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For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: A METHOD FOR CALANDERING PAPER ON BOARD

(57) Abstract: The invention relates to a method for calendering paper or board by leading a paper or board web through a calendering nip or area, where the web is subjected to pressing action together with thermal action. In the method, the web is brought, at the calendering nip or area, to a temperature higher than the glass transition temperature of the polymers contained in the web under such high pressure that the water in the web will vaporise, but will essentially remain as water. The web with thus remain in an essentially plastic state and calendering is continued until the desired calendering effect is achieved.



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A method for calendering paper or board

The present invention relates to a method for calendering paper or board.

- 5 Calendering is a process in which a fibrous web is pressed between usually two or more rolls, whereby due to mechanical working and heat, the paper is transformed both in the direction of the plane and in the direction of the thickness. There are also various belt calender solutions, such as that disclosed in the FI application 20020159, which has a calendering area adjustable in length. The length of the
- 10 calendering area in a belt calender may be, for example, within the range from 10 mm to 15 000 mm.

In current calendering processes, the calendering parameters include:

- surface temperature of rolls
- paper temperature
- 15 - diameter of rolls
- running speed
- linear load acting on the nip
- hardness of roll coating
- moisture (distribution) of paper
- 20 - roll surface topography
- length of nip
- number of nips

- Some of the above parameters are interconnected. In modern calendering methods,
- 25 the different parameters are each adjusted separately to obtain the desired end product. Some of the parameters are fixed due to the process and machine layout.

- The aim of the present invention is to provide a calendering method by which an effective calendering result is achieved by means of relatively simple adjustment
- 30 procedures.

- To achieve this aim, the method according to the invention is characterised in that in the method, the web is subjected, at the calendering nip or area, to a temperature higher than the glass transition temperature of the polymers contained
- 35 in the web under such high pressure that the liquid in the web will not vaporise, but

will remain essentially liquid, whereby the web is pressed in an essentially plastic state until the desired calendering effect is achieved, after which the pressure affecting the web is reduced in a controlled manner to a level lower than the vapour pressure corresponding to the said temperature, whereby the liquid in the web will
5 vaporise and the web will dry in a controlled manner, whereupon the polymers contained in the web are converted from the plastic state to the glassy state and the transformation of the polymers remains permanent. The said liquid in the fibre web may be water or an aqueous solution.

10 The required pressure corresponding to each temperature may be looked up with sufficient accuracy in the phase diagram for water or in a steam pressure table, for example in the publication Kari I. Keskinen, *Kemian laitetekniikan taulukoita ja piirroksia*, p. 24-35. These values may be modified depending on the composition of the aqueous solution in the fibrous web, for example, on the basis of test runs.

15 In the method according to the invention, the web is pressed in a plastic state to achieve the desired calendering result, after which the pressure affecting the web can be reduced in a controlled manner to a level lower than the vapour pressure corresponding to the said temperature, whereby the liquid in the web will vaporise
20 and the web will dry, whereupon the polymers contained in the web are converted from the plastic state to the glassy state and the transformation of the polymers remains permanent.

In the following are briefly described the polymers contained by the fibrous web and
25 their glass transition temperature based on the publication: Mikko Tani, dissertation for a diploma: "Rainan plastisoitumistekijöiden vaikutukset softkalanteroinnissa", 1.2.1994, Helsinki University of Technology.

The fibrous web typically contains three different types of biopolymer: cellulose,
30 amorphous hemicellulose and amorphous lignin, the proportion of which varies depending on the type of pulp and the wood species used for the pulp manufacture. With coated grades, the synthetic amorphous polymers or biopolymers, or both, contained in the coating paste may also be used. The transformations that take place in the polymers contained in paper are time-dependent and partly irreversible
35 (viscoelastic). The viscoelastic behaviour of polymers depends on the shearing rate,

the molar mass, the structure of the polymers, the amount of additives and temperature. Below a certain temperature characteristic of each polymer, the amorphous phase is in a glassy state. In that state, amorphous polymers and partly the amorphous parts of crystalline polymers have solidified into hard and brittle glass-like substances. Due to the effect of an external force, in the glassy state may take place permanent transformation in addition to reversible transformation. Permanent transformation in the glassy state taking place due to an external force is called plastic transformation. The physical and mechanical properties of an amorphous phase change considerably in the glass transition area, the centre point of which area is defined as glass transition temperature T_g . The polymers contained in paper are in the glassy state at room temperature. The glass transition temperatures of cellulose in absolutely dry conditions vary from 200°C to 250°C depending on the degree of crystallinity. The corresponding values for hemicellulose are 150°C to 220°C and for lignin 130°C to 205°C. Moisture content affects these temperatures. The glass transition temperature is dependent on the plasticizing effect of water, whereby an increase in water content lowers the glass transition temperature. Where the moisture content of the fibrous web increases to over 5%, the mechanical mass has been found to have two different glass transition temperatures, the lower of which is the glass transition temperature of the cellulose fraction and the higher that of the lignin fraction. Lignin can only absorb a limited amount of moisture, and thus its glass transition temperature remains constant when the moisture content exceeds 2.5%. For this reason, to plasticize lignin, mainly heat is required, whereas cellulose is plasticized with water and heat.

In the method according to the invention, the calendering of the web is achieved in such a way that at each point in time, each layer of the web is in an optimal temperature-moisture-pressure operating point from the point of view of plasticity. In the method according to the invention, one or more of the parameters may be fixed and the rest adjustable, or in an ideal process, all independent parameters are freely adjustable. In an ideal calendering process, the following may be considered as parameters independent of each other:

- temperature of surfaces in contact with the web
- entry temperature of paper
- moisture (distribution) of the paper
- pressure impulse exerted on the web (form and temporal duration of distribution).

Other parameters may be considered as case-specific constants.

5 The method according to the invention is applicable for use in both conventional calenders, where the fibrous web is pressed between two or more rolls, and in belt calenders, especially metal belt calenders, such as the metal belt calender according to application no. FI20020159.

Claim

1. A method for calendering paper or board by leading a paper or board web through a calendering nip or area, where the web is subjected to pressing action together with thermal action, **characterised** in that in the method, the web is brought, at the calendering nip or area, to a temperature higher than the glass transition temperature of the polymers contained in the web under such high pressure that the liquid in the web will not vaporise, but will remain essentially liquid, whereby the web is pressed in an essentially plastic state until the desired calendering effect is achieved, after which the pressure affecting the web is reduced in a controlled manner to a level lower than the vapour pressure corresponding to the said temperature, whereby the liquid in the web will vaporise and the web will dry in a controlled manner, whereupon the polymers contained in the web are converted from the plastic state to the glassy state and the transformation of the polymers remains permanent.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/FI 2004/050014

A. CLASSIFICATION OF SUBJECT MATTER

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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)

IPC7: D21G

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

SE,DK,FI,NO classes as above

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0617165 A1 (VALMET PAPER MACHINERY INC.), 28 Sept 1994 (28.09.1994), claims 1-6,15, abstract --	1
A	WO 9844196 A1 (VALMET CORPORATION), 8 October 1998 (08.10.1998), page 13, line 16 - page 14, line 24, abstract --	1
A	WO 8702722 A1 (SCOTT PAPER COMPANY), 7 May 1987 (07.05.1987), page 23, line 5 - line 18, figure 9, abstract -- -----	1

☐ Further documents are listed in the continuation of Box C.☒ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

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"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

"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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