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(54) **Title:** A METHOD OF COATING A FILLED ROLL WITH COMPOSITE MATERIAL, AND A FILLED ROLL COATED WITH COMPOSITE MATERIAL

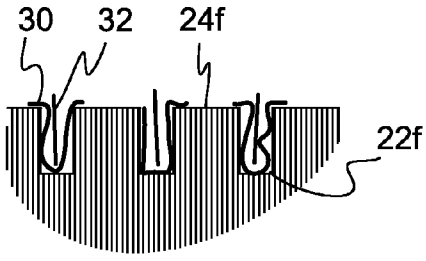


Fig. 4b

(57) **Abstract:** The present invention relates to improving such calender rolls that are so-called filled rolls or fiber rolls, i.e. formed of a metal core surrounded by radial round sheets of paper, cotton fabric, or similar natural or synthetic fiber material tightly pressed in axial direction. The present invention discusses a method of manufacturing a filled roll coated with composite material, and such a filled roll. The roll of the invention is provided with a fiber filling (18) having grooves (22f) in its outer surface and a reinforcement (30, 32) comprising fibers in said grooves, the fibers of the reinforcement (30, 32) being oriented in said grooves (22f) in a direction differing substantially from the direction of the grooves (22f).

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A method of coating a filled roll with composite material, and a filled roll coated with composite material

Field of the Invention

(001) The present invention relates to paper machine rolls. More particularly the present invention relates to improving such calender rolls that are so-called filled rolls or fiber rolls, i.e. formed of a metal core surrounded by radial round sheets of paper, cotton fabric, or similar natural or synthetic fiber material tightly pressed in axial direction.

Background of the Invention

(002) A paper machine multinip calender is formed of a series of rolls in a normally vertical stack arranged at the end of a paper machine (on-line) or separate from it (off-line). The purpose of a calender is to treat paper web so that desired level of surface properties and/or thickness is achieved, for example to smooth out the paper web for enabling printing and writing on it, and to increase the gloss on the paper surface. Calendering is understood as a process of using pressure for embossing a smooth surface on the still rough paper surface. A special type of multinip calender is a supercalender, in which hard and soft rolls are alternating. Hard rolls are made of cast iron or steel and they are heated, and soft rolls are covered by a polymer cover. In such a manner the working nip becomes wider and the specific pressure on the paper more even.

(003) The prior art knows two basic types of soft roll covers. The older rolls having a soft roll cover are known as filled rolls or fiber rolls, whose surface is made of paper or some other appropriate fibrous material like for instance cotton, rayon, Kevlar® or Nomex®. The more modern soft roll covering is made of composite material. The more modern soft roll covering is made of composite material, which comprises fiber reinforcements in a polymer matrix material.

(004) The above discussed filled rolls or fiber rolls, even the phrase ‘paper roll’ has been used, have been known for decades. The basic structure of filled rolls has been discussed in patent documents US 5,038,448, EP-A1-0 170 565, EP-A2-0 445 944, FI 58527, and US 5,307,563, among others. Thus, the rolls are formed of a steel core having, for instance, a stationary, or axially movable, end flange or pressure plate at

one end of the core, and an axially movable end flange, or pressure plate at the opposite end of the core. When assembling the roll annular sheets of paper or other suitable material are stacked on the stationary end flange along the full length of the core. After stacking the sheets on the core, the axially movable end flange, or pressure plate is positioned on the core and is pressed towards the opposite end flange such that an appropriate pressure is subjected to the stack of paper sheets, whereafter the end flange or pressure plate is locked on the core. The axial pressure applied to the sheets results in a desired surface hardness, or elasticity of the roll surface so that it functions in a desired manner when calendering the paper web.

(005) However, the fibrous surface of the filled roll or fiber roll is very delicate of its nature, and therefore depressions, dents or scratches are easily formed in the surface. This is the most serious problem of the fiber rolls. The defects in the roll surface result in marking of the paper and reduction in the paper quality. The standard remedy, which has been used to correct the surface defects, is to grind the surface i.e. to return the surface to exact cylindrical form. However, due to the delicacy of the roll surface the grinding interval has been short, which means repeated grinding operations resulting in reduced production capacity.

(006) Nowadays, composite covered rolls have been used as the soft calender rolls in new paper machine or calender installations. A composite covered roll is formed of a hollow cylindrical roll body, which is coated with composite. The composite covers are the most durable soft covers for calendering, both in load bearing capability as well as in grinding interval. That means that when changing from filled rolls to composite covered rolls the old filled roll construction cannot be used and a considerable investment must be made into new roll bodies (a typical supercalender has 6 soft roll positions). The problem in changing from filled rolls to composite covered rolls is the cost of the roll body.

(007) An intermediate solution to the problems of, on the one hand, fiber rolls, and on the other hand, the composite covered rolls is to cover the paper roll with a composite cover. By doing this there is need neither to invest in a new roll body nor to grind the roll surface in short interval. The covering of filled rolls with composite material was brought on the market in the 1990's. There are several patents or patent applications discussing the covering technology.

(008) FI-B-93881 discusses how the filled roll is covered with composite. First a primer layer is applied on a smoothened roll surface i.e. the paper filling, and thereafter a normal composite cover (with normal layer thickness) is applied on the primer layer. The primer is supposed to ensure a good bonding of the composite cover to the paper filling.

(009) US-B1-6,375,602 describes the application of a thick (40-100 mm) glass fibre woven layer on top of the filled roll filling before applying the normal composite cover. As an alternative, the paper filling is completely removed from the core, and a very thick (75 - 230 mm) layer of glass fibre woven fabric is applied before composite covering. The US document teaches that grooving of the filled roll surface can be applied for better cover bonding. In such a case the grooves are filled with roving, i.e. a fiber bundle running along the groove bottom for further improving bond strength. A drawing accompanying the patent shows a shallow V-shaped groove.

(0010) US-A1-2005/233880 is concerned of covering the filled roll with composite, specifically requiring grooving of the filled roll surface. The reason for grooving the roll surface has been discussed thoroughly. The object is to structure the surface of the filled rolls for improved bonding (larger bonding area, impregnation) and improved load transfer between cover and core. The structuring of the roll surface is done mainly by grooving, but also drillings (= holes) are proposed. The grooves may be oriented spirally but a circumferential direction is preferred. The grooves are preferably directly next to each other, and the depth thereof is between 3 - 20 mm, preferably about 10 mm. The grooves either have rounded tops and bottoms or sharp-cornered tops and bottoms. After the formation of the grooves in the roll surface polymer resin is applied to the grooves. The grooves allow resin to impregnate somewhat into the paper filling, and fill (partially) the grooves. Thus a good bonding is formed between filled roll and composite cover. It also improves load transfer between cover and core. The forming of the composite cover starts with winding rovings onto this grooved and resin impregnated roll such that the rovings run in the direction of the grooves and fill the grooves. Thus a smooth surface is formed for subsequent covering. The polymer is cured, and possibly the surface machined, before the composite cover is applied. Another option is to apply the composite cover directly to the grooved surface, which means, in practice, that after

the rovings have been wound such that they fill the grooves the winding is continued for the entire efficient length of the roll.

(0011) The above discussed prior art structures and coverings have some deficiencies. Grooving of the filled roll surface, and the filling thereof by means of polymer-impregnated roving, as described above does improve the bonding between the composite cover and the filled roll paper filling, but is not optimal in supporting a stiff substrate for the composite cover. Such stiff substrate is necessary in preventing the delamination between composite cover and the filled roll. Such delamination is typically caused by deformation of the paper filling under nip loading as well as by impacts such as occur in the supercalender nip. The nip deformation in itself causes high stresses in the cover-filling bondline and can cause delamination. Moreover, the paper filling may experience permanent deformation from the loading while the composite cover experiences only elastic deformation, thus resulting in a cavity under the composite cover. Such delamination most often causes the generation of a hot spot, with resulting damage to paper filling and composite cover. Filling the grooves with roving gives some stiffening of the filled roll surface, but is not highly effective since the main loading and deformation is in radial direction.

Summary of the Invention

(0012) An object of the present invention is to use the filled roll as a substrate for the composite cover, making the investment in a new roll body unnecessary.

(0013) Another object of the present invention is to arrange reinforcements on the filled roll surface in at least partially radial direction before applying the composite cover.

(0014) Yet another object of the present invention is to form grooves in the roll surface such that the groove shape is optimal for the desired fiber orientation.

(0015) Thus, the method of coating a filled roll with composite material, the filled roll having a metal core, a fiber filling thereon, and pressure plates at both ends of the fiber filling, the fiber filling having an outer surface, the method comprising the steps of a) forming grooves in the outer filling surface, b) applying a reinforcement on the filling, and c) applying one or more composite layers on the reinforcement, is characterized in

providing, in step b), the reinforcement with reinforcing fibers, and applying resin and reinforcement in the grooves such that the reinforcing fibres in the reinforcement run in a direction transverse to the grooves.

(0016) And accordingly, the filled roll coated with composite material, the filled roll having a metal core, a fiber filling thereon, and pressure plates at both ends of the fiber filling, the fiber filling having an outer surface provided with grooves having sidewalls, the roll surface being further provided with a reinforcement, and one or more composite layers, is characterized in that the reinforcement comprises reinforcing fibers in said grooves, a majority of the reinforcing fibers being oriented in said grooves in a direction differing substantially from the direction of the grooves.

(0017) Other characteristic features of the invention will become apparent from the appended patent claims.

(0018) The present invention brings about a number of benefits. The invention ensures both good bonding of the composite cover to the paper filling, as well as high stiffness of the paper-filling periphery and an adequate substrate for the composite cover. Good bonding is achieved by the grooving of the filled roll surface. The grooving increases the area of the filled roll surface. It also roughens the filled roll surface. And it also allows better impregnation of polymer into the filled roll surface. High stiffness is achieved by placing reinforcement into the grooves so that part or all of the fibres are positioned in radial or almost radial direction. Polymer in itself is not very strong or stiff, but fibre reinforcement of polymer forms a high performance composite. Fibre reinforcement is based on the principle of loading fibres in fibre direction, allowing full use of the fibre properties. This radial placement of the fibres allows loading of the fibres in compression under nip loading. It is preferable to have also some fibre reinforcement in circumferential direction to absorb stresses in this direction.

Brief Description of the Drawings

(0019) In the following the present invention is explained in more detail with reference to the appended figures of which

Fig. 1 illustrates schematically a prior art fiber roll,

Figs. 2a – 2f are axial partial cross-sections of a fiber roll surface in accordance with the present invention showing several alternative embodiments for the groove shapes of the roll surface,

Figs. 3a – 3f illustrate the groove shapes of Figs. 2a – 2f provided with the reinforcement in at least partially radial direction,

Figs. 4a – 4b illustrate three preferred embodiments of the present invention showing how the reinforcement is placed into the grooves,

Fig. 5a illustrates a preferred way of arranging reinforcing tapes into adjacent grooves, and

Fig. 5b illustrates in an enlarged scale the tape of Fig. 5a inserted into the groove showing the positioning of the reinforcing fibers.

(0020) Figure 1 illustrates a so-called fiber roll or filled roll 10 of prior art. The roll 10 comprises a roll core 12 made of metal, for instance steel, two press plates 16 at the opposite ends of the core, two tightening and locking means 14 in communication with the press plates 16 and the core 12, and a stack 18 of paper sheets between the press plates. The radial height of the paper sheets is normally somewhere between 50 and 200 mm, whereby the roll diameter ranges from about 250 – 900 mm. The roll core 12 extends outside the tightening and locking means 14 and functions as the shaft of the roll such that the roll may be supported on the calender frame by means of bearings.

(0021) Figures 2a – 2f show axial partial cross-sections of the paper roll surface 20 (shown in Fig. 1) of the present invention into which grooves 22a – 22f have been machined. The grooves extend substantially in circumferential direction. However, they may be inclined from the circumferential direction, but not more than 45 degrees. Figure 2a shows a roll surface configuration, where the cross-section of the surface forms a sinusoidal curve. The curve of Figure 2a is a general representation of grooves 22a having a rounded shape. Figure 2b illustrates grooves 22b having rounded bottoms, the grooves 22b either being arranged side by side or leaving a flat surface portion 24b therebetween as shown in Fig. 2b. Figure 2c illustrates V-shaped grooves 22c, which are arranged side by side such that the ridge 24c between the grooves is sharp, though it could naturally be rounded, too. Figure 2d illustrates another groove configuration where grooves 22d are still V-shaped but leave a flat surface portion 24d between adjacent grooves 22d. Figure 2e illustrates grooves 22e whose cross-section is substantially rectangular such that the width of the grooves 22e is the same as the

width of the land portions 24e between the grooves 22e. Figure 2f illustrates grooves 22f having a similar configuration as the grooves 22e of Fig. 2e, but grooves 22f have been arranged such that a wider flat portion or land portion 24f is left between the adjacent grooves 22f.

(0022) In addition to the groove shapes shown in Figures 2a – 2f, several other shapes are, naturally, possible. For instance, it is possible to combine the teachings of Figs. 2c and 2e, whereby grooves having two inclined sidewalls and a flat bottom result. Also, all or part of the sharp edges either at the groove bottom or at the envelope surface of the roll may be rounded off. Thus also grooves having a U-shaped configuration i.e. a rounded bottom with vertical or as well inclined sidewalls are applicable. As to the inclination of the sidewalls of the grooves, the inclination thereof is preferably more than 45° with the axial direction. By this arrangement the reinforcements may be positioned in the optimal direction along the groove sidewalls. The grooves may be continuous over the roll length, e.g. be formed of one or more spiralling grooves, or the grooves may extend circumferentially around the roll. The grooves may be placed directly next to each other, or densely packed with non-grooved or flat land areas in between. As to the surface quality of the grooves as well as the one of the remaining flat roll surface it is preferably rough to improve bonding and aid the polymer impregnation.

(0023) As to the dimensioning of the grooves, the groove depth may range from about 5 mm to 30 mm, the groove width may range from 0.5 to 10 mm, and the inclination of the groove sidewalls ranges at least for a part of the sidewall height from 45 to 90 degrees compared to the axial direction, or more generally to the envelope surface of the roll. And finally, if the groove edges either at the bottom or at the envelope surface of the roll are rounded, the radius of the rounded areas may range from 0 to 5 mm.

(0024) Figures 3a – 3f show the grooves of Figs. 2a – 2f provided with the reinforcement 26 in accordance with a few preferred embodiments of the present invention. The reinforcement 26 shown in the Figs. may be in the form of a non-woven fiber felt or fiber mat or fiber tape, or woven fabric or any combination of such being formed at least partially of reinforcing fibers. The type of the reinforcement 26 depends mainly, on the one hand, on the size of the groove, and, on the other hand, on the properties the reinforcement 26 should offer. The material for the reinforcing fibers is preferably, one or more of glass, aramid, carbon, boron, metal, and ceramic. In the case

of wovens or non-wovens, in accordance with a further preferred embodiment of the present invention, they have, after being inserted into the groove, as many reinforcing fibers as possible placed in substantially radial direction. As shown in the Figures 3a – 3f, the reinforcement 26 of the invention is arranged such that the reinforcing fiber direction differs from the groove 22 direction. The result is that the running direction of the reinforcement 26, when winding the reinforcement on the fiber filling or rather in the grooves is such that at least part of the reinforcing fibers has a component in radial direction of the roll. I.e. at least part of the reinforcing fibers, either in non-wovens, or in woven fabrics climbs along the sidewalls of the grooves 22.

(0025) The reinforcement 26 may consists of a woven fabric with a part, preferably most, of the reinforcing fibers in weft direction of the fabric. Another option for the reinforcement is a non-woven mat or felt or tape, with at least a part of the reinforcing fibres in transverse direction. The width of the reinforcement 26 may be similar to the depth of the groove, or more, but typically the reinforcement 26 is in the shape of a substantially narrow tape. The reinforcement 26 can be completely placed inside one groove, or a part of it may lie on the flat area next to the groove 22, or a part may be positioned into the next groove 22.

(0026) Figs. 4a and 4b show three different embodiments of the invention. In Fig. 4a (from left to right) it has been shown how the grooved surface of the filled roll has been provided with reinforcing fibers or the like reinforcements 26, in which a part of the fibres run transverse to the grooves 22f. Preferably either the surface of the roll, including the groove surfaces, or the reinforcements 26, or both have been impregnated with appropriate resin. The reinforcement 26 may, before application on the roll surface, have a resin treatment of its own, but preferably the roll surface is at least treated with resin either by means of spraying resin thereon or by applying resin by another means on the roll surface. The resin is chosen such that its properties match the desired properties of the roll. In other words, the resin should have sufficient strength, rigidity, fatigue resistance, and thermal stability to withstand the calendering conditions. For instance resins like epoxy, vinyl ester, polyamide, phenolic, polysulfone, polyetheretherketone, polyethersulfone, malimide, polyetherketone, cyanate ester, and blends and copolymers thereof are applicable. Epoxy resins and blends and copolymers thereof are preferred for calendering and supercalendering rolls. After the introduction of the reinforcements on the surface a suitable thread 28, a roving, for

instance, is wound along the grooves 22f such that it draws the reinforcements 26 to the bottom of the grooves 22f. Now, as the reinforcements 26 are substantially long in relation to the width of the groove 22f at least part of the length of the reinforcement 26 finds its position in radial direction. Depending on the amount of fibers or the like reinforcements 26 the grooves 22f will in this embodiment be more or less filled with mainly radially positioned reinforcements 26. Naturally, in case the reinforcements 26 are non-wovens or wovens the amount of reinforcing fibres within felt, mat, tape or fabric being positioned originally transverse to the grooves 22f dictate the amount of reinforcing fibers positioned in substantially radial direction in the filled groove 22f (to the right in Fig. 4a).

(0027) In case the groove is not filled sufficiently well in one single step described in the above paragraph, it is, naturally, possible to introduce another set of reinforcements along the roll surface, and wind another thread or roving into the groove for drawing another reinforcement layer into the groove. This procedure may be repeated as many times as needed to fill the grooves. When the groove has been filled to a desired degree with reinforcements running transverse to the groove, it is possible to continue with winding a roving along the groove to fill the groove.

(0028) Figure 4b illustrates an embodiment where an appropriate reinforcement is inserted in the groove 22f. For instance a resin-impregnated reinforcement 30, i.e. fiber mat or felt or tape or non-woven is laid on the roll surface, whereafter the reinforcement 30 is forced into the grooves 22f either by means of a thread in a similar manner as discussed in connection with Fig. 4a or by means of an appropriate tool. In a following step yet one more reinforcement 32, which may be either the same material as reinforcement 30 or different material is pushed in the groove 22f such that a three-layered reinforcement is formed in the groove 22f.

(0029) The procedure shown in Figs. 4a and 4b may be continued by laying either a base layer, an intermediate composite layer or a top composite layer on top of the bottom reinforcement layer. Naturally, as already discussed in prior art, after each curing step of a layer it is possible to machine the surface of the layer such that the thickness of each layer will be as uniform as possible, whereby also the properties of the layers are uniform.

(0030) The best results are likely to be achieved when the direction of the fibers in the reinforcement is about 90° to the envelope surface of the roll i.e. the fibers being substantially radial. However, in some cases the reinforcing fibers; i.e. reinforcing fibers in mats, felts, tapes, non-wovens, or wovens, may be somewhat inclined from the radial direction. It may be said that the fiber direction should form in the groove an angle of more than 45° with the envelope surface. Thus the fibers may incline in all directions, not only in axial direction but also in circumferential direction and all directions therebetween.

(0031) In an exemplary and preferred embodiment of the present invention the coating of a filled roll starts by machining the roll surface to roughen the surface. The main reasons for such a machining are to remove the possible scratches or dents in the surface, and to improve the bonding of the coating material to the actual surface material. After roughening the surface the grooves as shown in Fig. 2f are machined in the roll surface. The groove depth is 10 mm, the width about 1,6 mm, and the groove lead 7,6 mm. The next step is, preferably, to impregnate the roll surface, preferably, both within the grooves and outside thereof with polymer. Glass fibre tape having a width of 28 mm and a basis weight of 530 g /m^2 is used. The tape is such that 80 % of the tape fibres is in cross machine direction (CD), and the rest i.e. 20 % in machine direction (MD). The glass fibre tape is also impregnated with polymer before being folded, preferably in half, and applied into the groove. Preferably, the width of the glass fibre tape 34 and the groove geometry is chosen to match such that the edges of the glass fibre tapes 34 inserted in adjacent grooves abut each other as shown in Fig. 5a.

(0032) Fig. 5b illustrates in more detail a preferred way of inserting the glass fibre tape 34 into the groove 22. The enlarged Figure shows how the reinforcing fibres 34' forming the weft of the tape 34 climb along the sidewalls of the groove 22 in substantially radial direction of the roll.

(0033) In view of the above it has to be understood that only a few most preferred embodiments of the invention have been discussed. The above explanation should by no means be understood as limiting the scope of the invention, which is defined only by the appended claims. Thus it is evident that the groove shapes may differ from the above-discussed ones, as well as the reinforcement materials, or the resins etc. However, such features that can be found from the listed and other prior art documents

discussing filled rolls or paper machine rolls having a reinforced composite surface are considered as general state-of-the-art, which is known to a skilled man, and may thus be used in interpreting the attached claims.

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Claims

1. A method of coating a filled roll with composite material, the filled roll (10) having a metal core (12), a fiber filling (18) thereon, and pressure plates (16) at both ends of the fiber filling (18), the fiber filling (18) having an outer surface (20), the method comprising the steps of

a) forming grooves (22a – 22f) in the outer filling surface (20),

b) applying a reinforcement on the filling, and

c) applying one or more composite layers on the reinforcement,

characterized in step b) providing the reinforcement (26, 30, 32) with reinforcing fibers, and applying resin and reinforcement (26, 30, 32) in the grooves (22a – 22f) such that the reinforcing fibres in the reinforcement (26, 30, 32) run in a direction transverse to the grooves (22a – 22f).

2. The method as recited in claim 1, characterized in that the grooves (22a – 22f) extend in substantially circumferential direction

3. The method as recited in claim 1 or 2, characterized in, before applying the reinforcement (26, 30, 32) in the grooves (22a – 22f), folding the reinforcement (26, 30, 32) such that when applied in the grooves (22a – 22f) the reinforcement (26, 30, 32) runs along the sidewalls of the grooves (22a – 22f).

4. The method as recited in claim 2 or 3, characterized in providing the reinforcement (26, 30, 32) in the form of a glass fiber tape having the majority of reinforcing fibers in transverse direction, and applying the tape in the grooves (22a – 22f) such that the majority of reinforcing fibers are positioned in substantially radial direction.

5. The method as recited in claim 4, characterized in dimensioning the grooves (22a – 22f) in step a) and choosing the glass fiber tape such that when applied in adjacent grooves (22a – 22f) the side edges of the reinforcement tapes (26, 30, 32) abut one another on the roll surface between the grooves (22a – 22f).

6. The method as recited in claim 1 or 2, characterized in that step b) is divided in sub-steps

b1) laying the reinforcement (26, 30, 32) on the roll surface such that the major direction of the reinforcing fibers is transverse to the grooves (22a – 22f),

b2) drawing the reinforcement (26, 30, 32) into the grooves (22a – 22f) such that part of the reinforcement (26, 30, 32) runs along sidewalls of the grooves (22a – 22f).

7. The method as recited in claim 6, characterized in a further step

b3) of inserting one or more additional layers of reinforcement (26, 30, 32) in the grooves (22a – 22f).

8. The method as recited in any of the preceding claims, characterized in inserting the reinforcement (26, 30, 32) in the grooves (22a – 22f) such that the angle between the majority of the reinforcing fibers (26, 30, 32, 34) in the grooves (22a – 22f), and the envelope surface of the roll (10) is more than 45°.

9. The method as recited in any of the preceding claims, characterized in that the reinforcement is in the form of a fiber mat, a fiber felt, a fiber tape, a non-woven or a woven fabric.

10. A filled roll coated with composite material, the filled roll (10) having a metal core (12), a fiber filling (18) thereon, and pressure plates (16) at both ends of the fiber filling (18), the fiber filling (18) having an outer surface (20) provided with grooves (22a – 22f) having sidewalls, the roll surface (20) being further provided with a reinforcement, and one or more composite layers, characterized in that the reinforcement (26, 30, 32, 34) comprises reinforcing fibers in said grooves (22a – 22f), a majority of the reinforcing fibers being oriented in said grooves (22a – 22f) in a direction differing substantially from the direction of the grooves (22a – 22f).

11. The filled roll as recited in claim 10, characterized in that the grooves (22a – 22f) extend in substantially circumferential direction

12. The filled roll as recited in claim 10 or 11, characterized in that the reinforcement (26, 30, 32, 34) is in the form of a fiber mat (32), a fiber felt, a fiber tape, a non-woven or a woven fabric.

13. The filled roll as recited in claim 10 or 11, characterized in that the sidewalls of the grooves (22a – 22f) form at least for a part of their height an angle of more than 45° with the envelope surface of the roll (10).

14. The filled roll as recited in claim 10 or 11, characterized in that at least one of the fiber mat (32), the fiber felt, the fiber tape, the non-woven and the woven fabric is inserted into the grooves (22a – 22f) such that at least one of the fiber mat (32), the fiber felt, the fiber tape, the non-woven or the woven fabric runs at least partially along the side walls of the grooves (22a – 22f).

15. The filled roll as recited in any of the preceding claims 10 - 14, characterized in that the majority of the reinforcing fibers in the reinforcement (26, 30, 32) in the grooves (22a – 22f) form an angle of more than 45° with the envelope surface of the roll (10).

16. The filled roll as recited in any of the preceding claims 10 - 15, characterized in that the reinforcement (26, 30, 32) is at least partially made of at least one of glass, aramid, carbon, boron, metal, and ceramic fibers.

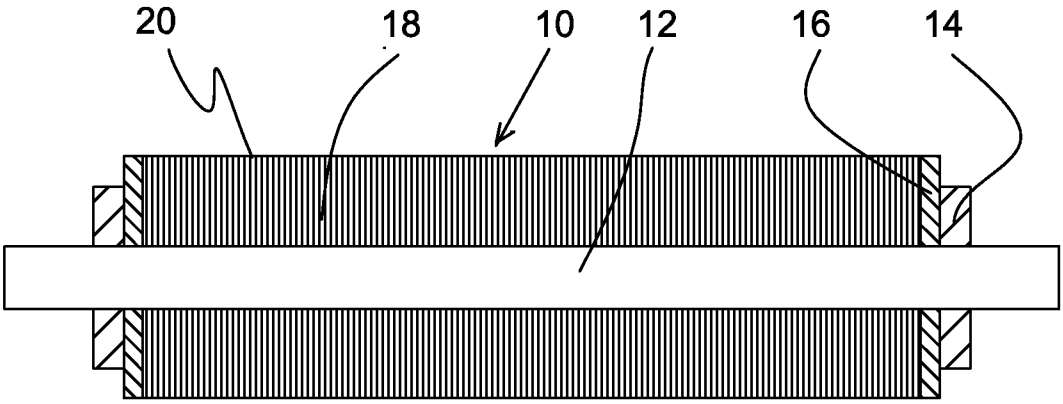


Fig. 1

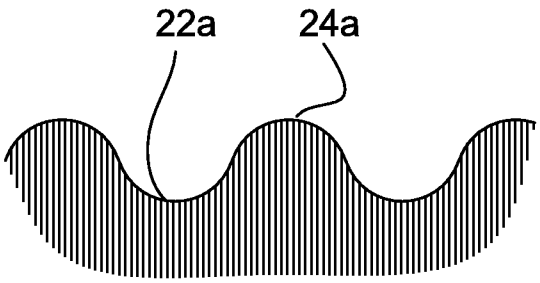


Fig. 2a

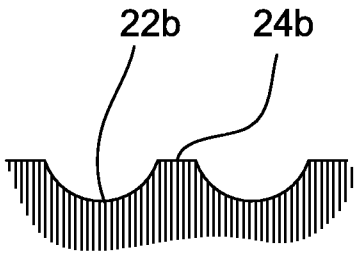


Fig. 2b

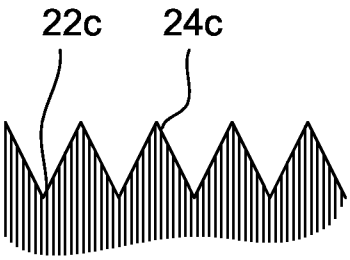


Fig. 2c

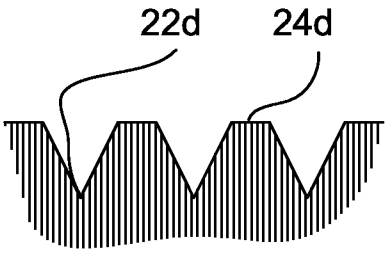


Fig. 2d

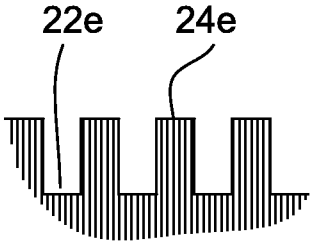


Fig. 2e

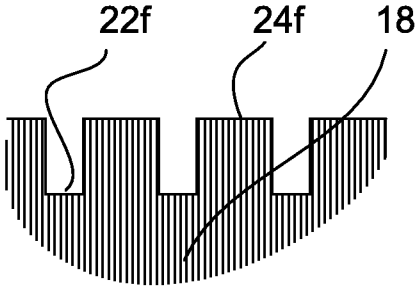


Fig. 2f

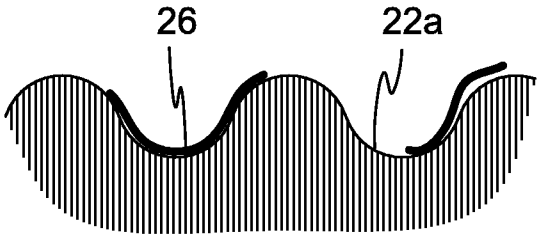


Fig. 3a

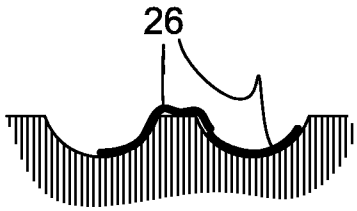


Fig. 3b

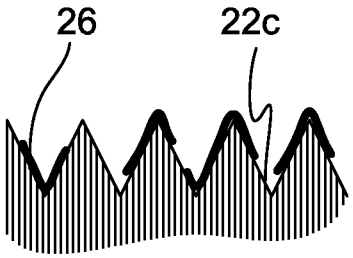


Fig. 3c

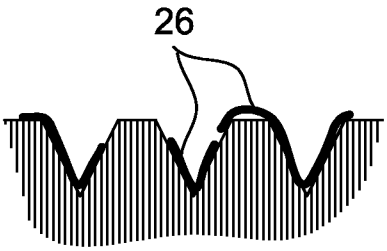


Fig. 3d

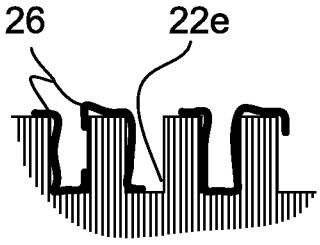


Fig. 3e

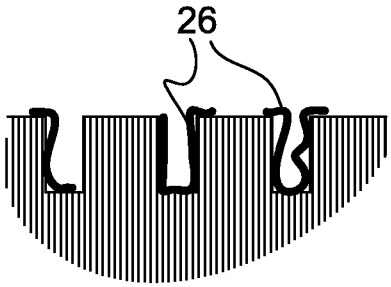


Fig. 3f

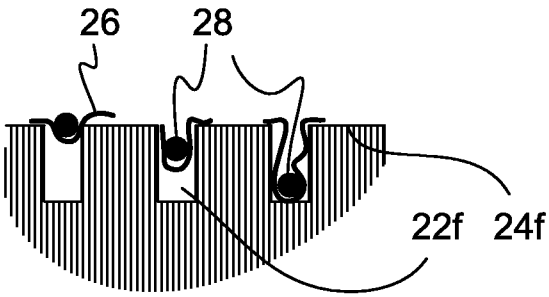


Fig. 4a

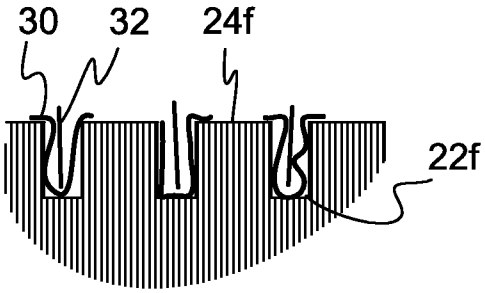


Fig. 4b

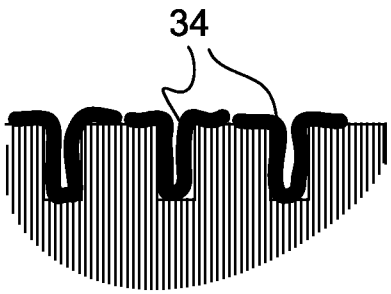


Fig. 5a

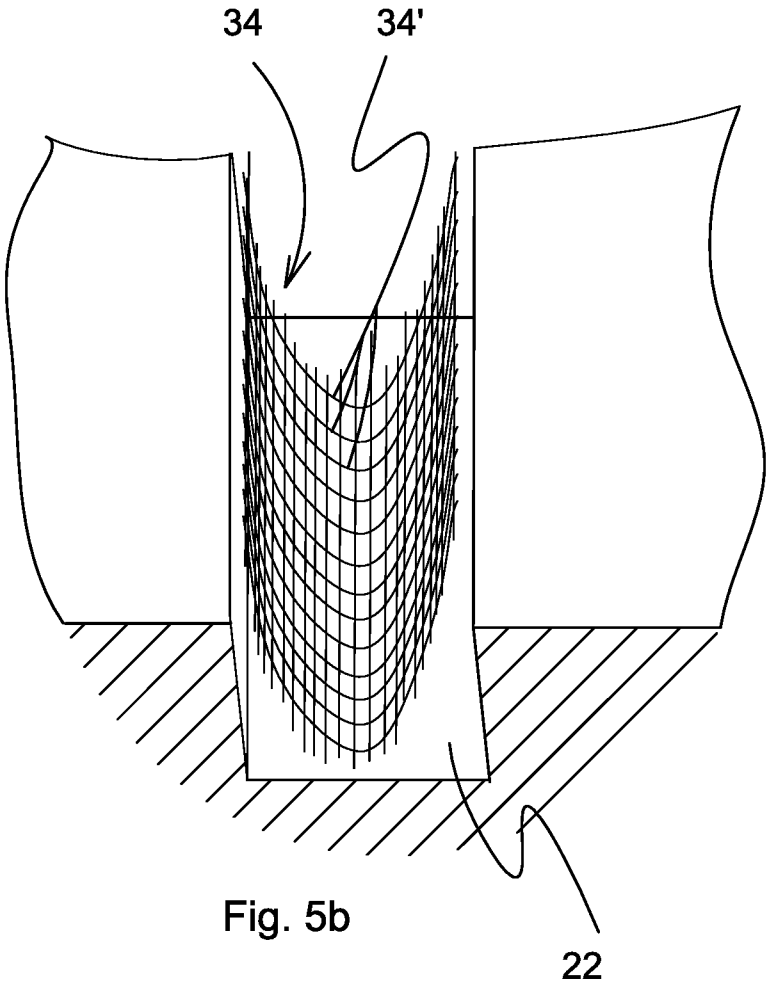


Fig. 5b

INTERNATIONAL SEARCH REPORT

International application No.
PCT/FI2007/050370

A. CLASSIFICATION OF SUBJECT MATTER

See extra sheet

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)

IPC8: D21G, F16C, B21B, B25F, B65B, B65H, B29D

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

FI, SE, NO, DK

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

EPO-INTERNAL, WPI

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2005233880 A1 (SOHL CARSTEN et al.) 20 October 2005 (20.10.2005), paragraphs 0002, 0007, 0009, 0011-0013, and 0016-0018, figures 1-3	1-16
A	US 6375602 B1 (JONES LISA) 23 April 2002 (23.04.2002)	1-16
A	US 4368568 A (WATANABE ATSUO) 18 January 1983 (18.01.1983)	1-16
A	US 3673025 A (FUKUYAMA YASUO et al.) 27 June 1972 (27.06.1972)	1-16

☐ 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

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"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

"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

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
12 December 2007 (12.12.2007)	28 February 2008 (28.02.2008)

Name and mailing address of the ISA/FI
National Board of Patents and Registration of Finland
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Mari Nummela
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INTERNATIONAL SEARCH REPORT

International application No.
PCT/FI2007/050370

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

I. Claims 1-9 are directed to a method of coating a filled roll with composite material.

II. Claims 10-16 are directed to a filled roll coated with composite material.

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☒ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/FI2007/050370

CLASSIFICATION OF SUBJECT MATTER

Int.Cl.
D21G 1/02 (2006.01)
F16C 13/00 (2006.01)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/FI2007/050370

Patent document cited in search report	Publication date	Patent family members(s)	Publication date
US 2005233880 A1	20/10/2005	EP 1586703 A1	19/10/2005
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