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(54) THERMOMECHANICAL PULP

(57) The invention relates to a method for manufacturing a thermomechanical pulp, the method comprising: conveying wood-based material having a dry matter content between 35% and 65% to a first refiner (R1), refining the wood-based material in the first refiner (R1), wherein a total amount of water added to the refiner(s) is in a range between 700 L and 1800 L per obtained ton of the thermomechanical pulp (3) (by dry weight), and wherein a dry matter content of the obtained thermomechanical pulp (3) is at least 70%. The invention further relates to a wood-based product.

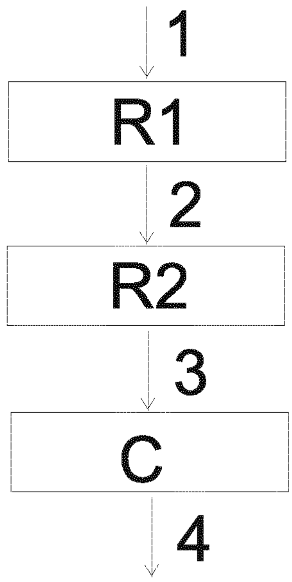

Fig.1

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Description

Technical field

[0001] This specification relates to a method for manufacturing a thermomechanical pulp. This specification further relates to a wood-based product comprising or consisting of thermomechanical pulp. This specification relates to a use of a thermomechanical pulp.

Background

[0002] Cellulose based fibers can be used as a raw material for many products, such as for papers, paperboards and biocomposites. For example, papers and paperboards can comprise mechanical pulp and/or chemical pulp, and wood-plastic composites can be made from a plastic and a chemical pulp.
[0003] Mechanical pulping is a process in which wood is mechanically refined into pulp. Mechanical pulping includes different mechanical processes. Depending on the process, the obtained mechanical pulp can be, e.g., stone groundwood pulp, pressurized groundwood pulp, thermomechanical pulp, or chemithermomechanical pulp. All these different kinds of mechanical pulp have different properties.
[0004] However, there is still a need for an improved method for manufacturing raw materials for different wood-based products.

Summary

[0005] It is an aim of this specification to provide a method for manufacturing a thermomechanical pulp. Further, it is an aim of this specification to provide a wood-based product comprising or consisting of thermomechanical pulp. Still further, it is an aim of this specification to provide a method for manufacturing a wood-based product comprising or consisting of thermomechanical pulp.
[0006] Aspects of the invention are characterized by what is stated in the independent claims. Some preferred embodiments are disclosed in the dependent claims. These and other embodiments are disclosed in the description and figures.
[0007] In conventional thermomechanical pulping, a lot of water is used for manufacturing steps. Water is used to lubricate and cool the refiners and thereby to prevent the heating and burning of the wood raw material. Furthermore, a lot of energy is used for refining wood chips in the refiners.
[0008] Surprisingly, by using a method according to this specification, water consumption and energy used for refiners can be substantially decreased. Thus, the technical effects of the manufacturing process can include:

- decreased dilution water consumption, e.g., 30-65 % smaller than conventionally,
- decreased total water consumption of separator(s), e.g., 60-80 % smaller than conventionally, and
- decreased specific energy consumption, e.g., 30-60% smaller than conventionally, determined as a total energy consumption for all refiners.

[0009] The raw material for thermomechanical pulping is organic material and constitutes a substrate that is susceptible to microbial growth when wet. Thus, when thermomechanical pulp made by conventional methods is applied, e.g., in the manufacture of thermal insulation, the pulp must be dried before it is used. Thus, conventionally, a lot of energy needs to be used for drying the formed pulp having high water content.
[0010] A drying process of thermomechanical pulp is an expensive process, while poorly dried pulps can have a quite limited shelf life creating additional challenges for their logistics and handling as well as their actual end use. Improvements for such problems have mainly been sought by improving drying process.
[0011] Surprisingly, thanks to the novel thermomechanical process using significantly smaller quantity of water than conventionally, the drying, and hence several problems relating to the drying of the thermomechanical pulp, can be avoided.
[0012] A method for manufacturing a thermomechanical pulp can comprise the following steps

- conveying wood-based material, such as wood chips, having a dry matter content between 35% and 65% to a first refiner,
- refining the wood-based material in the first refiner, thereby obtaining pulp having a dry matter content of at least 70%, preferably at least 75%,
- optionally, conveying the pulp from the first refiner to a second refiner, and further refining the pulp in the second refiner,

wherein

- a total amount of water added to the refiner(s) during the refining is in a range between 700 L and 1800 L, preferably in a range between 900 L and 1600 L, and most preferably in a range between 1000 L and 1500 L per obtained ton of the thermomechanical pulp (by dry weight), and
- a total specific energy consumption in the refiner(s), calculated as a combined total specific energy for all refiners, is in a range between 400 kWh per ton and 2500 kWh per ton, preferably between 800 kWh per ton and 1500 kWh per ton, measured as dry weight of the obtained thermomechanical pulp,

thereby obtaining a thermomechanical pulp having a dry matter content of at least 70%.

[0013] In this specification, the wording "total amount of water added to the refiner(s) during the refining" includes water that is first added to the wood-based material and then fed into the refiner(s) together with the wood-based material, as well as water added otherwise (i.e., separately from the wood-based material) into the refiner(s).

[0014] Advantageously, a proportion of spruce is at least 50 wt.%, more preferably at least 80 wt.%, determined from dry weight of the wood-based material. Technical effect is to obtain improved properties for the obtained thermomechanical pulp. Further, by using spruce, specific energy, i.e., quantity of energy used in a refiner per ton of raw material fed to the refiner can be smaller than by using pine.

[0015] If the method comprises the step of refining the pulp in the second refiner, a dry matter content of the thermomechanical pulp coming from the second refiner is preferably in a range between 80% and 98%, more preferably in a range between 88% and 98%. Technical effect is to obtain very dry pulp that is suitable for many applications without a drying step.

[0016] If the method comprises the two refiners, preferably from 65% to 85%, more preferably from 71% to 83%, and most preferably from 73% to 82%, from the total amount of water added to the refiners is added to the first refiner. Thus, preferably from 15% to 35%, more preferably from 17% to 29%, and most preferably from 18% to 27% from the total amount of water added to the refiners is added to the second refiner. Technical effect is to have environmentally friendly process, and to obtain good quality for the produced thermomechanical pulp.

[0017] The thermomechanical pulp according to this specification can also be called as a wood-based thermomechanical pulp.

[0018] The thermomechanical pulp can be compressed to obtain a compressed thermomechanical pulp-based product, i.e., a wood-based product comprising or consisting of the thermomechanical pulp. Thus, the method can further comprise the following steps:

- conveying the thermomechanical pulp to a compressing device, and
- compressing the pulp,

thereby forming a wood-based product, such as a pellet or a bale, comprising or consisting of the thermomechanical pulp.

[0019] In an advantageous embodiment, the wood-based product is a pulp sheet or a pulp web, a fluff roll, a bale, a briquette, or a pellet. Preferably, the wood-based product is the bale or the pellet.

[0020] As discussed, the method according to this specification has several technical effects. For example, the method for manufacturing a thermomechanical pulp does not need to have reject refiners. Thus, preferably, the process has only one or only two refiners. Technical effect is that process without reject refiners is more environmentally friendly and has decreased energy consumption and decreased costs.

[0021] Further, as the novel process does not need to have the reject refiners, the novel process neither needs washing devices for the reject, or devices for increasing solid content of the reject. Moreover, as the process does not need the reject lines, there is no need for separators for dividing the pulp into rejected and accepted pulps. Technical effect is that the process without reject lines is more environmentally friendly, has decreased energy consumption, and decreased costs.

[0022] Furthermore, the method for manufacturing a thermomechanical pulp according to this specification does not need a drying step. Thus, the process does not need a drying device. Thus, the obtained pulp can be compressed into a compressed wood-based product directly after the refining process, without any drying step between the last refining step and the compressing step. Technical effect is that process without a dryer is more environmentally friendly, has decreased energy consumption, and decreased costs. It is to be noted that a conventional drying process typically uses lots of energy for drying the pulp after the refining.

[0023] Furthermore, the novel pulping process does not need a latency treatment. Thus, the process does not need latency removal devices. Technical effect is that the process without latency removal devices has improved manufacturing efficiency.

[0024] In an embodiment, the thermomechanical pulp is an unbleached pulp. Technical effect is that the process without bleaching chemicals is more environmentally friendly.

[0025] As discussed, a total amount of water added to all refiners is preferably in a range between 700 L and 1800 L, more preferably in a range between 800 L and 1600 L, still more preferably in a range between 900 L and 1500 L, and most preferably in a range between 1000 L and 1300 L, determined per dry ton of the obtained thermomechanical pulp. Preferably, more than 65%, more preferably more than 71% of said water is added to the first refiner.
[0026] A total specific energy consumption in the refiner(s), calculated as combined total specific energy for all refiners, is preferably in a range between 400 kWh per ton and 2500 kWh per ton, more preferably between 600 kWh per ton and 2000 kWh per ton, measured as dry weight of the obtained thermomechanical pulp.
[0027] A total specific energy consumption in the refiner(s), if the production line has only one refiner, is preferably in a range between 400 kWh per ton and 1200 kWh per ton, more preferably between 600 kWh per ton and 1100 kWh per ton, measured as dry weight of the obtained thermomechanical pulp.
[0028] A total specific energy consumption in the refiners, if the production line has only two refiners, is preferably in a range between 800 kWh per ton and 2500 kWh per ton, preferably between 1000 kWh per ton and 2000 kWh per ton, measured as dry weight of the obtained thermomechanical pulp.
[0029] Technical effect is to provide thermomechanical pulp having good quality and suitable dry matter content for many applications in an environmentally friendly way, and with decreased energy consumption.
[0030] The method can further comprise the following step:

- separating wood-based material and vaporized water in a separator, preferably in a cyclone separator, before feeding the wood-based material to at least one refiner.

[0031] This can improve efficiency of the manufacturing process.
[0032] The wood-based material can be refined by using only one refiner, i.e., the first refiner. In this embodiment, the first refiner is also the last refiner, and the dry matter content of the thermomechanical pulp coming from the first refiner is preferably at least 70%.
[0033] Thus, a dry matter content of once refined pulp can be at least 70%, more preferably at least 75%, and most preferably at least 80%, determined from the pulp coming from the first refiner.
[0034] The method according to this specification can comprise refining the wood-based material by using only two refiners, i.e., the first refiner and the second refiner. In this embodiment, the second refiner is also the last refiner, and the dry matter content of the thermomechanical pulp coming from the second refiner is preferably at least 80%. It is to be noted that the wording "refining by using only two refiners" means that there is not any additional refiner in the process, such as a reject refiner.
[0035] Properties of the thermomechanical pulp can be adjusted according to an end use. Preferably, the thermomechanical pulp has at least one, more preferably more than one, such as at least 5, and most preferably all the following properties.

1) A length weighted fiber length of the thermomechanical pulp can be in a range between 0.8 mm and 1.25 mm.
2) An average fiber width of the thermomechanical pulp can be in a range between 28 μm and 31 μm.
3) An amount of fiber kinks of the thermomechanical pulp can be in a range between 1700 and 2300 kinks/m.
4) A fibrillation level of the thermomechanical pulp can be in a range between 1.9% and 2.3%.
5) A proportion of flake-like fines of the thermomechanical pulp can be in a range between 48% and 55%, determined from the thermomechanical pulp.
6) A proportion of fibrillar fines can be in a range between 25% and 38%.
7) The thermomechanical pulp can absorb from 5 to 8 their weight in liquid.
8) A proportion of spruce and/or pine can be at least 50 wt.%, more preferably at least 80 wt.%, determined from dry weight of the thermomechanical pulp. Preferably, a proportion of the spruce is at least 50 wt.%, more preferably at least 80 wt.%, determined from dry weight of the thermomechanical pulp.

[0036] The obtained thermomechanical pulp can be used for many products. The thermomechanical pulp can be particularly advantageous for many applications if it has the above-mentioned properties. The benefits are typically realized the better, the more of above-mentioned features are implemented in the thermomechanical pulp.
[0037] The obtained pulp is substantially dry (i.e., a water content is less than 30%, preferably less than 20%) without a drying step. Technical effect is that no separate driers are needed e.g. for litter pellets, or e.g. for bales used for thermal insulation materials.
[0038] An insulation board can comprise or consist of the thermomechanical pulp. The thermomechanical pulp can be used in an insulation board so that a proportion of the thermomechanical pulp is preferably at least 50 wt.%, more preferably at least 90 wt.% (by dry weight), and most preferably at least 95 wt.% (by dry weight).
[0039] A bale can comprise or consist of the thermomechanical pulp. The thermomechanical pulp can be used in a bale so that a proportion of the thermomechanical pulp is at least 80 wt.%, more preferably at least 95 wt.% (by dry

weight), and most preferably at least 99.8 wt.%, determined as dry weight of the bale.

[0040] A pellet, such as a litter pellet, can comprise or consist of the thermomechanical pulp. Preferably, a pellet comprises thermomechanical pulp so that a proportion of the thermomechanical pulp is at least 95 wt.% and most preferably at least 99.8 wt.%. In an advantageous embodiment, the pellet is a compressed wood-based product consisting of the thermomechanical pulp.

[0041] The thermomechanical pulp can be used as a growing medium for plants. In an advantageous embodiment, the thermomechanical pulp is used for replacing at least some, such as from 20 wt.% to 70 wt.%, preferably from 30 wt.% to 50 wt.% (by dry weight), peat in a growing medium. Thus, preferably, amount of thermomechanical pulp in the growing mediums is between 20 wt.% and 70 wt.%, preferably between 30 wt.% and 50 wt.% (by dry weight).

[0042] The thermomechanical pulp can be used as a cover material for plants. Amount of thermomechanical pulp in the cover material can be up to 100 wt.% (by dry weight), determined from total amount of the cover material.

[0043] A composite product can comprise a thermoplastic polymer and the thermomechanical pulp. The thermomechanical pulp can be used in a composite product so that a proportion of the thermomechanical pulp is preferably in a range between 20 wt.% and 60 wt.% (by dry weight).

[0044] In an embodiment, the thermomechanical pulp is used in one of the following applications: a packing cushion, a filter material, a filler e.g. in asphalt and brick industry, and a container.

[0045] Thus, the thermomechanical pulp formed in the process can be utilized in various applications, e.g. as building materials, pellets, and/or as growing medium for plants. The building material is preferably refined with two refiners while the growing medium is preferably refined only once.

[0046] The method according to this specification can have the particular advantage that it can be implemented by an existing production equipment, and that current thermomechanical processes and systems can be modified to correspond to the new process. It is thus possible to reuse an old, redundant system in a new process.

[0047] Thanks to the novel solution, it is possible to significantly reduce energy consumption and, hence, to reduce the production costs. For example, by reducing a specific energy and an amount of water needed in the process, a dry product can be obtained without a separate drying step and without burning the produced pulp.

[0048] Some of water vapour produced in the process can be utilized, for example, for heating of wood chips. In addition, or alternatively, at least some of water vapour produced in the process can be utilized, for example, for washing the wood chips. In addition, or alternatively, at least some of water vapour produced in the process can be utilized, for example, for heating of process waters.

[0049] The novel solution can be environmentally friendly way to obtain substantially dry thermomechanical pulp without a need for drying devices, such as long drying pipes. Further, it is possible to obtain a cellulose based raw material in a cost-effective manner.

[0050] The thermomechanical pulp in accordance with the specification can be environmentally friendly and promote the principle of sustained development. Due to the high dry matter content of the produced thermomechanical pulp, drying step is not needed, hence, the solution according to this specification can be energy-efficient solution. As the thermomechanical pulp according to this specification can be obtained with reduced energy consumption and without chemicals, the solution can also decrease environmental load. The thermomechanical pulp according to this specification is typically a recyclable raw material for many applications, also meeting the ever stricter environmental regulations. Furthermore, thanks to lignin in the thermomechanical pulp, wood-based products can be formed without adding binding agents.

Brief description of the drawings

[0051]

Fig. 1	illustrates, by way of an example, method steps according to an embodiment,
Fig. 2	shows a photo of a thermomechanical pulp,
Figs 3a-e	show fibers of a thermomechanical pulp,
Fig. 4	shows a photo of a thermomechanical pulp bale,
Fig. 5	shows a photo of wood pellets, and
Fig. 6	shows a photo of an obtained thermomechanical pulp.

[0052] The figures are schematic and are intended to illustrate the general principles of the disclosed solution. Therefore, the illustrations in the Figures are not necessarily in scale or suggestive of precise layout of system components.

Detailed description

[0053] The solution is described in the following in more detail with reference to some embodiments, which shall not be regarded as limiting.

[0054] In this specification, references are made to the figures with the following numerals and denotations:

1	wood-based material, such as wood chips,
2	refined pulp,
3	thermomechanical pulp,
4	wood-based product comprising or consisting of the thermomechanical pulp,
R1	first refiner,
R2	second refiner, and
C	compressing device.

Terms and standards

[0055] Unless otherwise indicated, the following standards refer to methods which can be used in obtaining stated values of parameters representing quality of a product:

Dry matter content	%	ISO 638,
Freeness, CSF	ml	ISO 5267-2,
Length weighted fiber length	Lc(l) mm	ISO 16065-2,
Grammage	g/m^2	ISO 536,
Bulk	cm^3/g	ISO 534,
Tensile strength	kN/m	ISO 1924-3,
Tensile index	Nm/g	ISO 1924-3,
Tear index	mNm^2/g	ISO 1974,
Bonding strength SB	Low J/m^2	ISO 16260,
Opacity	%	ISO 2471,
Light scattering coefficient	m^2/kg	ISO 9416,
Absorption coefficient	m^2/kg	ISO 9416, and
Preparation of laboratory sheets with recirculated white water		ISO 5269-3.

[0056] Unless otherwise indicated, fiber properties can be obtained by using Valmet Fiber Image Analyzer (Valmet FS5) according to the manufacturer’s instructions.

[0057] Valmet Fiber Image Analyzer (Valmet FS5) is an example of a device, which can be used according to the manufacturer’s instructions to perform the fiber furnish analysis. For example, automated optical analysis, such as an ultrahigh resolution (UHD) camera system equipped with image analysis software, may be used to acquire a greyscale image of a sample, of which image the properties of the fibers in the sample can be determined. The greyscale image can be acquired from a sample placed in a transparent sample holder, such as a cuvette, using a 0.5 millimeter depth of focus according to ISO 16505-2 standard.

[0058] Valmet Fiber Image Analyzer (Valmet FS5) can be used to determine fiber properties, such as fiber length and fiber width, by means of automated optical analysis using unpolarized light, according to ISO 16065-2: 2014.

[0059] For the purpose of the present description and the claims, unless otherwise indicated, all ranges include any combination of the maximum and minimum points disclosed and include any intermediate ranges therein, which may or may not be specifically enumerated herein.

[0060] The embodiments and examples recited in the claims and in the description are mutually freely combinable unless otherwise explicitly stated.

[0061] In this specification, the term "comprising" may be used as an open term, but it also comprises the closed term "consisting of". Thus, unless otherwise indicated, the word "comprising" can be read as "comprising or consisting of".

[0062] The term "specific energy" refers to the quantity of energy used in a refiner per ton of raw material fed to the refiner.

[0063] A refiner line according to this specification preferably comprises only 1 refiner or only 2 refiners.

[0064] In this specification, the term "once refined pulp" refers to a pulp coming from the first refiner R1.

[0065] In this specification, the wording "total amount of water added to the refiner(s) during the refining" includes or consists of

- water that is first added to the wood-based material and then fed into the refiner together with the wood-based material, and
- water added directly (i.e., separately from the wood-based material) into the refiner(s).

[0066] In this specification, the term "thermomechanical pulp" refers to a pulp coming from the last refiner. The last refiner can be, for example, the first refiner or the second refiner. If the system comprises, e.g., three refiners, the last refiner can be the third refiner. Preferably, the last refiner is the second refiner.

[0067] A conventional refiner line can comprise 1 to 5 reject refiner(s) for refining a reject. However, the method according to this specification does not need the reject refiners. Thus, preferably, the method for manufacturing the thermomechanical pulp comprises exactly 0 reject refiners.

[0068] Preferably, the method for manufacturing the thermomechanical pulp comprises 1 to 4 refiners (combined amount of main refiners and reject refiners), more preferably 1 to 3 refiners, and most preferably 1 to 2 refiners. In one advantageous embodiment, the method comprises only one refiner. Technical effect of having only one or only two refiners is to decrease energy consumption of the manufacturing process.

[0069] Percentage values relating to an amount of a material are percentages by weight (wt.%) unless otherwise indicated. All percentage values relating to an amount of a material refer to dry weight, unless otherwise indicated.

[0070] In this specification, the term "recycling" refers to new use of a material, wherein the material is recovered and provided for a new use.

[0071] In this specification, unless otherwise indicated, the term "thermomechanical pulp" refers to material originating from wooden material, which has been processed into fibrous form, such as fibers, using a thermomechanical process. The thermomechanical pulp 3 according to this specification can have a dry matter content of more than 70 %, preferably more than 80%, such as equal to or more than 90 % determined from the pulp after the last refiner, without a drying step.

Raw material

[0072] Wood species can be divided into two main groups denoted as softwood and hardwood. Softwood and hardwood have distinguished mechanical characteristics and chemical composition, which differ from each other.

[0073] The raw material for the thermomechanical process is cellulose based raw material, preferably wood, more preferably softwood, and most preferably spruce. By selection of the wood species and the wood processing method, different types of pulp having different qualities can be obtained. The thermomechanical pulp 3 according to this specification can, at least essentially, consist of softwood(s). The target is a fiber distribution having suitable content of long fibers and fines for an end use of the produced thermomechanical pulp 3. Thus, the raw material, such as wood chips, can consist of, or at least essentially consist of, softwood-based material.

[0074] Preferably, the raw material, i.e., the wood-based material 1, has a dry matter content in a range between 35 % and 65 %, determined as dry matter content of the wood-based material 1, when fed to a first refiner R1.

[0075] Preferably, the raw material for the thermomechanical pulp 3 according to this specification is fresh wood chips, with a dry matter content in a range between 35 % and 65 %, determined as dry matter content of wood chips when fed to a first refiner R1. The technical effect of this dry matter content is to provide particularly environmentally friendly solution as the wood chips do not need to be, e.g., dried but fresh chips can be fed to the first refiner R1.

[0076] Wood chips can be made of wood by methods known as such.

[0077] The produced thermomechanical pulp 3 can comprise equal to or more than 50 wt.%, preferably equal to or more than 75 wt.%, more preferably equal to or more than 88 wt.%, still more preferably equal to or more than 95 wt.%, and most preferably equal to or more than 99 wt.%, such as 100 wt.% (by dry weight), softwood, most preferably spruce. The technical effect is to obtain thermomechanical pulp 3 having good fiber distribution as well as suitable properties for different applications.

Method

[0078] Mechanical pulp refers to cellulose pulp obtained from a process wherein fibers have been produced through mechanical methods. Examples of a mechanical pulps are, for example, grinding-stone ground wood pulp (SGW), pressure ground wood pulp (PGW) and thermomechanical pulp (TMP). All these mechanical methods typically produce pulp having a dry matter content of less than 50 %.

[0079] A person skilled in the art knows the differences between the pulping methods. The pulp according to this specification is obtained by using a thermomechanical process.

[0080] Fig. 1 illustrates, by way of an example, some method steps according to an embodiment.

[0081] For environmental reasons, as well as for obtaining pulp having a suitable quality for different applications, the thermomechanical pulp is preferably manufactured by using 1 to 2 refiners, such as two refiners, most preferably only one or only two refiners. Thus, the system can comprise a first refiner R1, optionally a second refiner R2, and in an embodiment a third refiner.

[0082] Preferably, the process does not comprise reject refiners. The technical effect is to decrease energy consumption as well as other costs. The novel method can provide thermomechanical pulp that is suitable for many applications without a need of reject refiners.

[0083] The wood-based material 1, such as wood chips, can be, for example, sieved before they are conveyed to a first refiner R1. The technical effect is to improve quality of the produced thermomechanical pulp 3 and decrease problems in refiners.

[0084] The method for manufacturing thermomechanical pulp 3 can comprise a step of separation of sand, metal bits and other impurities from the wood-based material 1. Thus, the method can comprise, for example, the following step:

- separating impurities from the wood-based material 1 before the wood-based material, such as wood chips, are conveyed to the first refiner R1.

[0085] The step of separating impurities from the wood-based material 1 before the wood-based material 1 is conveyed to the first refiner can comprise e.g. a washing step. Thus, the method can comprise, for example, the following step:

- washing the wood-based material 1 before the wood-based material 1 is conveyed to the first refiner R1.

[0086] The washing typically comprises steps of first adding water to the wood-based material, following by removing water from the wood-based material e.g. by using a screw. Washed wood-based material can have a dry matter content between 35% and 65%, more preferably between 35% and 50%.

[0087] In an embodiment, the wood-based material 1 is preheated at a temperature in a range between 105°C and 130°C, preferably in a range between 110°C and 125°C before conveying the wood-based material to the first refiner. Technical effect is that without the preheating, fiber length of the obtained pulp can be substantially smaller than with the preheating.

[0088] The wood-based material can be preheated under a pressure of, for example, 40 kPa to 130 kPa, preferably from 50 kPa to 90 kPa. The technical effect is to improve fiber length of the obtained pulp. Without the preheating, fiber length of the obtained pulp can be substantially smaller than with the preheating.

[0089] Thus, the method can comprise the following step:

- preheating the wood-based material, preferably at a temperature of 110°C to 125°C.

[0090] A preheating time can be, for example, in a range between 0 and 7 min, such as in a range between 30 s and 5 min.

[0091] Alternatively, the wood-based material is not preheated before feeding the material to the first refiner R1. The technical effect is to increase efficiency of the process and/or to simplify the system. The preheated wood-based material, such as wood chips, is typically softer and may have higher energy consumption in refiners than such wood chips that are not preheated. Further, another technical effect is to improve brightness of the obtained pulp.

[0092] The method for manufacturing thermomechanical pulp 3 comprises a step of conveying wood-based material 1 to the first refiner R1. At this stage, the dry matter content of the wood-based material to be conveyed to the first refiner can be from 35 to 65%, preferably from 40% to 55%. The technical effect is that the wood-based material can be fresh chips having their natural dry matter content, and the wood-based material can be fed to the first refiner R1 without a pre-drying.

[0093] In the refining process, the wood-based material, such as wood chips, are crushed into fiber bundles and single fibers. In the refiner, vapour can be separated from the pulp obtained from the refiner, by means of a vapour separating device.

[0094] Therefore, the refiner line comprising at least one refiner can have at least one separator for separating fibers and vaporized water from each other. The separator can be e.g. a cyclone separator. In a preferred embodiment, a cyclone separator is located

- before the first refiner, and/or
- between the first refiner and the second refiner, and/or
- after the second refiner.

[0095] Some water can be added into the cyclone separator(s). Amount of water added into the separator(s) can be, for example, in a range between 50 L and 150 L per obtained ton of thermomechanical pulp, preferably in a range between 60 L and 90 L per obtained ton of thermomechanical pulp. The technical effect is to provide good performance without decreasing solid content of the wood-based material too much.

[0096] In an embodiment, amount of water added into the separator(s) is in a range between 0.2 and 1.0 l/s per cyclone separator, preferably in a range between 0.3 and 0.7 l/s per cyclone separator. The technical effect is to provide good performance without decreasing solid content of the wood-based material too much.

[0097] Thus, the method can comprise the following step:

- separating at least some water vapour and removing at least part of the separated water vapour from the wood-based material.

[0098] In this embodiment, the method can comprise the preheating step and at least part of the separated water vapour (steam) can be used for the preheating step.

[0099] The first refiner R1 can be, for example, a single disc refiner (SD), which can be a disc refiner or a conical refiner. In an embodiment, the first refiner is a double disc refiner. Technical effect is to provide cost efficiently thermomechanical pulp having suitable properties for many applications.

[0100] The term "bdt" refers to a bone dry ton. The term "bone dry ton" refers to a unit of weight equal to 2,000 pounds of woody material at zero percent (0%) moisture content, and is known by a person skilled in the art.

[0101] The specific energy applied for the first refiner R1 can be from 400 kWh/bdt to 1350 kWh/bdt, preferably in a range between 600 kWh/bdt and 1100 kWh/bdt, and more preferably in a range between 700 kWh/bdt and 1000 kWh/bdt. Technical effect is to obtain pulp having suitable properties without burning the pulp during the refining.

[0102] A total specific energy consumption in the refiner, if the production line comprises only one refiner, is preferably in a range between 400 kWh per ton and 1200 kWh per ton, more preferably between 600 kWh per ton and 1100 kWh per ton, measured as dry weight of the obtained thermomechanical pulp.

[0103] In an embodiment, the specific energy applied for the first refiner R1 is from 500 kWh/bdt to 800 kWh/bdt. The technical effect is to provide pulp having a high fiber length. Another technical effect is to provide cost efficiently pulp suitable, e.g., for insulation material.

[0104] In an embodiment the specific energy applied for the first refiner R1 is from 850 kWh/bdt to 1300 kWh/bdt. The technical effect is to provide a pulp with a high fibrillation degree. Another technical effect is to provide a pulp suitable, e.g., for papers.

[0105] Rotation speed of the first refiner R1 can be, for example, 1300 to 1700 rpm. The technical effect is to provide good refining conditions for the thermomechanical pulp.

[0106] A pressure of the first refiner R1 can be, for example, 300 kPa to 450 kPa, preferably in a range between 340 kPa and 410 kPa. Said pressure of the first refiner can be particularly advantageous for producing the dry pulp.

[0107] A temperature in the first refiner R1 can be from 130°C to 180°C, preferably in a range between 140°C and 170°C, more preferably in a range between 150°C and 160°C. The technical effect of the temperature is to efficiently dry the pulp while refining. However, too high temperatures (e.g., above 200°C) can burn the fibers and hence should be avoided.

[0108] The dry matter content of the once refined pulp, i.e., pulp coming from the first refiner R1, can be from 70 to 85%, preferably in a range between 72% and 80%, and still more preferably at least 75%, and most preferably at least 78%. The technical effect is to provide, cost efficiently, thermomechanical pulp having such dry matter content that is suitable for e.g. insulation materials, without additional drying step. Another technical effect is to provide substantially dry pulp without a drying device by using only one refiner.

[0109] Freeness of the once refined pulp, i.e., pulp coming from the first refiner R1, can be from 100 ml to 800 ml, preferably from 400 ml to 800 ml. The technical effect is to obtain, cost efficiently, pulp suitable for many applications. Further, said freeness can be particularly suitable for the pulp without a drying step.

[0110] In an advantageous embodiment, the thermomechanical pulp is obtained by using only one refiner R1. In another advantageous embodiment, the once refined pulp 2 can be conveyed to a second refiner R2, and the thermomechanical pulp is obtained by using only two refiners R1, R2.

[0111] The method for manufacturing the thermomechanical pulp according to this specification may not comprise a screening device downstream of the first refiner, such as between refiners. Thus, in an embodiment, the system does not have such a screening device for screening the pulp according to the fiber size that is located downstream from the first refiner. Thus, there may be exactly 0 screening devices downstream from the first refiner. The technical effect is to simplify the system so that the pulp flow can be conveyed from the first refiner without a screening step. Furthermore, it could be challenging to screen the substantially dry material.

[0112] As discussed, in an embodiment, the process comprises only one refiner, i.e., the first refiner.

[0113] The method for manufacturing the thermomechanical pulp according to this specification can comprise the second refiner R2.

[0114] The second refiner R2 can be, for example, a single disc refiner (SD), which can be a disc refiner or a conical refiner. In an embodiment, the second refiner is a double disc refiner. Technical effect is to provide cost efficiently thermomechanical pulp having suitable properties for many applications. Thus, the refining process for forming thermomechanical pulp 3 can be, at least partly, performed in the second refiner R2.

[0115] A total specific energy consumption in the refiners R1, R2, if the production line has (only) two refiners, is preferably in a range between 800 kWh per ton and 2500 kWh per ton, preferably between 1000 kWh per ton and 2000 kWh per ton, measured as dry weight of the obtained thermomechanical pulp.

[0116] The specific energy applied for the second refiner R2 can be 300 to 1000 kWh bdt, preferably in a range between 400 kWh/bdt and 750 kWh/bdt, more preferably in a range between 450 kWh/bdt and 700 kWh/bdt, and most preferably in a range between 500 kWh/bdt and 650 kWh/bdt, wherein the total specific energy consumption in the refiners R1, R2 is preferably as discussed in this specification. The technical effect is to provide, cost efficiently, thermomechanical pulp having suitable dry matter content as well as suitable properties for certain applications. The technical effect of the higher specific energy is to improve strength properties of the products to be obtained from the pulp. The technical effect of the lower specific energy is to provide a pulp having increased fiber length. Further, by using the higher specific energy, the obtained pulp can be particularly suitable for papers, and by using the lower specific energy, the obtained pulp can be particularly suitable for insulation materials.

[0117] Rotation speed of the second refiner R2 can be, for example, 1300 to 1700 rpm. The technical effect is to provide good refining conditions for the thermomechanical pulp.

[0118] A pressure of the second refiner R2 can be 150 kPa to 310 kPa, preferably 170 kPa to 290 kPa, and more preferably from 190 kPa to 270 kPa. Said pressure can be particularly advantageous for producing the dry pulp.

[0119] A temperature in the second refiner R2 can be from 130°C to 180°C, preferably in a range between 140°C and 170°C, more preferably in a range between 150°C and 160°C. The technical effect of the temperature is to efficiently dry the pulp while refining. However, too high temperatures (e.g., above 200°C) can burn the fibers and hence should be avoided.

[0120] When using two refiners, a dry matter content of the obtained thermomechanical pulp 3 can be at least 80%, such as from 80 to 98%, determined from the pulp coming from the second refiner. Thus, a dry matter content of the thermomechanical pulp 3 can be from 80 to 98 %, preferably from 85% to 97%, more preferably from 88% to 96%, and most preferably from equal to or more than 90% to 95%, determined from the thermomechanical pulp coming from the second refiner, i.e., without a drying step.

[0121] Freeness of the thermomechanical pulp 3 can be from 80 ml to 800 ml. This range is suitable for many applications. A lower freeness, such as from 100 ml to 200 ml, can be used, for example, for papers and paperboards. The higher freeness can be used, for example, for insulation materials.

[0122] In an embodiment, freeness of the thermomechanical pulp 3 is at least 100 ml, preferably from 150 ml to 250 ml. The technical effect is to provide pulp suitable for a paper.

[0123] In an embodiment, freeness of the thermomechanical pulp 3 is at least 400 ml, preferably from 450 ml to 700 ml. The technical effect is to provide, cost efficiently, e.g. an insulation material.

[0124] If the production line comprises only one refiner, the freeness of the thermomechanical pulp 3 is preferably at least 300 ml, for example in a range between 300 ml and 820 ml.

[0125] If the production line has (only) two refiners, the freeness of the thermomechanical pulp 3 is preferably less than 800 ml, for example in a range between 80 ml and 780 ml.

[0126] Thanks to the decreased energy consumption and heat formed in the refiners, as well as smaller dilution water than conventionally, the wood-based material can be dried during the refining, without a need for a dryer.

[0127] Preferably, at least 65% such as from 65 to 87%, more preferably from 71 to 83% from the total amount of water added to the refiner(s) during the refining is added to the first refiner. Technical effect is to strongly improve quality of the obtained thermomechanical pulp.

[0128] Amount of dilution water added to the refining, if determined by l/s, depends on the refining line. Amount of dilution water added to the refining (in addition to the water coming from the raw material) can be, for example, less than 3 l/s, preferably less than 2.5 l/s, such as 0.5 l/s to 2.5 l/s, still more preferably less than 2 l/s, and most preferably less than 1.8 l/s, such as less than 1.5 l/s. In an embodiment, from the dilution water, for example, approximately 0.5 to 2.5 l/s can be dosed to the first refiner R1, and 0 to 0.7 l/s can be dosed to the second refiner R2 (if used). In an embodiment, amount of dilution water added to the first and/or the second refiner is 0.5 to 1.8 l/s, or 0 to 1 l/s. The technical effect is to obtain very dry pulp.

[0129] Thanks to the novel solution, water contained in the chips and the water added to the refiners can be sufficient to make the chips a good fibrous raw material. Technical effect of the added water and low specific energy level of the refiners is that chips do not burn in the blade gap.

[0130] Thanks to the novel solution, thermomechanical pulp 3 can be manufactured without a dryer by using a refiner line having, e.g. two refiners, i.e., a first refiner R1 and a second refiner R2.

[0131] As discussed, the method for manufacturing the thermomechanical pulp 3 having a dry matter content of at least 70%, such as in a range between 70% and 98%, preferably does not comprise a dryer. Thus, preferably, the method for manufacturing the thermomechanical pulp 3 having a dry matter content of at least 70%, typically at least 80%, comprises exactly 0 drying devices.

[0132] The thermomechanical pulp 3 manufactured according to this specification can have desired optical and strength properties for many applications. The optical properties of the novel thermomechanical pulp are typically better than optical properties of conventionally produced thermomechanical pulp.

[0133] Moreover, shive content of the obtained thermomechanical pulp can be substantially low. Thus, the method according to this specification typically does not need reject refiners. This can improve cost efficiency of the process. The low shive content of the thermomechanical pulp is important feature for some applications as shives cannot be easily separated from the dry pulp.

Thermomechanical pulp

[0134] The thermomechanical pulp 3 according to this specification can be environmentally friendly product that can be produced without chemicals.

[0135] It was noted during experimental tests that properties of thermomechanical pulp 3 which is produced according to this specification without a separate drying step differed from properties of conventionally produced and dried thermomechanical pulp.

[0136] Thermomechanical pulp production according to this specification is typically more intensive than conventional production and thus fiber characteristics and shape, such as fiber length, fiber width, kinks, kink angle etc., can change compared to conventional thermomechanical pulps. For example, shive content of pulp, fibrillation level of fibers and proportion of fibrillar fines at a certain freeness can be lower than those of a conventional thermomechanical pulp, while e.g. a proportion of flake-like fines can be higher. These changes were also be seen from obtained hand sheets as lower sheet bulk, tear index, stretch and tensile index, while e.g. bonding strength, light scattering coefficient and opacity were improved.

[0137] Fig. 2 shows a photo of a thermomechanical pulp manufactured according to this specification.

[0138] The thermomechanical pulp 3 can comprise, essentially consist of, or consist of wood-based material. Preferably, a proportion of wood-based material(s) is at least 95 wt.%, more preferably at least 98%, and most preferably at least 99.5 wt.%, such as 100 wt.%, determined as dry weight of the thermomechanical pulp 3.

[0139] Preferably, the thermomechanical pulp 3 is refined without chemicals, and the obtained thermomechanical pulp 3 does not comprise chemicals, i.e., amount of chemicals in the thermomechanical pulp 3 is preferably 0 wt.%.

[0140] The thermomechanical pulp 3 can essentially consist of, or consist of, softwood(s). Different wood species have distinguished mechanical characteristics and chemical composition, which differ from each other. Preferably, equal to or more than 50 wt.%, more preferably equal to or more than 65 wt.%, still more preferably equal to or more than 80 wt.%, and still more preferably equal to or more than 90 wt.%, and most preferably equal to or more than 95 wt.%, such as 100 wt.% of the obtained thermomechanical pulp 3 is from spruce and/or pine. More preferably, equal to or more than 50 wt.%, still more preferably equal to or more than 65 wt.%, still more preferably equal to or more than 80 wt.%, still more preferably equal to or more than 90 wt.%, and most preferably equal to or more than 95 wt.%, such as 100 wt.%, of the obtained thermomechanical pulp 3 is from spruce. By selection of the wood species for the thermomechanical pulp 3, predetermined qualities can be obtained. Further, by using spruce, specific energy, i.e., quantity of energy used in a refiner per ton of raw material fed to the refiner can be smaller than by using pine. Furthermore, spruce is preferred for this process as pine extracts may cause several challenges to the manufacturing process.

[0141] An average fiber length of the thermomechanical pulp 3 can be in a range between 0.8 mm and 1.25 mm, preferably in a range between 0.9 mm and 1.2 mm, and most preferably in a range between 1.0 mm and 1.15 mm, determined according to standard ISO 16065-2, e.g., as a length weighted fiber length Lc(l). The technical effect is to obtain suitable strength properties for many applications.

[0142] An average fiber width of the thermomechanical pulp 3 can be in a range between 28 μm and 31 μm, preferably in a range between 28.5 μm and 30.5 μm, and most preferably in a range between 29 μm and 30 μm. Fiber width can be determined, for example, by using a fiber image analyzer. A term "fiber width" refers to a maximum width of each fiber. The technical effect is to provide a such binding surface area between fibers which is suitable for many applications. Further, the average fiber width has an effect on strength properties of the obtained thermomechanical pulp.

[0143] Amount of fiber kinks in the thermomechanical pulp 3 can be in a range between 1700 and 2300 kinks/m, such as in a range between 1800 and 2250 kinks/m, preferably equal to or less than 2200 kinks/m, such as in a range between 1900 and 2200 kinks/m, and most preferably equal to or less than 2150 kinks/m. Technical effect of this range is to control integral structure of fibers so that fiber properties can be within a suitable range for many applications.

[0144] Fibrillation of the thermomechanical pulp 3 can be in a range between 1.9% and 2.3%, preferably in a range between 1.95% and 2.25%, more preferably in a range between 2.0% and 2.2%, and most preferably in a range between 2.05% and 2.15%. Technical effect of this range is to provide cost efficiently thermomechanical pulp having predetermined strength properties which are suitable for many applications.

[0145] Proportion of flake-like fines in the thermomechanical pulp 3 can be in a range between 48% and 55%, preferably in a range between 49% and 54%, more preferably in a range between 49.5% and 53%, and most preferably in a range between 50% and 52%. Technical effect of this range is to provide improved optical properties, such as improved opacity. Another technical effect is to improve e.g. readability properties of papers and/or magazines, if the pulp is used for papers.
[0146] Proportion of fibrillar fines in the thermomechanical pulp 3 can be in a range between 25% and 38%, preferably in a range between 27% and 36%, more preferably in a range between 29% and 34%, and most preferably in a range between 30% and 33%. Technical effect of this range is to provide, cost efficiently, thermomechanical pulp having predetermined strength properties which are suitable for many applications.
[0147] Proportion of shives in the thermomechanical pulp 3 can be in a range between 0.2% and 0.8%, preferably in a range between 0.3% and 0.7%, more preferably in a range between 0.4% and 0.6%, and most preferably in a range between 0.45% and 0.55%. Technical effect of this range is that e.g. pellets can be easily formed from the thermomechanical pulp 3 and the formed pellets can maintain their form without e.g. additives. Another technical effect is to provide an improved smoothness for products, such as paper, containing the thermomechanical pulp. Furthermore, as shives usually causes a decreased strength for products, another technical effect is to provide improved strength properties for products containing the thermomechanical pulp.
[0148] Lignin content of the thermomechanical pulp 3 can be in a range between 20 and 35 wt.%, preferably in a range between 30 and 35 wt.%. Technical effect of this range is that due to the lignin e.g. pellets can be easily formed from the thermomechanical pulp 3 as the lignin can bind the particles together, and the formed pellets can maintain their form.
[0149] The percentage of fines, i.e., particles shorter than 20 μm, of the thermomechanical pulp 3 can be in a range between 48 wt.% and 57 wt.% (by dry weight), preferably in a range between 50 wt.% and 55 wt.% (by dry weight). Technical effect of this range is to provide good printability and strength properties for papers comprising the thermomechanical pulp. Another technical effect is to provide pulp having controlled properties for insulation materials.
[0150] The thermomechanical pulp 3 can absorb from 5 to 8, preferably from 6 to 7 their weight in liquid. Technical effect of this range is that the thermomechanical pulp can be good material e.g. for litter pellets.
[0151] The water absorption can take time. The thermomechanical pulp 3 can absorb 3 times their weight in liquid in a time range from 200 to 500 seconds, preferably from 300 to 400 seconds. Technical effect of this time range is to provide improved pulp for insulation materials.
[0152] A dry matter content of the obtained thermomechanical pulp 3 can be at least 70 wt.%, preferably from 80 to 98 wt.%, more preferably from 85 wt.% to 97 wt.%, still more preferably from 88 wt.% to 96 wt.%, and most preferably from equal to or more than 90 wt.% to 95 wt.%. The technical effect is that the dry pulp can be particularly suitable for insulation boards and litters. Furthermore, thermomechanical pulp 3 can be environmentally friendly solution because the pulp does not need a drying step.
[0153] The thermomechanical pulp 3 is a natural product, typically essentially made of wood-based material(s) and it is typically e.g. ink free product (compared e.g. magazines which may be used for litters or for insulation materials).
[0154] Some preferred applications for the thermomechanical pulp according to this specification are discussed below.

Wood pellets

[0155] Pellets can be formed from the thermomechanical pulp, for example, by using a conventional pelletizer.
[0156] The pellets can consist of, or at least essentially consist of, the thermomechanical pulp. Therefore, the pellets can comprise at least 90 wt.%, preferably at least 95 wt.%, more preferably at least 98 wt.%, still more preferably at least 99 wt.%, and most preferably at least 99.8 wt.% thermomechanical pulp (by dry weight). The technical effect is that the wood pellet without chemicals is an environmentally friendly product. The wood pellet can also be cost-effective alternative for many applications.
[0157] The thermomechanical pulp can contain lignin. Amount of lignin can be 25 to 35 wt.%. The technical effect is that pellets can be formed from the thermomechanical pulp without additives.
[0158] The pellet comprising or consisting of the thermomechanical pulp can be usable for many applications.

Litter pellets, such as cat litter pellets or pet cage litter pellets

[0159] The wood pellets can be litter pellets, such as cat litter pellets and/or pet cage litter material. Furthermore, the wood pellets can be a litter material e.g. in horse stables, piggeries, and barns. The wood pellet according to this specification is environmentally friendly solution, which can have excellent odor retention, i.e., a litter having wood pellets can have better (decreased) smell than a litter having conventional pellets. Wood pellets made from the thermomechanical pulp according to this specification are safe option for pets because they do not contain toxic components.
[0160] The content of the thermomechanical pulp in litter pellets can be at least 90 wt.%, preferably at least 95 wt.%, more preferably at least 98 wt.% and most preferably at least 99 wt.% (by dry weight). Preferably amount of added chemicals in litter pellets is 0 wt.%. Therefore, pellets are natural products which can be safe for pets. When liquid comes

in contact with the pellets, they can form sawdust-like material. Technical effect is to provide substantially track-free pellets which essentially stay in the litter box.

[0161] Wood pellets can be used with conventional litter boxes and can improve cleanliness compared to conventional materials.

Bales

[0162] Referring to Fig. 4, the obtained thermomechanical pulp can be formed into bales.

[0163] The content of the thermomechanical pulp in a bale can be at least 90 wt.%, preferably at least 95 wt.%, more preferably at least 98 wt.% and most preferably at least 99 wt.%, such as 100 wt.% (by dry weight). Preferably amount of chemicals in the bale is 0 wt.%. Therefore, bales are natural products which can be used for many applications.

[0164] Amount of lignin in the bale can be 28 to 35 wt.%. The technical effect is that bales can be formed easily without additives.

Paper and paperboard

[0165] The thermomechanical pulp according to this specification can be used to replace at least some of chemical pulp and/or chemithermomechanical pulp (CTMP) in paper making industry.

[0166] Thus, a paper or a paperboard can comprise the thermomechanical pulp according to this specification. Technical effect is to provide environmentally friendly, chemical free solution for replacing chemical pulp and/or chemithermomechanical pulp.

[0167] The thermomechanical pulp can be used as a buffering pulp as sometimes paper mills can suffer from a shortage of pulp. The thermomechanical pulp according to this specification can be easily stored e.g. at a mill pulp storage and used whenever it is needed for production. Further, as the thermomechanical pulp according to this specification is easy to store, the pulp can be produced at times when electricity price is low.

[0168] The paper or a paperboard can also comprise other cellulose-containing natural fibers, such as chemical pulp(s) and/or other thermomechanical pulps.

[0169] Further, the paper or a paperboard can comprise, for example, filler(s) and/or additive(s).

[0170] Amount of the thermomechanical pulp according to this specification can be e.g. in a range between 1 wt.% and 15 wt.% (by dry weight), preferably from 2 to 10 wt.% (by dry weight), determined from total amount of cellulose based fibers in the paper or paperboard.

Insulation board

[0171] The thermomechanical pulp can be formed into an insulation board.

[0172] An insulation board can comprise or essentially consist of the thermomechanical pulp according to this specification. The technical effect of the thermomechanical pulp in the insulation board is to provide good thermal insulation properties together with improved soundproof properties. Furthermore, the insulation board can be healthier alternative than e.g. magazines as it does not contain e.g. inks and other papermaking chemicals such as retention chemicals, biocides, and fillers.

[0173] In the case of the insulation board, fire retardant chemical(s) can be added into the product. Amount of the fire retardant chemical(s) can be, for example, from 5 to 10 wt.%, determined from a total weight of the insulation board. Technical effect is to provide fireproof insulation board.

Composites

[0174] The thermomechanical pulp can be used in composite products.

[0175] The technical effect of the thermomechanical pulp is that mechanical properties of a composite product can be significantly improved compared to sawdust. For example, sawdust, if used in wood-plastic composites, is so shaped that it does not actually reinforce the product but instead functions merely as filler in a plastic matrix. Furthermore, sawdust requires drying, because high moisture content in the filler weakens the quality of the manufactured composite product.

[0176] Another technical effect of the thermomechanical pulp is to provide more environmentally friendly and cost-efficient material than chemical pulp. Further, the thermomechanical pulp can provide some improved strength properties compared to chemical pulp.

[0177] A total content of the thermomechanical pulp in a composite product can be in the range of 20 - 60 wt.% (by dry weight), such as in the range of 30- 50 wt.% (by dry weight). Technical effect is to provide environmentally friendly material which can improve mechanical properties of the composite product.

[0178] A composite product can comprise one or more than one thermoplastic polymer and the thermomechanical pulp. The thermoplastic polymers can comprise polyolefins, such as polyethylene, polypropylene, polymethyl pentene or polybutene-1, or polyamide, polystyrene, polyethylene terephthalate (PET), polyvinyl chloride (PVC) or polycarbonate. Preferably the thermoplastic polymers comprise mainly polyolefins, such as polyethylene and/or polypropylene. Thus, the thermoplastic polymer(s) can comprise, mainly comprise, or consist of polyolefin(s). The polyolefin(s) can be bio-based polyolefin(s).

[0179] The composite may contain one or more coupling agent(s). The coupling agent(s) can be used for improving an adhesion between the thermomechanical pulp and thermoplastic polymer(s). The mixture may comprise 0-7% (by dry weight) of the coupling agent, such as 1-4% (by dry weight). The coupling agent may be or comprise e.g. a maleic anhydride based coupling agent. However, surprisingly, when using the thermomechanical pulp according to this specification, the coupling agent is not necessary component for the composite.

[0180] The composite may further comprise additives. The additives can comprise one or more from foaming agents (blowing agents), binders, cross-linking agents, pigments, dyes, UV protective agents, lubricants and/or other additives customary in the art of natural fiber plastic composites. In an embodiment, the content of the additives in the composite product can be in the range of 0.5-10% (by dry weight), such as in the range of 1-5% (by dry weight).

[0181] The method for manufacturing a composite can comprise the following steps: providing raw materials including at least thermoplastic polymer(s) and the thermomechanical pulp, mixing the materials, and forming the mixture into a composite product. In one embodiment, the method comprises forming the mixture of the materials into a composite product by extruding and/or by injection molding.

[0182] The composite can be, e.g. in a form of a pellet. The composite can be, e.g., a composite board.

Growing medium

[0183] The obtained thermomechanical pulp can be used as a growing medium for plants. The thermomechanical pulp can be used as a growing medium as such. It is possible to compress that thermomechanical pulp and use the compressed thermomechanical pulp as the growing medium.

[0184] Amount of lignin in the growing medium can be, e.g., 28 to 35 wt.%. The technical effect is that the thermomechanical pulp can be compressed easily without additives.

EXPERIMENTAL TESTS

Example 1: Thermomechanical pulping

[0185] Thermomechanical pulp according to this specification was manufactured without a dryer by using a thermomechanical pulp (TMP) refiner line. Fig. 2 shows a photo of an obtained thermomechanical pulp.

[0186] The experimental tests included test points having softwood and/or hardwood which were refined into different freeness levels. The experimental tests further included reference points consisting of conventional thermomechanical pulp which was refined into the same freeness levels.

[0187] During the experimental tests, refiner power as well as dilution water dosing were adjusted to keep the pulp quality stable while maximizing the pulp consistency. Amount of dilution water was less than 2.5 l/s for the test points, from which approximately 0.5 to 1.8 l/s was dosed to the first and second refiners R1. Amount of dilution water for reference points was from 9 to 10 l/s, from which approximately 4 l/s was dosed to the first refiner R1.

[0188] The refiner line had a separator for separating fibers and vaporized water from each other. During the experimental tests, amount of water added into the separator for the test points was in approximately 0.5 l/s, while the amount of water used for the reference points was approximately 1.5 l/s.

[0189] The outcome of the trial was outstanding: for test points, pulp production succeeded in the consistency over 90%, different test points having a dry matter content from 80% up to 97%.

Example 2: Novel thermomechanical pulp vs. conventional thermomechanical pulp

[0190] Properties of the thermomechanical pulp manufactured according to this specification were compared to conventional thermomechanical pulp. The pulps were made from the same raw materials.

[0191] Properties of the obtained pulps were compared by using same Freeness levels for the test points and the reference points. For all test and reference points, Freeness was kept in a range between 265 ml and 320 ml.

[0192] According to the test results, properties of the novel thermomechanical pulp differed clearly from properties of conventional thermomechanical pulp.

[0193] For all test points, a number of fiber shives was much lower for the test points, being less than half compared to the reference points. Fiber length of the test points was lower (approximately 0.2-0.3 mm lower) than fiber length of the reference points, but still suitable for many applications.

[0194] Further, when the test points were compared to reference points, fibrillation of fibers was lower, proportion of flake-like fines was clearly higher, and proportion of fibrillar fines was significantly lower. Amount of fiber kinks increased approximately 800 kinks/m compared to reference points and kink angle of the test points was approximately 3° higher than kink angle of the reference points.

[0195] Hand sheets were manufactured by using the pulp from the test points as well as pulp from the reference points. Strength properties and optical properties were determined from the hand sheets.

[0196] When the produced hand sheets were compared, bonding strength was significantly higher, but tear index, tensile index and tensile energy absorption were significantly lower than for the reference points. However, the test points provided suitable strength properties, including tensile, impact strength and bursting strength, for many applications.

[0197] The novel thermomechanical pulp had improved optical properties: light scattering coefficient of the test points was much higher than light scattering coefficient of the reference points, and opacity of the test points was significantly higher than opacity of the reference points.

[0198] Thus, according to the test points, properties of the novel thermomechanical pulp differed significantly from properties of conventional thermomechanical pulps.

Example 3: Thermomechanical pulp vs. chemical pulp

[0199] Properties of the novel thermomechanical pulp (test points) were compared to properties of chemical pulp made by using a hardwood (reference points).

[0200] Surprisingly, when test points were compared to reference points, fiber lengths of the pulps were same or at least approximately same.

[0201] Fibrillation level of test points was significantly higher than fibrillation level of reference samples. Further, amount of fibrillated fines was significantly higher than amount of fibrillated fines of the reference points.

[0202] Hand sheets were manufactured by using the thermomechanical pulp (test points) and the chemical pulp (reference points). Strength and optical properties of the pulps were determined from the hand sheets.

[0203] According to the test results, tensile strength of the test points was decreased only slightly, and bursting strength was at the same level for the test and reference points. Furthermore, opacity of the test points was at least 1 unit greater, up to 7 units greater than opacity of the reference points. Bulk of the test points was at least 2%-units, up to 7 %-units higher than bulk of the reference points.

[0204] Thus, according to the test results, it is possible to replace at least some of chemical pulp with the novel thermomechanical pulp.

Example 4: Paper

[0205] During experimental tests in paper making, some of chemical pulp (from birch) was replaced with the novel thermomechanical pulp.

[0206] Surprisingly, properties of the obtained paper were at the same level, even when some chemical pulp was replaced with the novel thermomechanical pulp.

[0207] Further, during experimental tests, some of conventional thermomechanical pulp was replaced with the novel thermomechanical pulp.

[0208] Surprisingly, properties of the obtained paper were at the same level, even when some conventional thermomechanical pulp was replaced with the thermomechanical pulp.

[0209] Therefore, the novel thermomechanical pulp was suitable for papers.

Example 5: Wood pellets

[0210] Wood pellets were manufactured from the thermomechanical pulp according to this specification. Fig. 5 shows a photo of obtained wood pellets.

[0211] Surprisingly, the thermomechanical pulp was suitable raw material for wood pellets without any additives. Thus, it was possible to produce wood pellets consisting of the thermomechanical pulp.

[0212] The wood pellets made of the thermomechanical pulp had good moisture uptake and clamping ability.

Example 6: Wood pellets for cat litters

[0213] The pellets made from the thermomechanical pulp (see Example 5 above) were tested for cat litters.

[0214] Surprisingly, during the experimental tests, all cats abandoned cat litters having conventional pellets and, after only few days, used cat litters having the novel wood pellets.

[0215] Furthermore, according to the test results, the wood pellets had excellent moisture uptake properties as well as excellent odor retention.

Example 7: Dry wood bales

[0216] Referring to Figs 2, 4 and 6, a total of 12 m^3 thermomechanical pulp bales were produced during experimental tests by using the method according to this specification.

[0217] Surprisingly, it was possible to obtain bales consisting of the novel thermomechanical pulp. During experimental tests, the bales had a size of 90 cm x 110 cm x 80 cm, but a person skilled in the art is able to produce bales having varied sizes.

Example 8: Composites

[0218] Wood-plastic composites were manufactured by using the novel thermomechanical pulp, and chemical pulp (reference 1). All amounts of materials were the same, only the wood material was changed between the test points.

[0219] Surprisingly, the thermomechanical pulp was as good raw material for wood-plastic composites as chemical pulp. For example, by using thermomechanical pulp, strength properties of the wood-plastic composites were at a good level.

[0220] Further, surprisingly, the reference points having chemical pulp needed a coupling agent while the test points having the thermomechanical pulp did not need any coupling agent.

Example 9: Growing medium

[0221] The novel thermomechanical pulp was tested for growing medium. Surprisingly, the novel thermomechanical pulp was suitable for replacing peat in a growing medium. According to the experimental tests, amount of thermomechanical pulp in the growing medium can be more than 0 wt.%, preferably from 20 wt.% to 70 wt.% (by dry weight).

[0222] The invention is not limited solely to the examples presented in Figures and the above description, but it may be modified within the scope of the appended claims.

Claims

1. A method for manufacturing a thermomechanical pulp, the method comprising:

- conveying wood-based material (1), such as wood chips, having a dry matter content between 35% and 65% to a first refiner (R1),
- refining the wood-based material in the first refiner (R1), thereby obtaining a pulp having a dry matter content of at least 70%,
- optionally, conveying the pulp from the first refiner (R1) to a second refiner (R2), and further refining the pulp in the second refiner (R2),

wherein

- a total amount of water added to the refiner(s) during the refining is in a range between 700 L and 1800 L, preferably in a range between 900 L and 1600 L, and most preferably in a range between 1000 L and 1500 L per obtained ton of the thermomechanical pulp (3) (by dry weight),
- a total specific energy consumption in the refiner(s), calculated as a combined total specific energy for all refiners, is in a range between 400 kWh per ton and 2500 kWh per ton, preferably between 800 kWh per ton and 1500 kWh per ton, measured as dry weight of the obtained thermomechanical pulp,

thereby obtaining a thermomechanical pulp having a dry matter content of at least 70%, preferably at least 75%, wherein, optionally, the method further comprises:

- conveying the thermomechanical pulp to a compressing device, and
- compressing the pulp,

thereby forming a wood-based product, such as a pellet or a bale, comprising or consisting of the thermomechanical pulp.

2. The method according to claim 1, comprising the step of refining the pulp in the second refiner (R2), wherein

   - a dry matter content of the thermomechanical pulp (3) coming from the second refiner (R2) is in a range between 80% and 98%, preferably in a range between 88% and 98%, and/or
   - 65 to 85% from the total amount of water added to the refiner(s) during the refining is added to the first refiner.

3. The method according to any of the preceding claims, wherein the method further comprises:

   - separating the wood-based material and vaporized water in a separator, preferably in a cyclone separator, before feeding the wood-based material to at least one refiner (R1, R2).

4. The method according to any of the preceding claims comprising

   - only one refiner, the one refiner being the first refiner (R1), or
   - only two refiners, wherein the two refiners are the first refiner (R1) and the second refiner (R2).

5. The method according to any of the preceding claims, wherein the wood-based product is a pulp sheet, a fluff roll, a bale, a briquette, or a pellet, preferably the bale or the pellet.

6. A wood-based product, such as a pellet or a bale, obtainable by the method according to any of the preceding claims 1 to 5.

7. The method or the wood-based product according to any of the preceding claims, wherein

   - a proportion of shives is in a range between 0.2% and 0.8%, determined from the thermomechanical pulp, and/or
   - an amount of fiber kinks is in a range between 1700 and 2300 kinks/m, determined from the thermomechanical pulp, and/or
   - a fibrillation of the thermomechanical pulp is in a range between 1.9% and 2.3%.

8. The method or the wood-based product according to any of the preceding claims, wherein

   - a length weighted fiber length of the thermomechanical pulp is in a range between 0.8 mm and 1.25 mm, measured according to standard ISO 16065-2, and/or
   - an average fiber width of the thermomechanical pulp is in a range between 28 μm and 31 μm.

9. The method or the wood-based product according to any of the preceding claims, wherein

   - a proportion of flake-like fines is in a range between 48% and 55%, determined from the thermomechanical pulp, and/or
   - a proportion of fibrillar fines is in a range between 25% and 38%, determined from the thermomechanical pulp.

10. The method or the wood-based product according to any of the preceding claims, wherein the thermomechanical pulp absorbs from 5 to 8 their weight in liquid.

11. The wood-based product according to any of the preceding claims 6 to 10, wherein the wood-based product is a pellet, such as a litter pellet.

12. A composite product comprising

   - a thermoplastic polymer, and
   - a wood-based product according to any of the preceding claims 6 to 10.

13. The wood-based product according to any of the preceding claims 6 to 10, wherein the wood-based product is an insulation board.

14. The wood-based product according to any of the preceding claims 6 to 10, wherein the wood-based product is a bale.

15. A use of a thermomechanical pulp obtainable by the method according to any of the preceding claims 1 to 5

- in a pellet, or in a bale so that a proportion of the thermomechanical pulp is at least 50 wt.%, preferably at least 80 wt.%, more preferably at least 90 wt.%, and most preferably at least 95 wt.% (by dry weight), or
- in an insulation board so that a proportion of the thermomechanical pulp is preferably at least 50 wt.%, more preferably at least 90 wt.% (by dry weight), or
- in a composite product comprising a thermoplastic polymer and the thermomechanical pulp so that a proportion of the thermomechanical pulp is preferably in a range between 20 wt.% and 60 wt.% (by dry weight).

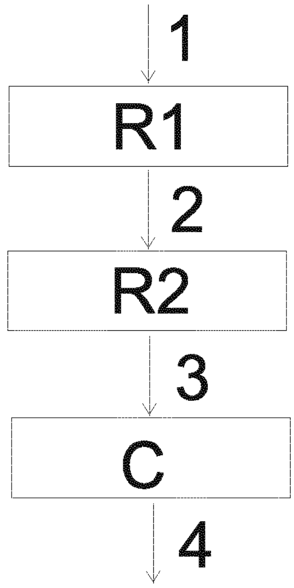

Fig.1

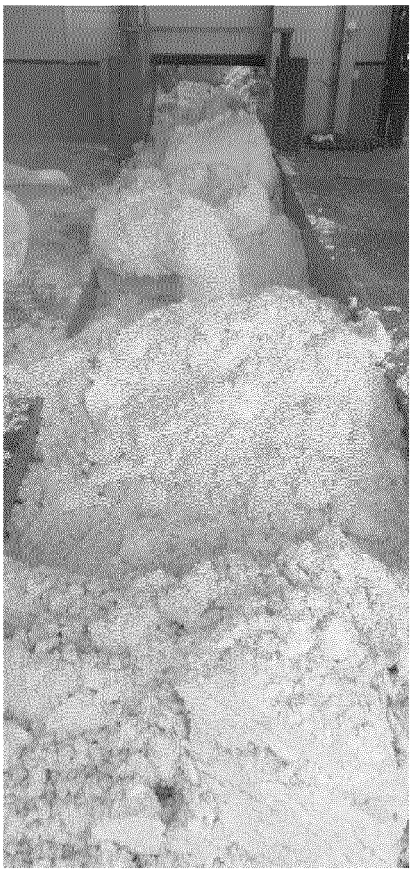

Fig.2

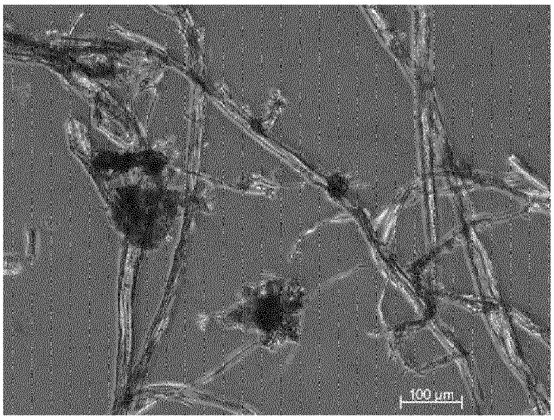

Fig.3a

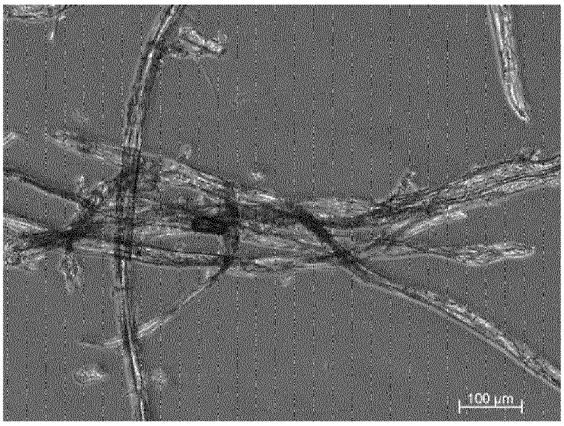

Fig.3b

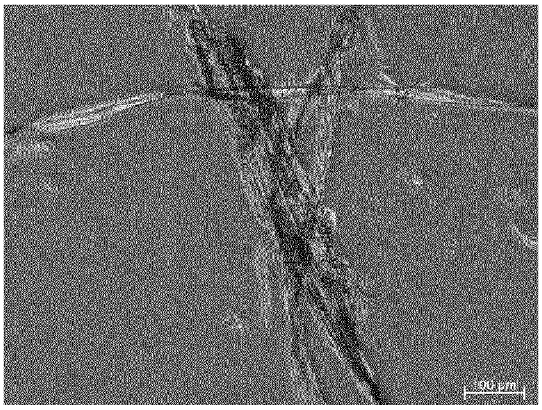

Fig.3c

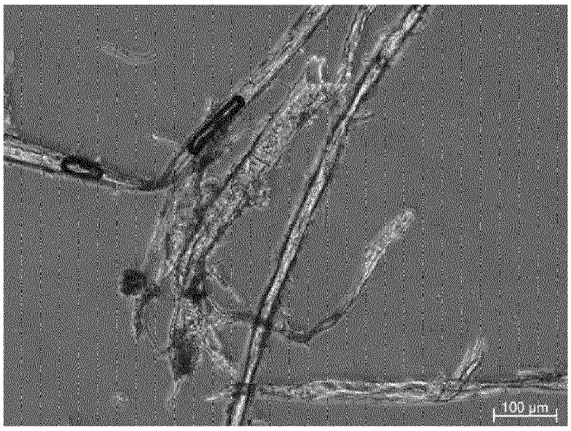

Fig.3d

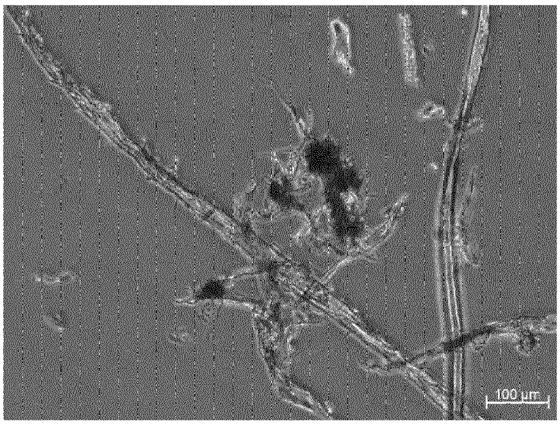

Fig.3e

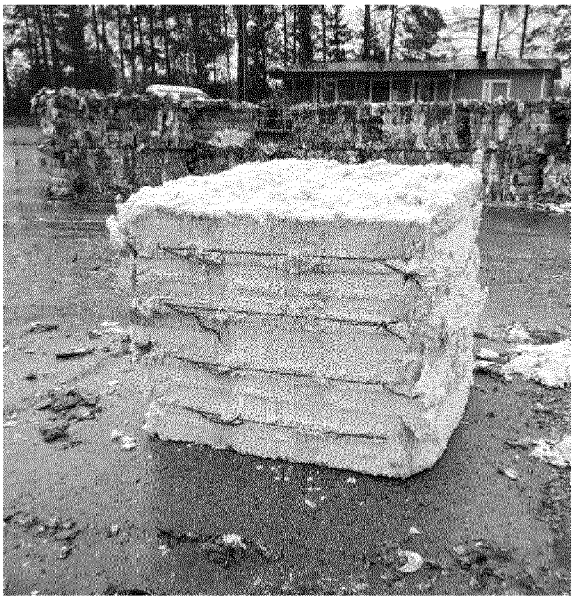

Fig.4

Fig.5

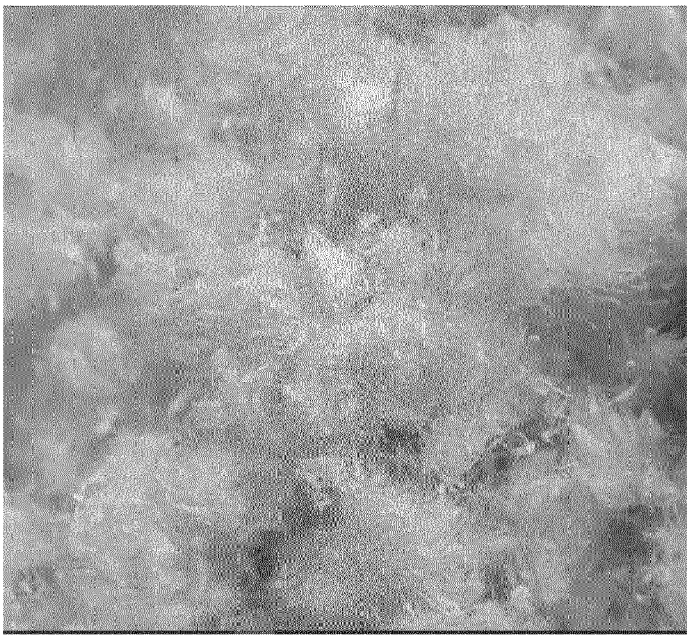

Fig.6