and/or to prevent moisture from evaporating from the fibrous web during the heat exchange process.

Fig. 4A shows heat transfer equipment, which can be used in connection with the multi-roll calender, among others, to heat the fibrous web arriving at the calender and to simultaneously pre-cool the fibrous web leaving the calender. The figure shows a multi-roll calender 7 comprising alternating polymer rolls 71; 71a...71d and thermo rolls 72; 72a...72c that can be heated. In the middle of the calender, there is again a reverse nip, where the roll-nip lies between two polymer rolls (the rolls 71b and 71c). The heat transfer equipment 6 itself comprises a heat conductive roll, such as a metal roll 6a and four guide rolls 6b of the fibrous web W.

The roll 6a functions as a heat exchanger, which is used to transfer heat from the fibrous web W; Wa, which has been heated in the multi-roll calender 7 during calendering, to the relatively cold fibrous web W; Wb that comes to be calendered. The heated fibrous web W; Wa cools during the process, whereby the temperature of the cooled fibrous web W; Wd that goes to the reel-up decreases closer to the temperature of the fibrous web that is suitable for reeling. On the other hand, the temperature of the cold fibrous web W; Wb rises during the heat exchange process, whereby the temperature of the heated fibrous web W; Wc that goes to the calender 7 from the heat transfer equipment is more suitable for calendering, and

the fibrous web does not require such an intensive heating during the actual calendering process. In this way, the heat transfer equipment 6 saves both heating energy in heating the fibrous web arriving at the calender and cooling energy in cooling the fibrous web that goes to the reel-up from the calender.

Fig. 4B shows in more detail the heat transfer process that takes place in the heat exchanger 6a (metal roll) of the heat transfer equipment 6. In principle, the heat transfer equipment illustrated in the figure is similar to the one described above in connection with Fig. 4A. The cold fibrous web W; W1 comes to the surface of the heat exchange roll 6a in point E, guided by the guide roll 6b', on the one hand, and the hot fibrous web W; W2, guided by the guide roll 6b''' in point G, on the other hand. The hot fibrous web W; W2 circulates the jacket of the roll, delivering heat to the surface of the metal roll in the contact region between the fibrous web and the surface of the metal roll, cooling at the same time. The cooled fibrous web W2 diverges from the surface of the metal roll 6a in point H, guided by the guide roll 6b''''. The cold fibrous web W; W1 also circulates the surface of the metal roll, whereby heat is transferred from the surface of the metal roll 6a onto the fibrous web W1. The heated fibrous web W; W1 exits the surface of the roll 6a in point F, guided by the guide roll 6b''. In this way, the cold fibrous web W1 is heated in the contact region K between the fibrous web W1 and the surface of the metal roll 6a, the contact region K being the region of the surface of the metal roll 6 between the points E - F, and the hot fibrous web W2, in turn, cools in the contact region between the points G - H of the surface of the roll. The fibrous webs W1 and W2 are transferred forward along the surface of the metal roll, for example, by rotating the guide rolls 6b.

To enhance the heating of the cold fibrous web W; W1 and to prevent moisture form evaporating, this fibrous web W1 is arranged to travel in a closed space in the contact region K of the fibrous web and the surface of the roll 6a by means of an endless metal belt 6c. The endless metal belt M is brought onto the fibrous web W1 by the guide roll 6b; 6b' in the meeting region E of the cold fibrous web and the surface of the roll and, at the same time, it is removed from top of the roll and the fibrous web in the region F, where the heated fibrous web and the surface of the roll 6 diverge, by means of the guide roll 6b; 6b''. The metal belt M and also the fibrous web W1 that stays under the belt can be pressed against the surface of the roll 6a by means of the guide rolls 6b' and 6b'' to enhance the heat transfer between the surface of the roll 6 and the fibrous web W1 in the contact region E – F of the fibrous web W1 and the surface of the roll 6. The fibrous webs W1 and W2

can come from the different processing states of the same unit process, such as calendering, but they can also come from the various unit processes of the paper/board manufacture.

Fig. 4C shows another embodiment of the heat transfer equipment (heat exchanger) 6, which uses the same indirect heat exchange principles of two fibrous webs that are at different temperatures as in Figs. 4A and 4B. Now, the heat transfer equipment 6 includes a roll member that consists of a pair of rolls 61 that comprises two metal rolls 6a; 6a' and 6; 6a". An endless, tight metal belt M rotates on top of the jacket of the rolls of the pair of rolls 61, whereby the metal belt M forms the supporting surfaces M1 and M2 between the rolls 6a' and 6a" of the pair of rolls, rotating above and below the pair of rolls. This heat exchanger that is formed by the pair of rolls 61 and the metal belt M is used to heat the cold fibrous web W; Wb that goes to the multi-roll calender 7 and to simultaneously cool the hot fibrous web W; Wa leaving the multi-roll calender 7. The fibrous web Wa to be cooled and the fibrous web Wb to be heated are thus not in a direct contact with the roll member but the metal belt M that rotates on the surface of the roll member. The fibrous web Wb that is heated travels along with the supporting surface M1 that is located below the pair of rolls, when the metal belt M rotates, whereby it receives heat from the metal belt M2 at the same time. The fibrous web Wa that is cooled, in turn, travels along with the supporting surface M2 of the upper side of the pair of rolls, whereby it delivers heat to the metal belt M. The fibrous web W can further be pressed by a suitable control system an/or extra pressing rolls to the surface of the metal belt M to enhance the heat transfer in the contact regions between the metal belt M and the fibrous web, which are formed between the fibrous web Wa and Wb and the corresponding supporting surfaces M1 and M2.

Only a few embodiments of the method according to the invention and the cooling arrangement used therein are presented above, and it is obvious to those skilled in the art that it is possible to implement the invention in various other ways within the inventive idea claimed.

Accordingly, the method and the cooling arrangement according to the invention can also be used in connection with other unit processes, wherein the fibrous web should not dry too much when cooled. Dry coating of the fibrous web is such a unit process, among others.

The supporting surface M that is used in the method can be, for example, a metal belt, a tight coated or lined polymer belt, a multilayer metal belt or the like. The wire can also be used as the supporting surface.

Claims

1. A method for cooling a fibrous web (W) in a contact region K between the fibrous web and a cooling surface, the fibrous web being supported by at least one supporting surface (M) in the said contact region (K), whereby the fibrous web is cooled so that a cooling power is mainly transferred to the fibrous web by conduction, **characterized** in that at least one supporting surface (M) and the surface of the fibrous web (W) and at least one cooling surface and the surface of the fibrous web (W) are arranged in a mutual contact in at least a portion of the contact region (K) by pressing the supporting surface/surfaces (M) and the fibrous web (W) and the cooling surface and the fibrous web (W) towards each other by such a compression pressure (P) that the evaporation temperature of water in the fibrous web increases and that the effective contact area between the fibrous web (W) and the surface intended to cool it becomes sufficient for the cooling capacity.

2. A method according to Claim 1, **characterized** in that the supporting surface (M) and the fibrous web (W) and the fibrous web (W) and the surface that is to cool it are pressed towards each other by such a force (F) that the compression pressure (P) between the fibrous web (W) and the supporting surface (M) and/or the surface that is to cool the fibrous web is at least 0.1MPa to 15MPa, preferably 0.5MPa to 15MPa, and that the effective contact are between the fibrous web (W) and the surface that is to cool the same is at least 15% of the total contact area between them.

3. A method according to any of the preceding Claims, **characterized** in that the evaporation of the steam/water from the fibrous web (W) through the supporting surface (M) in the contact region (K) is further essentially prevented.

4. A method according to any of the preceding Claims, **characterized** in that the effective contact time between the supporting surface (M) and the fibrous web (W) in the contact region is at least 50ms, preferably at least 150ms.

5. A method according to any of the preceding Claims, **characterized** in that the cooling of the fibrous web (W) is carried out through one or more cooling supporting surfaces (M).

6. A method according to Claim 5, **characterized** in that the fibrous web (W) is arranged in a lateral contact with the supporting surfaces (M; M1, M2) in

the contact region (K), and that the surfaces (W1, W2) of the fibrous web (W) are cooled by a similar or different cooling capacity on the said supporting surfaces.

7. A method according to Claim 5 or 6, **characterized** in that the supporting surface (M) is cooled by spraying fluid or gas onto its surface.

8. An arrangement (1) for cooling a fibrous web (W) in a contact region K between the fibrous web and a cooling surface, the fibrous web being supported by at least one supporting surface (M) in the said contact region (K), whereby the fibrous web is cooled by a cooling device (4) so that the cooling capacity is mainly transferred to the fibrous web by conduction, **characterized** in that the arrangement includes a pressure apparatus (5), which can be used to arrange at least one supporting surface (M) and the fibrous web (W) and the fibrous web (W) and the surface of the cooling device (4) in such a mutual contact in at least a portion of the contact region, that a compression pressure (P) can be provided between the supporting surface/surfaces (M) and the fibrous web (W) and the cooling surface of the cooling device (4) and the fibrous web (W), through which compression pressure (P) the evaporation temperature of the water in the fibrous web (W) increases and the effective contact area between the fibrous web (W) and the surface of the cooling device (4) that is intended to cool the same becomes sufficient for the cooling capacity.

9. An arrangement (1) according to Claim 8, **characterized** in that a pressure apparatus (5) can be used to provide a compression pressure (P) of at least 0.1MPa to 15MPa, preferably 0.5MPa to 15MPa, between the supporting surface (M) and the fibrous web (W) and/or the surface of the cooling device (4) and the fibrous web (W), and an effective contact area of at least 15% of the total contact area between the fibrous web (W) and the surface of the cooling device (4) that cools the same.

10. An arrangement (1) according to Claim 8 or 9, **characterized** in that the surface of the cooling device (4) is a supporting surface that can be cooled, such as a belt (M) or the jacket (43a) of a cooling roll member, such as a cooling cylinder (43).

11. An arrangement (1) according to Claim 10, **characterized** in that the surface of the cooling device (4) is an endless belt (M) that is impervious to liquid, flexible, inelastic, and heat conductive.

12. An arrangement (1) according to any of Claims 8 to 11, **characterized** in that in the arrangement, both sides (W1, W2) of the fibrous web (W) in the contact region (K) are supported by a cooling supporting surface (M; M1, M2).

13. An arrangement (1) according to Claim 12, **characterized** in that the supporting surfaces (M; M1, M2) are of a material that is essentially impervious to water vapour and their tightness and the width in the cross direction of the fibrous web are such as to form a space around the fibrous web that is closed at its edges, in which space a pressure of over 0.1, preferably over 0.5PMPa can be generated by the pressure apparatus (5).

14. An arrangement (1) according to Claim 13, **characterized** in that at least one of the supporting surfaces (M; M1, M2) is wider than the fibrous web (W).

15. An arrangement (1) according to Claim 13 or 14, **characterized** in that the tightness of the supporting surfaces (M; M1, M2) can be adjusted.

16. An arrangement according to any of Claims 8 to 15, **characterized** in that the supporting surface (M) is a metal belt.

17. An arrangement according to any of Claims 8 to 16, **characterized** in that the cooling means (4) includes one or two metal belts (M), which are cooled by a cooler (41) outside the metal belts.

18. An arrangement according to any of Claims 8 to 17, **characterized** in that the cooling means (4) further comprises one or two wires that are used as the supporting surface.

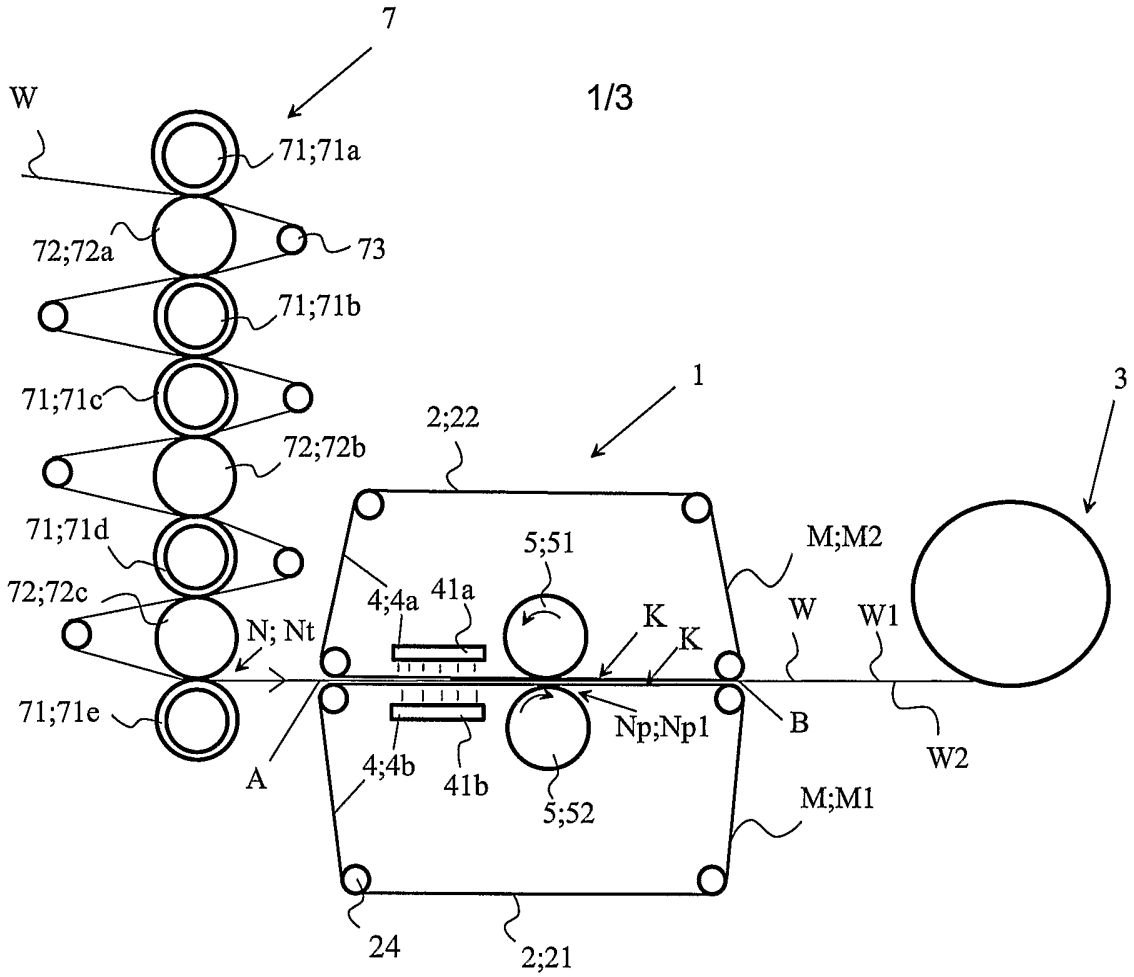

7
W
71;71a
72;72a
73
71;71b
71;71c
72;72b
71;71d
72;72c
71;71e
N; Nt
A
1
2;22
4;4a
41a
5;51
K
K
M;M2
W
W1
3
B
W2
Np;Np1
4;4b
41b
5;52
M;M1
24
2;21

Fig. 1

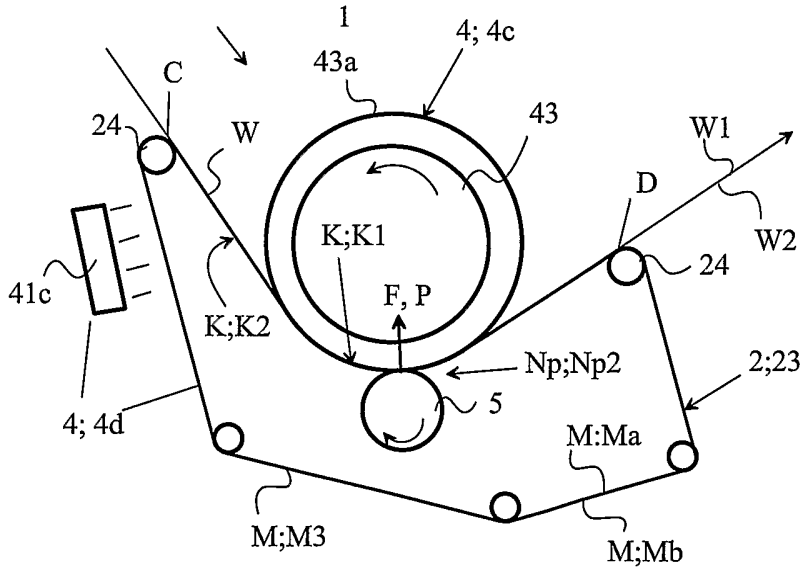

1
4; 4c
43a
C
24
W
43
W1
D
K;K1
W2
41c
24
F, P
K;K2
Np;Np2
2;23
5
4; 4d
M:Ma
M;M3
M;Mb

Fig. 2

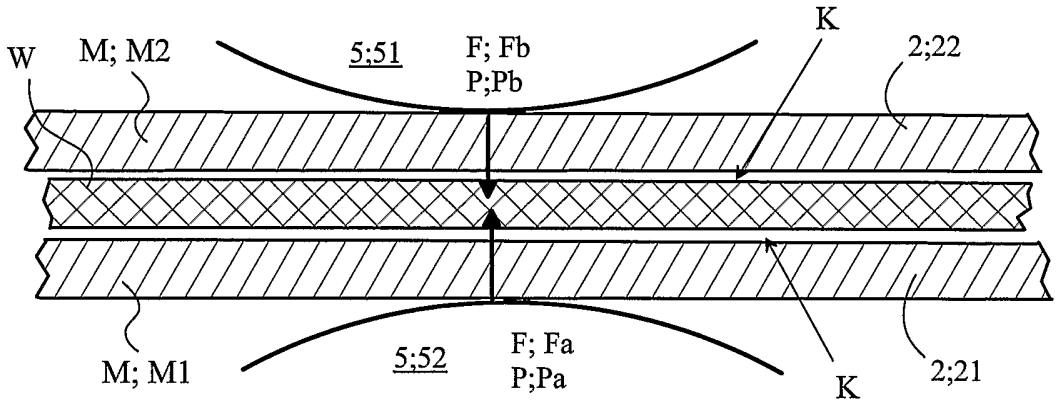


Fig. 3

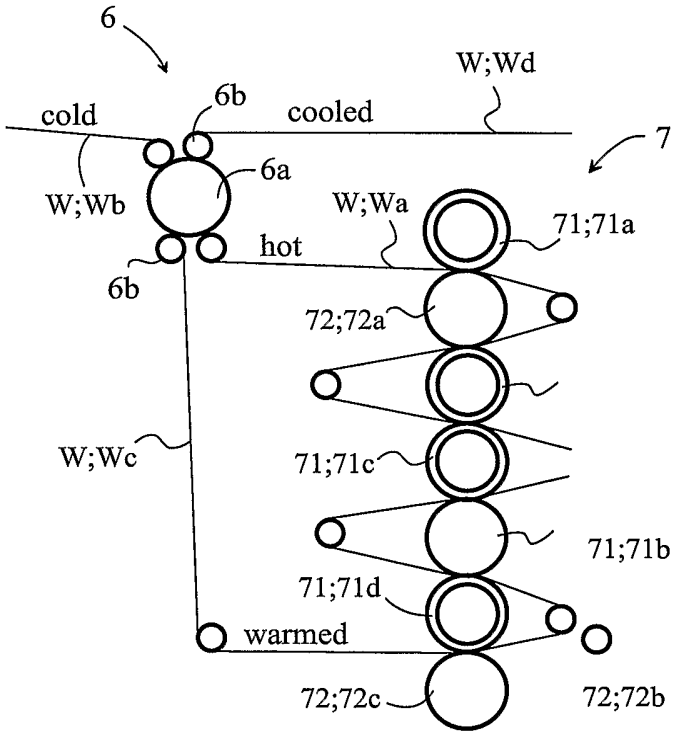


Fig. 4a

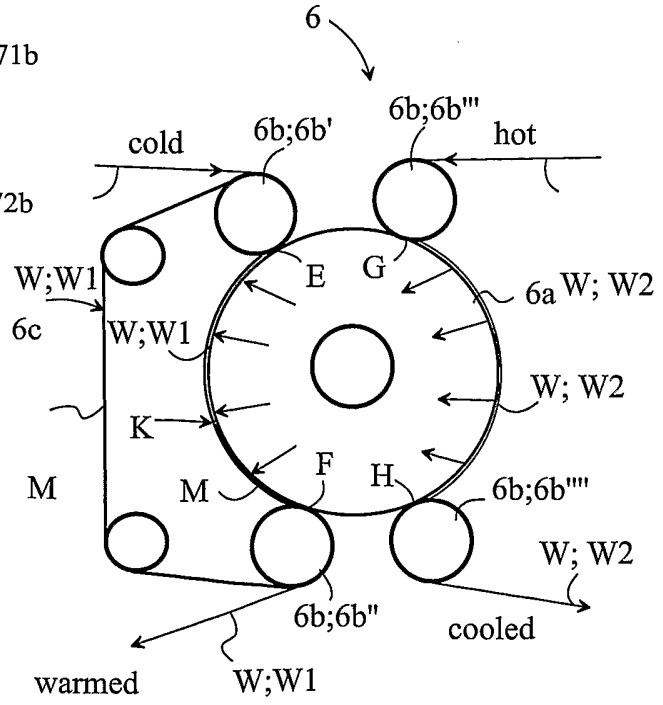


Fig. 4b

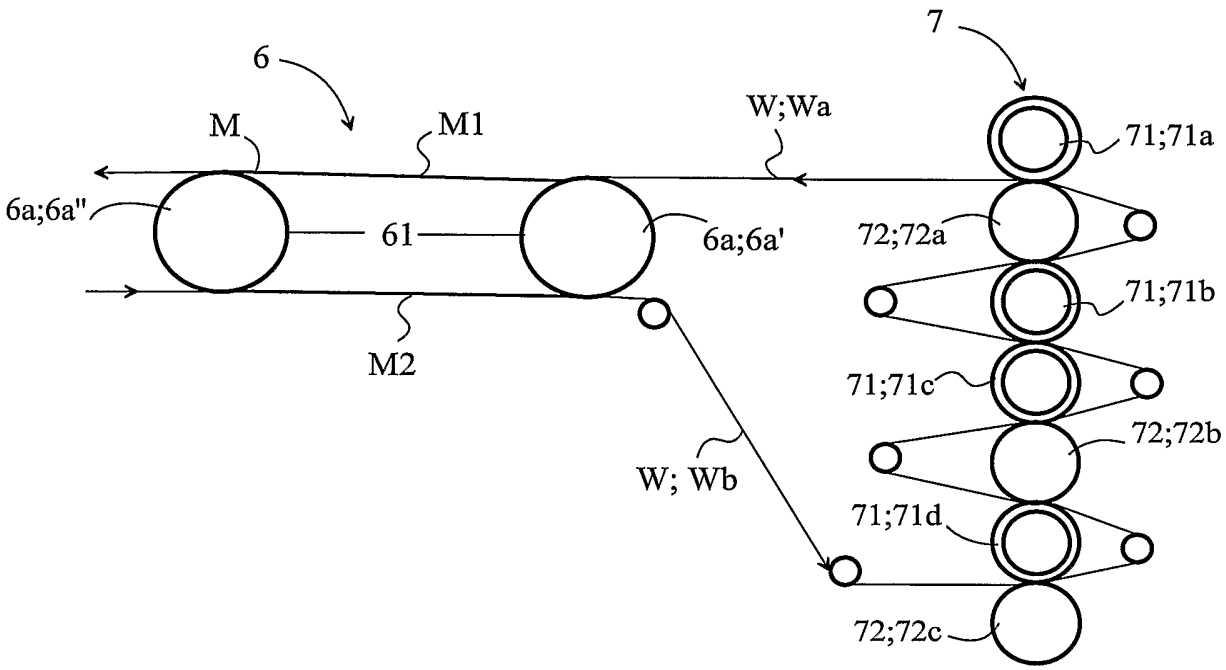

6
7
M
M1
W;Wa
71;71a
6a;6a"
61
6a;6a'
72;72a
71;71b
M2
71;71c
72;72b
W; Wb
71;71d
72;72c

Fig. 4C

INTERNATIONAL SEARCH REPORT

International Application No
PCT/FI2005/000304

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 D21G1/00

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 7 D21G

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

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

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE 102 17 910 A1 (VOITH PAPER PATENT GMBH) 13 November 2003 (2003-11-13) cited in the application paragraph '0041! - paragraph '0044!; figure 2	1,3,5,8, 10,16
A	US 5 245 920 A (HESS ET AL) 21 September 1993 (1993-09-21) the whole document	1,8

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

° Special categories of cited documents:

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
28 September 2005	10/10/2005

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Helpiö, T.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/FI2005/000304

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