

**Tissue Paper Products, Rolls and Stacks of Tissue Paper
Products, and Manufacturing Methods**

Technical Field

The present disclosure relates to a tissue paper product, such as household towel or toilet paper, comprising a least three plies, wherein the outermost plies of the tissue paper product are embossed. The disclosure also relates to a roll of such a tissue paper product and to a stack of such a tissue paper product. Moreover, the disclosure relates to methods of manufacturing the same.

Technical Background

In the following, a "tissue paper product" relates to an absorbent paper based on cellulose wadding. The latter is also referred to as a tissue paper base-sheet in this field of technology.

Fibres contained in a tissue paper product are mainly cellulosic fibres, such as pulp fibres from chemical pulp (e.g. Kraft or sulphite), mechanical pulp (e.g. ground wood), thermo-mechanical pulp, chemo-mechanical pulp and/or chemo-thermo-mechanical pulp (CTMP). Pulps derived from both deciduous (hardwood) and coniferous (softwood) can be used. Fibres may also come from non-wood plants, e.g., cereal, bamboo, jute, and sisal. The fibres or a portion of the fibres may be recycled fibres, which may belong to any or all of the above categories. The fibres can be treated with additives, e.g. fillers, softeners, such as, but not limited to, quaternary ammonium compounds and binders, conventional dry-strength agents, temporary wet strength agents or wet-strength agents, in order to facilitate the original paper making or to adjust the properties thereof. The tissue paper product may also contain other types of fibres, e.g.,

regenerated cellulosic fibres or synthetic fibres for enhancing, for instance, strength, absorption, smoothness or softness of the tissue paper product.

Whenever reference is made to the "softness" of a tissue paper product in this text, reference is made to the property of softness as determined through an evaluation by panel members. A panel of ten members was used in this case. Panel lists are used to rank products in terms of softness. Softness Panel values are used as comparative values enabling a comparison between tested samples. The softer the product/tissue paper product is, the higher the rated value. The softness scale was in the present case set from 0 to 2.5 (2.5 being the highest value). Each sample is composed of one product, i.e., a tissue paper product. Alternatively, each sample is a ply. Samples are first conditioned for a minimum of two hours in a controlled area at 23°C and 50% relative humidity. Then, evaluation by the panel members takes place.

Tissue paper products may be used for personal and household use as well as for commercial and industrial use. They may be adapted to absorb fluids, remove dust, and for other cleaning purposes. If tissue paper is to be made out of pulp, the process essentially comprises a forming step that includes a headbox- and a forming wire section, and a drying section, either through air drying or conventional drying on a Yankee cylinder. The production process may also include a crepe and, finally, typically a monitoring and winding step.

Several plies may be combined together by a combining operation of a chemical nature (e.g., by adhesive bonding), or of a mechanical nature (e.g., by knurling or so-called edge-embossing), or a combination of both.

Further, the processing to finished tissue product may involve, e.g., longitudinal cut, folding, cross cut, etc. Moreover, individual tissue products may be positioned and

brought together to form stacks, which may be individually packaged. Such processing steps may also include application of substances like scents, lotions, softeners or other chemical additives.

When several plies are combined together using adhesive bonding, a film of adhesive is deposited over some or all of the surface of at least one of the plies, then the adhesive-treated surface is placed in contact with the surface of at least one other ply.

When several plies are combined together using mechanical bonding, the plies may be combined by knurling, by compression, by edge-embossing, union embossing and/or ultrasonic. Additionally or as an alternative thereto, at least some bonding can also be carried out using water instead of some other adhesive.

Mechanical and adhesive bonding may also be combined to combine several plies.

The processing step from the base tissue to a finished tissue paper product occurs in processing machines (converting machines) which include operations such as unwinding the base tissue, calendaring of the tissue, laminating, printing or embossing together to form a multi-ply product.

Embossing can be used to change the shape of a ply from flat to shaped, so that there are areas that are raised and/or recessed from the rest of the surface. It therefore constitutes a deformation of the previously flat sheet, and results in a ply having a particular relief. Usually, the thickness of the ply or of the multiple plies is increased after embossing compared with its initial thickness.

An embossing process is carried out between an embossing roll and a counter roll. The embossing roll can have protrusions

or depressions on its circumferential surface leading to embossed protrusions/depressions in the paper web. Counter rolls may be softer than the corresponding embossing roll and may consist of rubber, such as natural rubber, or plastic materials, paper or steel. If the counter roll is made of a softer material like rubber, a contact area/nip can be formed between the embossing roll (e.g., steel roll) and the counter roll by the deformation of the softer roll.

By embossing, a pattern can be applied to a tissue paper fulfilling a decorative and/or functional purpose. A functional purpose may be to improve the properties of the hygiene paper product, that is, the embossment may improve the product thickness, absorbency, bulk, softness, etc. A functional purpose may also be to provide a joint to another ply in a multi-ply product.

Another type of embossment is referred to herein as a "pre-embossment". A pre-embossment could preferably be applied to a web or ply prior to its joining to the other plies of a multi-ply tissue product.

Such pre-embossment may be made for a functional purpose e.g. as laid out in the above to increase the thickness of the ply, the absorbency, bulk and/or softness.

"Micro-embossment" is used herein for an embossment pattern with a dense configuration. Typically, the micro-embossment may comprise dots in the range 25 to 120 dots per cm², optionally 40 to 100 dots per cm², or 50 to 80 dots per cm². A micro-embossment may advantageously be a pre-embossment. The micro-embossed dots may have different relatively simple surface shapes such as circles, ovals, squares, rectangles or diamonds.

Although the multi-ply tissue paper products and methods for production thereof proposed in the past may be very useful in

many applications, there is still a need for improvements. Such improvements would be desirable particularly with respect to the thickness, the strength, the softness, the bulkiness, and/or the absorption capacity of the multi-ply tissue products.

There is, hence, a desire for an improved tissue paper product with at an improvement in at least one of the above-mentioned properties, and for a manufacturing method for such a product.

Summary

Aspects of the above-mentioned object are achieved by a tissue paper product in accordance with the present disclosure.

One aspect of this disclosure relates to a tissue paper product, such as toilet paper or household towel, wherein the tissue paper product comprises between two and four plies. These two, three, or four plies include at least a first ply and a second ply, and the two plies, three plies, or four plies are ply-bonded, optionally using an adhesive such as lamination glue or mechanical bonding, such as edge embossing, to form the tissue paper product. The first ply and the second ply are the outermost plies of the tissue paper product.

A grammage of the tissue paper product is in a range of 24 to 50 g/m² if a total number of plies of the tissue paper product is 2, in a range of 34 to 65 g/m² if a total number of plies of the tissue paper product is 3, and in a range of 55 to 95 g/m² if a total number of plies of the tissue paper product is 4.

Whenever reference is made to the "grammage" (or "basis weight") in this text, reference is made to the basis weight

(grammage) as determined by a test method following the principles set forth in standard EN ISO 12625-6:2016 for determining the basis weight. Test pieces of 50 cm² are punched from the sample sheet. Test pieces are chosen randomly from the entire sample and should be free of folds, wrinkles and any other deviating distortions. The pieces are conditioned at 23°C, 50 % RH (Relative Humidity) for at least 2 hours. A pile of 20 pieces is weighed on a calibrated balance. The basis weight (grammage) is the weighed mass divided by the total area 1000 cm² (20x50cm²) and recorded as mean value with standard deviations.

The first ply is made of Conventional Wet Press (CWP) paper. The first ply has been embossed with a heated embossing roll. The first ply may be the top ply or the bottom ply, depending on the embodiment of the tissue paper product.

Producing a ply from paper-making fibers according to "Conventional Wet Paper" (CWP) processing may, e.g., rely on the manufacturing of "Dry Creped Tissue" or "Wet Crepe Tissue" and is to be distinguished from a "Process for Structured Tissue" such as the Through Air Drying (TAD) manufacturing method, the manufacture of un-creped through-air dried (UCTAD) tissue, or alternative manufacturing methods, e.g. the Advanced Tissue Molding System (ATMOS) of the company Voith, or Energy Efficient Technologically Advanced Drying eTAD of the company Georgia Pacific, or Structured Tissue Technology SST of the company Metso Paper. Hybrid processes like NTT (New Textured Tissue of the company Metso Paper), which are alternations of the conventional processes, can be used.

The second ply is a structured paper ply, such as a ply made of TAD, UCTAD, eTAD, Atmos, or NTT.

The embossing of the first ply with a heated embossing roll may be advantageous as the embossments may have a better

shape memory, i.e., they may be more resilient against shape deformation when the tissue paper product is wet. That is, the embossments being less affected when the ply is wet. This means that the tissue paper product may have a better absorption capacity than a comparable tissue paper product which does not comprise at least one ply that was embossed using a heated embossing roll. Moreover, as compared to a product without a ply that was embossed using a heated embossing roll with a certain thickness and strength (tensile strength), a higher thickness may be reached while retaining the same tensile strength. In other words, the tissue paper product in accordance with the present disclosure has high thickness and good absorption properties, as well as a high tensile strength. In particular, with the same embossing load during a manufacturing process, a higher thickness of the tissue product may be reached.

Whenever reference is made to the "absorption capacity" in this text, reference is made to an absorption capacity measured as follows. The measurements are carried out using the basket immersion method. A test sample with a defined width and total mass is placed in a cylindrical basket which is dropped from a defined height over a water surface with deionized water in accordance with ISO 14487 (conductivity ≤ 0.25 mS/m at 25 °C). The time is measured between when the basket is dropped until the test sample is fully wet. The average time recorded for a number of samples is equated to the water absorption time. The amount of absorbed water is determined from the dry and wet weight of the test sample. Previous to the measurement, the test samples are to be conditioned a sufficient time under 23°C and 50% relative humidity (see ISO 187-standard atmosphere for conditioning and testing tissue). The resulting water absorption capacity is reported in grams water per gram test piece to the nearest 0.1 g/g. The method is carried out in accordance with ISO 12625-8:2011 (water-absorption time and water-absorption capacity, basket-immersion test method).

Whenever reference is made to the "thickness" in this text, reference is made to the thickness as obtained in accordance with European standard EN 12625-3 using the Frank Thickness Gauge equipment (Model 16502) or the like. The tissue paper sheet to be measured is cut into pieces of minimum 80mm in any direction and the pieces are conditioned at 23°C, 50 % RH (Relative Humidity) for at least 2 hours. During measurement a sample piece is placed between a fixed bottom plate and a pressure foot. The pressure foot is then lowered at a speed of 2.0 mm/s. The thickness value for the sheet is then read after the pressure value is stabilized. The Essity Internal diameter of the pressure foot is 35.7 mm. The lower plate dimension is minimum 20% bigger. The pressure applied is 2.0 kPa during the measurement.

Whenever reference is made to a "tensile strength" in this text, the tensile strengths in question can be measured and compared as dry tensile strengths following the standard EN ISO 12625-4:2005 or as wet tensile strengths following the standard ISO 12625-5:2005.

The dry strength is determined according to EN ISO 12625-4:2005, Tissue Paper and Tissue Products, Part 4: Determination of width-related breaking strength, elongation at break and tensile energy absorption. For exemplary purposes, the tensile tester used for the measurement featured two clamps of 50 mm width. Each clamp can grip the test piece firmly, but without damage, along a straight line across the full width of the test piece (the clamping line). The distance between the clamping lines was set at 100 mm. For special tests, the distance is reduced if the available length of the sample is lower than 100 mm (e.g., toilet tissue in cross direction). The tissue paper product to be measured, i.e., two sheets of a single-ply or multi-ply product, was cut into test pieces of 50 mm wide with parallel edges. Each sheet was cut into two different types of test pieces by cutting in the

machine direction and in the cross direction. The obtained test pieces were then conditioned in an atmosphere of 23° C., 50% RH (Relative Humidity) for at least 4 hours. The test piece to be measured was placed between the clamps without any strain, and such that any observable slack is eliminated. At the beginning, a pre-tensile force of 25 cN is applied (zero of stretch) then the elongation rate between the clamps was kept constant at 5 cm/min. The maximum tensile force required to break the test piece was obtained. The measurement was repeated with six test pieces and the values obtained were averaged. The dry tensile strength was calculated by means of the following formula: Mean dry tensile strength [N/m] = (mean maximum tensile force [N] / initial width of the test piece [mm]) × 10⁻³.

The wet strength was determined according to EN ISO 12625-5 Tissue Paper and Tissue Products, Part 5: determination of width-related wet load at break, 2005. (optionally the following description which follows the principles of the DIN NORM). For exemplary purposes, when experimentally verifying the wet strength of a product, the tensile test was accordingly performed by means of an electronic tensile test apparatus (Model 1122, Instron Corp., Canton, Mass., USA) with a constant rate of elongation of 50 mm/min using a Finch device. To prepare the test strips, 6 samples each having a length of 150 mm and a width of 50 mm were cut from the raw tissue (single ply) prepared in such a manner that the longitudinal direction of the test strips coincided with the machine direction (MD) or cross-direction (CD). The free clamping length when using the Finch clamp was about 50 mm. The test strip was secured with both ends in a clamp of the test apparatus. The other end (loop) formed in this way was placed around a pin and treated at 23°C with distilled water until complete saturation. The depth of immersion of the loop formed by the test strip is at least 20 mm. The soaking duration (immersion time) is 15 s, the rate of elongation is set to a constant (50 ± 2) mm/min, the measurement of the

breaking strength is performed on the sample immersed in distilled water. Six test strips at a time were measured, the result being indicated as an arithmetic mean. To ensure that the wet strength of the samples has fully developed, which is particularly necessary in the case of samples in which additional wet-strength agents were used to boost wet strength, e.g., by their addition in the mass, the samples to be tested were always artificially aged before conducting the tensile test. Aging was effected by heating the samples in an air-circulating drying cabinet to $(80 \pm 1) ^\circ\text{C}$ for a period of 30min. Six test strips at a time were measured, the result being indicated as an arithmetic mean.

The tissue paper products in accordance with the present disclosure may have similarly high thicknesses as comparative products, in which the CWP ply is replaced by another structured paper ply that was not heat-embossed (but which are otherwise manufactured analogously), due to the fact that the CWP has been heat-embossed, while they may at the same time be cheaper to manufacture. In other words, the heat-embossed CWP ply may add less costs to the production of the tissue paper product than another structured ply.

The tissue paper product may in particular be a toilet paper. However, also other tissue paper products are covered, for example, hand towels, napkins, facial tissues, toilet paper, etc.

If ply-bonding with an adhesive is used, the adhesive may, e.g., be a polyvinyl alcohol and/or a methyl cellulose based adhesives. An adhesive may, for example, be applied based on spraying equipment.

The first ply may comprise two types of embossments and may have been processed using "double height embossing" whereby one or several rolls with embossing protrusions having different heights were used. Double height embossing may not

only serve to provide bulk to the fibrous product but also to provide an improved optical appearance to the product. The optical appearance can be improved by combining embossing and coloring steps. Another reason for embossing is to generate higher absorbency or improved perceived softness.

Tissue paper products in particular for use as hygiene or wiping products primarily include all kinds of dry-creped tissue paper, wet-creped paper, TAD-paper (Through Air Drying), tissue paper based on structured technologies such as ATMOS®, NTT, UCTAD and cellulose or pulp-wadding, or combinations, laminates or mixtures thereof. Typical properties of these hygiene and wiping products include the ability to absorb tensile stress energy, their drapability, good textile-like flexibility, properties which are frequently referred to as bulk softness, a high surface softness and a high specific volume with a perceptible thickness. A liquid absorbency as high as possible and, depending on the application, a suitable wet and dry strength as well as an appealable visual appearance of the outer product's surfaces are desired. These properties, among others, allow these hygiene and wiping products to be used, for example, as cleaning wipes such as windscreen cleaning wipes, industrial wipes, kitchen paper or the like; as sanitary products such as, for example, bathroom tissue, handkerchiefs, household towels, towels and the like; as cosmetic wipes such as for example facials and as serviettes or napkins, etc. Furthermore, the hygiene and wiping products can be dry, moist, wet, printed or pre-treated in any manner. In addition, the hygiene and wiping products may be folded, interleaved or individually placed, stacked or rolled, connected or not, in any suitable manner.

According to some embodiments, the first ply comprises micro-embossments with a micro-embossment height in a range of 0.1 mm to 1.2 mm.

According to some embodiments, the first ply comprises macro-embossments with a macro-embossment height in a range of 0.2 mm to 2.0 mm, optionally 0.8 mm to 1.4 mm. The first ply may, in particular, comprise micro-embossment and macro-embossments. The density of the total number of embossments of the first ply may be in a range of from 25 to 120 dots/cm², optionally 40 to 100 dots/cm², or 50 to 80 dots/cm². These densities may, to an increasing degree for narrower ranges, promote high tensile strength and good absorption capacities of the respective tissue paper product.

According to embodiments, an embossing density may be measured, e.g., using 3D tomography (for example, using Alicona Infinite Focus SL with the software IF-MeasureSuite Version 5.1). Alicona Infinite Focus SL with the software IF-MeasureSuite Version 5.1 may also be used to measure a surface area that has been embossed and/or an embossment height. The embossment height may be defined as a distance from a bottom of the ply to a top of the ply in sectional view.

The macro-embossments may cover between 1% and 20% of a total surface of the first ply, optionally between 2% and 10%, or between 3% and 6%. The macro-embossments may be provided with a density of 15 dots/cm² or less, optionally 10 dots/cm² or less.

According to some embodiments, the first ply has been embossed with a heated first embossing roll heated to a temperature in the range of 80°C to 170°, optionally 100°C to 165°, 110°C to 165°, 120°C to 160°, or 130°C to 155°.

The first embossing roll that was used to emboss the first ply may be heatable to a surface temperature in the range of 80°C to 170°, optionally 100°C to 165°, 110°C to 165°, 120°C to 160°, or 130°C to 155°. These temperature ranges may to an increasing degree with narrower ranges promote the

manufacturing of a tissue paper product with good shape memory and/or large thickness, high machine direction (MD) and/or cross direction (CD) tensile strength, and good absorption properties.

The references to the temperatures of the heatable embossing roll(s) in this text are references, in particular, to surface temperatures of the embossing roll. These may be measured, for example, using an infrared thermometer. Moreover, the temperature values refer to temperatures in the steady state of the manufacturing apparatus, i.e., not while running and while plies are in contact with the embossing rolls. In particular, the surface temperature of the heatable embossing roll may drop during manufacturing, due to various effects such as heat conduction to the ply in contact with the roll, etc. For example, a surface temperature of 170°C might be measured in the steady state (when the embossing roll is not in contact with a ply), and this temperature might decrease to a temperature in the range of 100°C to 130°C during manufacturing, etc. In other words, while the manufacturing is taking place, there may be variations in temperature.

To summarize regarding the indicating of temperatures used to heat-emboss the first ply, the temperatures may thus be referred to as "steady-state" temperatures, i.e., temperatures pertaining to a state in which the embossing roll is heated, but manufacturing is not running (the embossing roll is not in contact with a ply).

According to some embodiments, the second ply has been embossed with a non-heated embossing roll. According to other embodiments, the second ply may not have been embossed in the sense of not having been pre-embossed prior to the prior ply bonding having been carried out.

According to some embodiments, the first ply has been

moistened, prior to the step of embossing the first ply, with a liquid, such as water with or without one or several additives. The first ply may be moistened with an amount of liquid in the range of 2% to 12% of the basis weight of the first ply, or optionally 4% to 10% of the basis weight of the first ply, prior to being embossed. Analogous statements hold with respect to the second ply.

The first ply may be moistened with an amount of liquid in the range of 2% to 12% of the basis weight of the first ply, or optionally 4% to 10% of the basis weight of the first ply. Analogous statements hold with respect to the second ply.

According to some embodiments, the first ply has not been moistened with a liquid prior to the step of embossing. In these cases, the first ply may also be referred to as a dry heat-embossed ply.

Some embodiments of the tissue paper product comprise exactly two plies. In the following, these will be referred to as the first ply and the second ply.

The tissue paper product comprises two plies. In fact, a total number of plies of the tissue paper product is two. Put differently, the tissue paper product consists of two plies. However, the latter statement does not imply that the tissue paper product cannot comprise other constituents (other than plies), such as adhesive, additives, etc. It means only that the number of plies is two. At least one of the two plies is an embossed ply. However, both plies may be embossed plies.

The (heat-embossed) first ply comprises first embossments with a first height (h1). The first height (h1) is in a range of 0.2 mm to 2.0 mm.

The second ply may comprise second embossments with a second height (h2). The second height (h2) is in a range of 0.2 mm

to 2.0 mm.

The adhesive, such as lamination glue, may have been applied to tips of the first embossments of the first ply and/or to tips of the second embossments of the second ply.

The first ply may comprise third embossments with a third height (h_3) smaller than the first height (h_1) ($h_1 > h_3$).

The second ply may comprise fourth embossments with a fourth height (h_4) smaller than the second height (h_2) ($h_2 > h_4$).

Some embodiments of the tissue paper product comprise exactly three plies. These will in the following be referred to as the first ply and the second ply and a third ply, located between the first ply and the second ply.

The tissue paper product comprises three plies. In fact, a total number of plies of the tissue paper product is three. Put differently, the tissue paper product consists of three plies. However, the latter statement does not imply that the tissue paper product cannot comprise other constituents (other than plies), such as adhesive, additives, etc. It means only that the number of plies is three. At least one of the three plies is an embossed ply. One of the three, two of the three, or all three plies may be embossed plies.

The third ply may be made of Conventional Wet Press (CWP) paper.

The first ply may comprise first embossments with a first height (h_1), the first height (h_1) being in a range of 0.2 mm to 2.0 mm. The adhesive, such as lamination glue, may be applied to tips of the first embossments of the first ply.

The second ply may comprise second embossments with a second height (h_2), the second height (h_2) being in a range of 0.2

mm to 2.0 mm.

The first ply may comprise third embossments with a third height (h_3) smaller than the first height h_1 ($h_1 > h_3$).

The second ply may comprise fourth embossments with a fourth height (h_4) smaller than the second height h_2 ($h_2 > h_4$).

According to some embodiments, the third ply has not been embossed prior to ply bonding. Sometimes, the third ply (the middle ply) may be referred to as an unembossed ply. With "unembossed", it is meant that the third ply is not pre-embossed prior to the final ply-bonding being carried out. That is, the third ply may no longer be flat after the ply-bonding, but has not beforehand been embossed using an embossing roll.

The adhesive, such as lamination glue, may have been applied to the third ply at parts bonded to tips of the first embossments of the first ply and/or to tips of the second embossments of the second ply, and/or the adhesive, such as lamination glue, may have been applied to tips of the first embossments of the first ply and/or to tips of the second embossments of the second ply.

According to some embodiments, the first ply and the third ply have been embossed together to form the first embossments on the first ply and the third ply.

According to some embodiments, the third embossments have been formed only on the first ply but not on the third ply. According to other embodiments, the first ply and the third ply have been embossed together to form the third embossments on the first ply and the third ply.

Some embodiments of the tissue paper product comprise exactly four plies. These will be referred to in the following as the

first ply and the second ply, and a third ply and a fourth ply. The third ply and the fourth ply are located between the first ply and the second ply. The third ply may be made of Conventional Wet Press (CWP) paper, and/or the fourth ply may be made of Conventional Wet Press (CWP) paper.

The tissue paper product comprises four plies. In fact, a total number of plies of the tissue paper product is four. Put differently, the tissue paper product consists of four plies. However, the latter statement does not imply that the tissue paper product cannot comprise other constituents (other than plies), such as adhesive, additives, etc. It means only that the number of plies is four. At least one of the four plies is an embossed ply. One of the four may be an embossed ply, or two of the four, three of the four, or all four plies may be embossed plies.

The first ply may comprise first embossments with a first height (h_1), the first height (h_1) being in a range of 0.2 mm to 2.0 mm.

The second ply may comprise second embossments with a second height (h_2), the second height (h_2) being in a range of 0.2 mm to 2.0 mm.

The first ply may comprise third embossments with a third height (h_3) smaller than the first height h_1 ($h_1 > h_3$).

The second ply may comprise fourth embossments with a fourth height (h_4) smaller than the second height h_2 ($h_2 > h_4$).

The adhesive, such as lamination glue, may have been applied to the third ply and/or the fourth ply at parts bonded to tips of the first embossments of the first ply and/or to tips of the second embossments of the second ply, and/or the adhesive, such as lamination glue, may have been applied to tips of the first embossments of the first ply and/or to tips

of the second embossments of the second ply.

The first ply and the third ply may have been embossed together to form the first embossments on the first ply and the third ply.

According to some embodiments, the fourth ply has not been embossed prior to ply-bonding or has been embossed separately from the first ply and the third ply.

According to some embodiments, the third embossments are formed only on the first ply but not on the third ply. According to other embodiments, the first ply and the third ply have been embossed together to form the third embossments on the first ply and the third ply.

According to some embodiments, the first ply, the third ply, and the fourth ply have been embossed together to form the first embossments on the first ply, the third ply, and the fourth ply.

According to some embodiments, the first ply, the third ply, and the fourth ply have been embossed together to form the third embossments on the first ply, the third ply, and the fourth ply.

According to some embodiments, the third embossments have been formed on the first ply and the third ply, but not on the fourth ply.

According to some embodiments, the third embossments have been formed on the first ply, but not on the third ply and the fourth ply.

According to some embodiments, the third ply and the fourth ply have been embossed together separately from the first ply and the second ply. According to other embodiments, one of

the third ply and the fourth ply has been separately embossed from the first ply and the second ply, and the other one of the third ply and the fourth ply is unembossed. According to yet other embodiments, the third ply and the fourth ply are unembossed. With "unembossed", reference is made to a ply that was not pre-embossed prior to the final ply-bonding.

The first embossments may be provided on an area constituting between 1% and 20% of a total surface of the first ply, and/or a density of the third embossments may be in a range of 25 to 120 embossments/cm², optionally 40 to 100 embossments/cm², or 50 to 80 embossments/cm².

The grammage of each of the plies of any one of the above-described embodiments of the tissue paper products may be in a range of 13 to 30 g/m², optionally 16 to 28 g/m², or 18 to 24 g/m².

According to some embodiments, the first ply may include one or two types of embossments, being decorative embossments with an embossing height in a range of 0.2 mm to 2.0 mm, optionally 0.8 mm to 1.4 mm, and/or micro-embossments with an embossing height in a range of 0.1 mm to 1.2 mm. The decorative embossments may be provided with a density of 15 dots/cm² or less, optionally 10 dots/cm² or less.

According to some embodiments, the second ply may include one or two types of embossments, being decorative embossments with an embossing height in a range of 0.2 mm to 2.0 mm, optionally 0.8 mm to 1.4 mm, and/or micro-embossments with an embossing height in a range of 0.1 mm to 1.2 mm. The decorative embossments may be provided with a density of 15 dots/cm² or less, optionally 10 dots/cm² or less.

Micro-embossments and/or decorative embossments may be in the form of lines or dots or other shapes. In the case that the decorative embossments are dot-shaped, the density may be

lower than 10 embossments/cm² for the decorative embossments.

One aspect of this disclosure relates to a tissue paper product, such as toilet paper or household towel, wherein the tissue paper product comprises between two and four plies, including at least a first ply and a second ply, the two plies, three plies, or four plies being ply-bonded, optionally using an adhesive such as lamination glue or mechanical bonding, such as edge embossing, to form the tissue paper product, the first ply and the second ply being the outermost plies of the tissue paper product.

A grammage of each of the plies being in a range of 13 to 30 g/m², optionally 16 to 28 g/m², or 18 to 24 g/m². The first ply is made of Conventional Wet Press (CWP) paper. The second ply is a structured paper ply, such as a ply made of TAD, UCTAD, eTAD, Atmos, or NTT, and the first ply has been embossed with a heated embossing roll.

The embossing of the first ply with a heated embossing roll may be advantageous as the embossments may have a better shape memory, i.e., they may be more resilient against shape deformation when the tissue paper product is wet. That is, the embossments being less affected when the ply is wet. This means that the tissue paper product may have a better absorption capacity than a comparable tissue paper product which does not comprise at least one ply that was embossed using a heated embossing roll. Moreover, as compared to a product without a ply that was embossed using a heated embossing roll with a certain thickness and strength (tensile strength), a higher thickness may be reached while retaining the same tensile strength. In other words, the tissue paper product in accordance with the present disclosure has high thickness and good absorption properties, as well as a high tensile strength. In particular, with the same embossing load (as used for manufacturing a comparative product under the same conditions with the exception embossing without a heated

embossing roll) during a manufacturing process, a higher thickness of the tissue product may be reached.

The tissue paper products in accordance with the present disclosure may have similarly high thicknesses as comparative products, in which the CWP ply is replaced by another structured paper ply that was not heat-embossed (but which are otherwise manufactured analogously), due to the fact that the CWP has been heat-embossed, while they may at the same time be cheaper to manufacture. In other words, the heat-embossed CWP ply may add less costs to the production of the tissue paper product than another structured ply.

Another aspect of this disclosure relates to a roll of tissue paper product made of a spirally wound continuous web of the tissue paper product of any one of the above-described embodiments.

The tissue paper product has a first end and a second end. The web of tissue paper product is wound such as to define an axially extending inner hole centrally positioned relative to the roll and such that the first end is located on the outer side of the roll and the second end is located at the inner hole.

A moisture content of a mother reel used to supply plies for manufacturing tissue paper products in accordance with the present disclosure may be in a range of 3% to 15%, optionally 3% to 10%, or optionally 4% to 7%.

According to some embodiments, the tissue paper product of the roll is provided with perforations for tearing off individual sheets.

A diameter of the roll may be in a range of 85 to 200 mm (including the boundaries). Such a roll is particularly suitable for household towels.

This disclosure also relates to a stack of unfolded sheets or a stack of folded sheets of the tissue paper product in accordance with any one or several of the above-described embodiments. In the case of some embodiments, the folded sheets may be separate individual folded sheets, or individual separate interfolded sheets. Alternatively, continuous sheets (with or without perforations for separating sheets) may be folded to form the stack. Optionally, the folded sheets may be multi-interfolded.

This disclosure also relates to a method of manufacturing a tissue paper product, such as toilet paper or household towel, comprising at least two plies. The method may be used to manufacture a tissue paper product in accordance with any one or several of the above-described embodiments of tissue paper product. Every one of the features of an embodiment of the tissue paper product translates into a feature of an embodiment of the method, and vice versa. These statements equally apply to embodiments of the method in accordance with the present disclosure for manufacturing tissue paper products comprising two plies, three plies, or four plies.

The method comprises the steps of:

- feeding between two and four plies, including at least a first ply made of Conventional Wet Press (CWP) paper and a second ply being a structured paper ply, such as a ply made of TAD, UCTAD, eTAD, Atmos, or NTT, with each ply having a grammage in a range of 13 to 30 g/m², optionally 16 to 28 g/m², or 18 to 24 g/m²;
- embossing the first ply on a first embossing roll with first embossing protrusions with a first height (h1) to form first embossments on the first ply,
- embossing the second ply on a second embossing roll with second embossing protrusions with a second height (h2) to form second embossments on the second ply,

- ply-bonding the two plies, three plies, or four plies ply, optionally using an adhesive, such as a lamination glue, or mechanical bonding, such as edge embossing, to form the tissue paper product.

The step of embossing the first ply is performed using a heated first embossing roll.

With "edge embossing", reference is made to a technique of mechanically bonding plies on the edges. This may be done with wheels with lines of side embossing and a flat counter-cylinder, and the ply-bonding is effected by exerting mechanical pressure.

Each of the embossing rolls used for manufacturing the tissue paper product may be a roll comprising a hard material such as metal, especially steel. Alternatives comprise embossing rolls made of hard rubber or hard plastics materials. The embossing rolls can be a male roll having individual protrusions. Typical heights/depths of the engraved embossing patterns are between 0.2 and 2.0 mm. For the heated embossing, a heatable embossing roll is used.

The machinery used for performing the method may comprise an application system for adhesive consisting of applicator roll, adhesive transfer roll and adhesive bath can be designed as a so-called immersion roll system in which the adhesive transfer roll is partially immersed into the adhesive bath and transports adhesive by means of surface tension and adhesive forces out of the adhesive bath. By adjusting the gap between the adhesive transfer roll and the applicator or application roll, or by adjusting the relative speed of the transfer roll relative to the applicator roll, the amount of adhesive to be applied can be adjusted. Application rolls may be structured rolls. Additionally or as an alternative thereto, water can be used (instead of adhesive) for ply-bonding.

The at least one heatable roll may be heatable from the inside or outside by a heating means.

The heating means may comprise heat carrying fluid and/or rely on induction and/or infrared heating.

The heatable roll may be heatable to a surface temperature in the range of 80°C to 170°, optionally 100°C to 165°, 110°C to 165°, 120°C to 160°, or 130°C to 155°. These temperature ranges may to an increasing degree with narrower ranges promote the manufacturing of a tissue paper product with good shape memory and/or large thickness, high machine direction (MD) and/or cross direction (CD) tensile strength, and good absorption properties.

The references to the temperatures of the heatable embossing roll(s) in this text are references, in particular, to surface temperatures of the embossing roll. These may be measured, for example, using an infrared thermometer. Moreover, the temperature values refer to temperatures in the steady state of the manufacturing apparatus, i.e., not while running and while plies are in contact with the embossing rolls. In particular, the surface temperature of the heatable embossing roll may drop during manufacturing, due to various effects such as heat conduction to the ply in contact with the roll, etc. For example, a surface temperature of 170°C might be measured in the steady state (when the embossing roll is not in contact with a ply), and this temperature might decrease to a temperature in the range of 100°C to 130°C during manufacturing, etc.

The indicated temperature ranges may, to an increasing degree with increasingly narrower ranges, promote being able to produce tissue paper products with an increased (cross-and/or main direction) tensile strength as compared to reference products which are made the same way but without using heated

embossing rolls. The strength increase may be in a range of about 5-25% or even 20-25%. In addition or alternative thereto, a gain in absorption capacity of about 15% and/or an increase in cross-directional (CD) tensile strength of about 5-10% may be achieved, while (for each case) the softness of the product may not be decreased or only insignificantly decreased with respect to the respective reference product.

The method may comprise a step of embossing the second ply using a non-heated second embossing roll.

The first ply may be moistened with a liquid, such as water with or without one or several additives. The first ply may be moistened with an amount of liquid in the range of 2% to 12% of the basis weight of the first ply, or optionally 4% to 10% of the basis weight of the first ply, prior to being embossed with a heated embossing roll, prior to the step of embossing the first ply.

To moisten the first ply, a manufacturing apparatus may include a wetting unit that is configured to provide a liquid, such as water or, for example, water provided with one or several additives such as softening agents and/or vitamins and/or scents, to the first ply. According to some embodiments, the wetting unit is configured to spray the liquid onto the respective ply. The wetting in these ranges may, to an increasing degree with increasingly narrower ranges, promote high tensile strength, good softness properties, and absorption capacity in the manufactured tissue paper products.

According to some embodiments, the apparatus does not comprise a wetting unit for providing a liquid to any of the plies. In other words, the apparatus may be configured to process the first ply without wetting it with a liquid. Such embodiments may promote high tensile strength, good softness properties, and absorption capacity in the manufactured

products.

According to some embodiments, the first ply is, hence, not moistened with a liquid prior to the step of embossing the first ply. The first ply may in these cases be referred to as a dry heat-embossed ply.

Some embodiments of the method manufacture a tissue paper product comprising exactly two plies and having a grammage in a range of 24 to 50 g/m². These embodiments may comprise the steps of:

- embossing the first ply with the heated first embossing roll with the first embossing protrusions to form the first embossments with a first height (h1) in a range of 0.2 mm to 2.0 mm; and
- embossing the second ply with the second embossing roll with the second embossing protrusions to form the second embossments with a second height (h2) in a range of 0.2 mm to 2.0 mm.

According to some embodiments, the first embossing roll also comprises third embossing protrusions, and the step of embossing the first ply forms first and third embossments on the first ply. According to other embodiments, the method comprises a step of embossing the first ply with a third embossing roll with third embossing protrusions to form third embossments. In other words, a second type of embossments may be formed on the first ply either with one and the same embossment roll as used for the first embossments, or they may be formed with another embossing roll.

Analogous statements hold for yet further types of embossments (different types referring to embossments with different shapes and/or different embossment heights, etc.).

The third embossments may have a third height (h3) smaller

than the first height h_1 ($h_1 > h_3$).

According to some embodiments, the second embossing roll also comprises fourth embossing protrusions, and the step of embossing the second ply forms second and fourth embossments on the third ply. According to other embodiments, the method comprises a step of embossing the second ply with a fourth embossing roll with fourth embossing protrusions to form fourth embossments. In other words, a second type of embossments may be formed on the second ply either with one and the same embossment roll as used for the second embossments, or they may be formed with another embossing roll.

Analogous statements hold for yet further types of embossments (different types referring to embossments with different shapes and/or different embossment heights, etc.).

The height of the fourth embossments h_4 may be smaller than the height of the second embossments h_2 ($h_2 > h_4$).

Some embodiments of the method manufacture a tissue paper product comprising exactly three plies and having a grammage in a range of 34 to 65 g/m². The three plies will in the following be referred to as the first ply, the second ply, and a third ply, located between the first ply and the second ply.

Embodiments of the method comprise the steps of:

- embossing the first ply with the heated first embossing roll with the first embossing protrusions to form the first embossments with a first height (h_1) in a range of 0.2 mm to 2.0 mm; and
- embossing the second ply with the second embossing roll with the second embossing protrusions to form the second embossments with a second height (h_2) in a range of 0.2

mm to 2.0 mm.

According to some embodiments, the first embossing roll also comprises third embossing protrusions, and the step of embossing the first ply forms first and third embossments on the first ply. According to other embodiments, the method comprises a step of embossing the first ply with a third embossing roll with third embossing protrusions to form third embossments. In other words, a second type of embossments may be formed on the first ply either with one and the same embossment roll as used for the first embossments, or they may be formed with another embossing roll.

Analogous statements hold for yet further types of embossments (different types referring to embossments with different shapes and/or different embossment heights, etc.).

The third embossments may have a third height (h_3) smaller than the first height h_1 ($h_1 > h_3$).

According to some embodiments, the second embossing roll also comprises fourth embossing protrusions, and the step of embossing the second ply forms second and fourth embossments on the third ply. According to other embodiments, the method comprises a step of embossing the second ply with a fourth embossing roll with fourth embossing protrusions to form fourth embossments. In other words, a second type of embossments may be formed on the second ply either with one and the same embossment roll as used for the second embossments, or they may be formed with another embossing roll.

Analogous statements hold for yet further types of embossments (different types referring to embossments with different shapes and/or different embossment heights, etc.).

The height of the fourth embossments h_4 may be smaller than

the height of the second embossments h_2 ($h_2 > h_4$).

Some embodiments of the method do not comprise a step of embossing the third ply. In other words, according to these embodiments, the third ply is not pre-embossed prior to the step of final ply-bonding of all three plies.

According to some embodiments, the method comprises a step of embossing the first ply and the third ply together to form the first embossments on the first ply and the third ply.

The first ply and the third ply may be embossed together to form also the third embossments on the first ply and the third ply.

Some embodiments of the method manufacture a tissue paper product comprising exactly four plies and having a grammage in a range of 55 to 95 g/m². The four plies will in the following be referred to as the first ply, the second ply, as well as a third ply and a fourth ply, the third ply and the fourth ply being located between the first ply and the second ply.

The third ply may be made of Conventional Wet Press (CWP) paper.

The fourth ply may be made of made of Conventional Wet Press (CWP) paper.

According to some embodiments, the method comprises the steps of:

- embossing the first ply with the heated first embossing roll with the first embossing protrusions to form the first embossments with a first height (h_1) in a range of 0.2 mm to 2.0 mm;
- embossing the second ply with the second embossing roll

with the second embossing protrusions to form the second embossments with a second height (h_2) in a range of 0.2 mm to 2.0 mm.

The first embossing roll may also comprise third embossing protrusions, and the step of embossing the first ply forms the first and third embossments on the first ply, the third embossments having a third height (h_3) smaller than the first height (h_1) ($h_1 > h_3$).

Some embodiments of the method comprise a step of embossing the first ply with a third embossing roll with third embossing protrusions to form third embossments on the first ply, the third embossments having a third height (h_3) smaller than the first height (h_1) ($h_1 > h_3$). Analogous statements hold for yet further types of embossments (different types referring to embossments with different shapes and/or different embossment heights, etc.).

According to some embodiments, the second embossing roll also comprises fourth embossing protrusions, and the step of embossing the second ply forms second and fourth embossments on the second ply. According to other embodiments, the method comprises a step of embossing the second ply with a fourth embossing roll with fourth embossing protrusions to form fourth embossments. In other words, a second type of embossments may be formed on the second ply either with one and the same embossment roll as used for the second embossments, or they may be formed with another embossing roll. Analogous statements hold for yet further types of embossments (different types referring to embossments with different shapes and/or different embossment heights, etc.).

Embodiments of the method may comprise the step of embossing the first ply and the third ply together to form the first embossments on the first ply and the third ply.

The method may not comprise a step of embossing the fourth ply. In other words, the fourth ply may not be pre-embossed prior to the final ply-bonding being carried out. According to other embodiments, the fourth ply is embossed separately from the first ply and the third ply.

According to some embodiments, the third embossments are formed only on the first ply but not on the third ply. According to other embodiments, the first ply and the third ply are embossed together to form the third embossments on the first ply and the third ply.

The first ply, the third ply, and the fourth ply may be embossed together to form the first embossments on the first ply, the third ply, and the fourth ply.

The first ply, the third ply, and the fourth ply may be embossed together to form the third embossments on the first ply, the third ply, and the fourth ply. Alternatively, the third embossments may be formed on the first ply and the third ply, but not on the fourth ply. Yet alternatively, the third embossments may be formed on the first ply, but not on the third ply and the fourth ply.

According to some embodiments, the third ply and the fourth ply are embossed together separately from the first ply.

The method may not comprise a step of (pre-)embossing the third ply. The method may also not comprise a step of (pre-)embossing the fourth ply.

According to some embodiments, the first embossments are formed on an area of the first ply constituting between 1% and 20% of a total surface of the first ply, and/or the third embossments are formed with a density in a range of 25 to 120 embossments/cm², optionally 40 to 100 embossments/cm², or 50 to 80 embossments/cm².

An embossing load during the embossing of the first ply may be in a range of from to 1 to 50 kg/cml, or optionally 5 to 40 kg/cml.

This disclosure further relates to a tissue paper product manufactured according to any of the above-mentioned embodiments of the method in accordance with the present disclosure. Such a tissue paper product may have a good shape memory in terms of the resilience of the embossments after having been wet. The statements about shape memory for the respective embodiments of the tissue paper product are equally applicable to the tissue paper product manufactured in accordance with the method of the present disclosure.

This disclosure also relates to a roll of a tissue paper product, such as toilet paper or household towel, made of a spirally wound continuous web of the tissue paper product having a first end and a second end, the web of the tissue paper product being wound such as to define an axially extending inner hole centrally positioned relative to the roll and such that the first end is located on the outer side of the roll and the second end is located at the inner hole, the tissue paper product being the tissue paper product manufactured in accordance with an embodiment of the method in accordance with the present disclosure.

This disclosure also relates to a stack of unfolded sheets or of folded sheets of tissue paper product manufactured in accordance with an embodiment of the method in accordance with the present disclosure.

Additional advantages and features of the present disclosure, that can be realized on their own or in combination with one or several features discussed above, insofar as the features do not contradict each other, will become apparent from the following description of particular embodiments.

Brief Description of the Drawings

For a better understanding of the present disclosure and to show how the same may be carried into effect, reference will now be made, by way of example only, to the accompanying drawings, in which:

The description is given with reference to the accompanying drawings, in which:

Figs. 1 and 2 are sectional views of a first embodiment and a second embodiment of a tissue paper product in accordance with the present disclosure, each of which comprises two plies;

Figs. 3 to 6 are sectional views of a third embodiment, a fourth embodiment, a fifth embodiment, and a sixth embodiment of a tissue paper product in accordance with the present disclosure, each of which comprises three plies;

Fig. 7 depicts a manufacturing apparatus with which a first embodiment of the method of manufacturing a tissue paper product in accordance with the present disclosure is carried out; and

Fig. 8 depicts a manufacturing apparatus with which a second embodiment of the method of manufacturing a tissue paper product in accordance with the present disclosure is carried out.

The embodiments of a tissue paper product of Figs. 1 and 2 comprise two plies: a top ply 1, 1' and a bottom ply 2, 2'.

The top ply 1, 1' is in both cases double-height embossed, i.e., it comprises two types of embossments with different heights. The bottom ply 2 of the embodiment of Fig. 1 is embossed with one type of embossments. The bottom ply 2' is either not embossed (not pre-embossed) or embossed with one type of embossments.

The top ply 1 and the bottom ply 2' of the embodiment of Fig. 1 have been ply-bonded. An example of where they are ply-bonded is shown in Fig.1 as region 4. In the case of the embodiment of Fig. 1, they have been ply-bonded using an adhesive (lamination glue). However, according to other embodiments, the ply-bonding could, e.g., have been effected using mechanical bonding such as edge embossing.

The top ply 1* of Fig. 1 is a structured paper ply made of TAD, UCTAD, eTAD, Atmos, or NTT. The top ply 1* has been embossed with a non-heated embossing roll.

The bottom ply 2' of Fig. 1 is made of Conventional Wet Press (CWP) paper (and is thus an example of a "first ply" in the sense of the present application). The bottom ply 2' has been embossed using a heated embossing roll, i.e., with a heated first embossing roll heated to a temperature in the range of 80°C to 170°. It is illustrated with a thickened line, in order to illustrate that it has been heat-embossed.

The embodiment of Fig. 2 differs from the one of Fig. 1 in that the top ply 1' of Fig. 2 is a ply made of Conventional Wet Press (CWP) paper and the bottom ply 2* of Fig. 2 is a structured paper ply made of TAD, UCTAD, eTAD, Atmos, or NTT. The bottom ply 2* has either not been embossed (not pre-embossed) or has been embossed with a non-heated embossing roll. The top ply 1' has been embossed using a heated

embossing roll, i.e., with a heated first embossing roll heated to a temperature in the range of 80°C to 170°. It is illustrated with a thickened line, in order to illustrate that it has been heat-embossed.

A grammage of the tissue paper product of Fig. 1 and of Fig. 2 is in a range of 24 to 50 g/m², respectively.

The embodiments of Figs. 3 to 6 are embodiments comprising exactly three plies.

The top ply 1* of the embodiment of Fig. 3 is a structured paper ply made of TAD, UCTAD, eTAD, Atmos, or NTT. It was embossed using a non-heated embossing roll. The middle ply 3 of Fig. 3 is a ply made of Conventional Wet Press (CWP) paper and it was not pre-embossed (prior to the final ply-bonding). The bottom ply 2' of the embodiment of Fig. 3 is a ply made of Conventional Wet Press (CWP) paper. It was embossed using a heated embossing roll heated to a temperature in the range of 80°C to 170°. It is illustrated with a thickened line, in order to illustrate that it has been heat-embossed.

The top ply 1' of the embodiment of Fig. 4 is a ply made of Conventional Wet Press (CWP) paper. It was embossed using a heated embossing roll heated to a temperature in the range of 80°C to 170°. It is illustrated with a thickened line, in order to illustrate that it has been heat-embossed. The middle ply 3 of Fig. 4 is a ply made of Conventional Wet Press (CWP) paper and it was not pre-embossed (prior to the final ply-bonding). The bottom ply 2* of the embodiment of Fig. 4 is a structured paper ply made of TAD, UCTAD, eTAD, Atmos, or NTT. It was either not embossed (not pre-embossed) or embossed using a non-heated embossing roll.

In the case of the embodiment of Fig. 5, the top ply 10' and the neighboring ply 11' are both made of Conventional Wet Press (CWP) paper and have been double-height heat-embossed

together using an embossing roll heated to a temperature in the range of 80°C to 170°. The bottom ply 2* of Fig. 5 is a structured paper ply made of TAD, UCTAD, eTAD, Atmos, or NTT. It was either not embossed (not pre-embossed) or embossed using a non-heated embossing roll.

The embodiment of Fig. 6 differs from the one of Fig. 5 in that the top ply 1* is a structured paper ply made of TAD, UCTAD, eTAD, Atmos, or NTT, that was embossed using a non-heated embossing roll, and that the bottom ply 20' and the neighboring ply 21' are made of Conventional Wet Press (CWP) paper and have been double-height heat-embossed together using an embossing roll heated to a temperature in the range of 80°C to 170°.

The grammage of the tissue paper products of Figs. 3, 4, 5, and 6 is in a range of 34 to 65 g/m².

Fig. 7 is a schematic representation of (a part of) and embodiment of a manufacturing apparatus for manufacturing a tissue paper product in accordance with the present disclosure using a first embodiment of a method in accordance with the present disclosure. In the following, it will be described how the first embodiment of the method is carried out using the apparatus illustrated in Fig. 7.

A first ply 15, being a structured paper ply made of TAD, UCTAD, eTAD, Atmos, or NTT, is provided. It is unwound from a first unwinding roll 210. A second ply 25 made of Conventional Wet Press (CWP) paper is provided. It is unwound from a second unwinding roll 220.

The CWP paper ply 25 is moistened in a wetting unit 150 with water and then heat-embossed between an embossing roll 50 and a counter roll 60. The heatable embossing roll 50 is heated to a steady-state temperature in the range of 80°C to 170°C.

The TAD paper ply 15 is embossed between a non-heatable embossing roll 40 and a counter roll 35. It is also provided with adhesive using a transfer roll 80.

The structured (TAD) ply 15 and the heat-embossed ply 25 are then ply-bonded between the embossing roll 40 and a marrying roll 70. The two-ply tissue paper product 110 is then wound-up on the winding roll 300.

The only difference between the apparatus of Fig. 7 and the one of Fig. 8, is that the one of Fig. 8 does not comprise a wetting unit. In other words, the CWP ply 25 is, in the case of using the apparatus of Fig. 8, not pre-moistened prior to the heat-embossing step been carried out between the heatable roll 50 and the counter roll 60.

Each of the tissue paper products of Figs. 1 to 6 as well as the ones manufactured using the apparatus of Fig. 7 or Fig. 8 has a high absorption capacity, a large thickness (as compared to conventional products with a similar strength), and a high (tensile) strength (as compared to conventional products with a similar thickness). Specifically, the tissue paper products have a good wetness shape memory, i.e., the embossments disappear less than in comparable conventional products when the product has been wet.

EXPERIMENTAL RESULTS

In the following, experimental examples of embodiments (examples) in accordance with the present disclosure will be compared with conventional tissue paper products.

In order to evaluate the performance of tissue paper products in accordance with the present disclosure (manufactured in accordance with the method in accordance with the present disclosure), several reference products were manufactured. The reference products were manufactured without using any

heat-embossing, i.e., without embossing a ply using a heated embossing roll.

Reference Products A (two TAD plies)

A first reference product ("reference A") consisted of two structured TAD plies. Both structured paper plies made of TAD were provided with a grammage of about 20g/m². The top ply was embossed with a single height embossing design, and the bottom ply was not embossed. Lamination glue was applied to the top ply, and the two plies were then ply-bonded to manufacture a two-ply product.

The embossing pressure used when embossing the top ply was adjusted such that the embossing design was visible on the top ply.

Reference Product B1 (two CWP plies)

A second reference product ("reference B1") was manufactured with two CWP plies. Both CWP plies were provided with a grammage of about 20g/m². The top ply was embossed with a double height embossing design comprising some micro-embossing dots. Glue was applied to the top ply at tips of the embossments with the larger height. The bottom ply was embossed with a micro-embossing design having around 80 dots/cm². Finally, the two plies were ply-bonded together with a marrying roll.

The CWP paper used for reference product was selected such that the softness level was similar to that of the TAD ply used for reference product A.

The embossing pressure between the rubber rollers and the embossing rollers was adjusted to achieve a product thickness of about 0.41mm.

Reference Product B2 (two CWP plies)

Reference product B2 was manufactured almost identically to reference product B1. The difference is that the embossing pressures were adjusted in order to achieve the same product thickness as in the case of reference product A, i.e., a thickness of 0.45mm.

Reference Product C1 (CWP ply + TAD ply)

Reference product C1 was manufactured with a top ply being a CWP ply with a grammage of around 20g/m² and a bottom ply being a TAD ply with a grammage of around 20g/m². The top ply was embossed (with a non-heated embossing roll), while the bottom ply was not embossed. The embossing pressure of the top ply was adjusted so that the product thickness was about the same as the one of reference product A.

Reference Product C2 (CWP ply + TAD ply)

Reference product C1 was manufactured with a top ply being a TAD ply with a grammage of around 20g/m² and a bottom ply being a CWP ply with a grammage of around 20g/m². The top ply and the bottom ply were both embossed (with non-heated embossing rolls). The bottom ply was embossed with a micro-embossing design having around 80 dots/cm².

The embossing pressure for embossing the top ply was adjusted so that the embossing design was visible on the top ply. The embossing pressure for the bottom ply was adjusted such that the reference product C2 had about the same thickness as reference product A.

The following table summarizes measurement results for the basis weight (grammage), the thickness, the main directional tensile strength (MDT), the cross directional tensile strength (CDT), the geometrical mean tensile strength (i.e.,

the square root of the product of the MDT and the CDT), the absorption capacity, and the softness of the various reference products.

	Top ply paper	Bottom ply paper	Basis weight	Thickness	MDT	CDT	geometrical mean tensile	Absorp tion	Softness
			(g/m ²)	mm	(N/m)	(N/m)	(N/m)	(g/g)	
Reference A	TAD	TAD	39.4	0.45	215	135	170	12.4	1.7
Reference B1	CWP	CWP	39.2	0.41	213	77	128	8.4	1.6
Reference B2	CWP	CWP	38.9	0.45	199	72	120	8.5	1.6
Reference C1	CWP	TAD	39.4	0.45	195	113	149	11.5	1.7
Reference C2	TAD	CWP	38.7	0.45	178	97	131	11.7	1.7

A comparison of the reference products shows that reference product B1 has only a slightly lower thickness (about 9% lower) as compared to the thickness of reference product A (as the structured ply lead to larger thickness), but the tensile strength (in particular, the CDT and the GM tensile strength) were significantly lower than for the reference product A. Also the softness of reference product B1 is lower than the softness of reference product A. Reference product A is, however, substantively more expensive to manufacture than reference product B1.

Reference product B2 is an example showing that the thickness of reference product A could be reached despite using two CWP plies, due to embossing each of the plies with a design including micro-embossing dots. However, the tensile strength is much lower than for reference product A (-47% in terms of CDT and -29% in terms of GMT). The absorption and the softness of reference product B2 are also noticeably lower than for reference product A.

Reference product C1 has about the thickness and the softness of reference product A, but the CD tensile strength, GM tensile strength, and the absorption are significantly lower than the ones of reference product A. Reference product C1 has a larger CD tensile strength and GM tensile strength, as well as higher absorption and softness as compared to reference product B2.

The top surface of reference product C2 is the same as the one of reference product A (a TAD ply as a top ply), but it nevertheless has a lower overall tensile strength than reference product C1.

For comparison to the reference products, the following products in accordance with the present disclosure were manufactured: exemplary products D1, D2, and D3 were manufactured including a step of moistening the bottom ply prior to embossing. The exemplary products D4, D5, and D6 were manufactured without any pre-moistening.

Exemplary Product D1 (TAD ply + wet heat-embossed CWP ply)

Exemplary product was manufactured using a TAD ply with a grammage of around 20g/m² as a top ply and a CWP ply of around 20g/m² as a bottom ply. The top ply was embossed with a non-heated embossing roll.

The embossing pressure used for the top ply was adjusted such that the embossing design was visible on the top ply.

The bottom CWP ply was pre-moistened spraying some water onto it, using a rotor spraying system. The amount of water added to the bottom ply was around 1.2g/m². The bottom ply was then heat-embossed by a heatable embossing roll to form a micro-embossing design with around 80 dots/cm². The embossing roll was heated to a steady-state temperature of around 150°C.

While the manufacturing was running, the CWP ply was heated up to a temperature that was typically close to about 90°C.

The embossing pressure for the bottom ply was adjusted to achieve a similar product thickness as for the reference product A.

Exemplary Product D2 (TAD ply + wet heat-embossed CWP ply)

The embossing pressure for the top ply was adjusted such that the embossing design was visible on the top ply.

The embossing pressure for the bottom ply was adjusted such that the resulting product had about the same geometric mean tensile strength as the reference product C1.

Exemplary Product D3 (TAD ply + wet heat-embossed CWP ply)

The embossing pressure for the top ply was adjusted such that the embossing design was visible on the top ply.

The embossing pressure for the bottom ply was adjusted to the maximum supported by the embossing unit.

The following table summarizes measurement results for the basis weight (grammage), the thickness, the main directional tensile strength (MDT), the cross directional tensile strength (CDT), the geometrical mean tensile strength (i.e., the square root of the product of the MDT and the CDT), the absorption capacity, and the softness of the various reference products. The table also indicates the embossing load used for the step of heat-embossing the respective CWP plies.

	Top ply paper	Bottom ply paper	Heated embossing load	Basis weight	Thickness	MDT	CDT	geometrical mean tensile	Absorption	Softness
			kg/cm ²	(g/m ²)	mm	(N/m)	(N/m)	(N/m)	(g/g)	
Example D1	TAD	CWP	22.0	38.5	0.46	214	107	151	11.4	1.7
Example D2	TAD	CWP	31.0	37.8	0.51	208	101	145	12.2	1.7
Example D3	TAD	CWP	42.0	37.6	0.54	197	93	135	12.8	1.7

Exemplary product D1 has about the same thickness as reference product C2, but a higher tensile strength (+20% in MDT, +10% in CDT and +15% in GMT). The absorption capacity and the softness are similar.

Compared to the reference product C1, exemplary product has a higher MD tensile strength (+10%), while the level of GM tensile strength, the absorption capacity, and the softness are similar.

Exemplary product D2 has a larger thickness, tensile strength, and absorption capacity as compared to reference product C2. Compared to reference product C1, the tensile strength and the softness appear to be similar, but the thickness and the absorption capacity are both larger. Compared to reference product A, exemplary product D2 has higher thickness (+13%), about the same absorption capacity and softness, and only tensile strength is lower than for comparative product A (with two TAD plies).

Exemplary product D3 achieves an even higher thickness than reference product A (+20%), while having comparable absorption capacity and softness.

It was thus found that the pre-moistening combined with the embossing using a heated embossing roll using one ply made of TAD and one ply made CWP allows to manufacture products with similar properties as comparative products made of two TAD plies, without relying on heat-embossing. However, the production costs of the exemplary products are lower.

Further exemplary products were made analogously as the exemplary products D1, D2, and D3, but leaving out the step of pre-moistening the CWP ply prior to the step of heat-embossing. In other words, the CWP ply was dry heat-embossed.

Exemplary Product D4 (TAD ply + dry heat-embossed CWP ply)

Exemplary product D4 was manufactured exactly the same way as exemplary product D1, with the exception of omitting the step of moistening the CWP ply prior to the step of heat-embossing.

Exemplary Product D5 (TAD ply + dry heat-embossed CWP ply)

Exemplary product D5 was manufactured exactly the same way as exemplary product D2, with the exception of omitting the step of moistening the CWP ply prior to the step of heat-embossing.

Exemplary Product D6 (TAD ply + dry heat-embossed CWP ply)

Exemplary product D6 was manufactured exactly the same way as exemplary product D3, with the exception of omitting the step of moistening the CWP ply prior to the step of heat-embossing.

The following table shows the measurement results obtained for exemplary products D4, D5, and D6.

	Top ply paper	Bottom ply paper	Heated embossing load	Basis weight	Thickness	MDT	CDT	geometrical mean tensile	Absorption	Softness
			kg/cmI	(g/m ²)	mm	(N/m)	(N/m)	(N/m)	(g/g)	
Exemplary D4	TAD	CWP	22.0	39.2	0.46	193	107	144	11.6	1.7
Exemplary D5	TAD	CWP	31.0	38.4	0.51	192	96	136	12.0	1.7
Exemplary D6	TAD	CWP	42.0	38.1	0.54	198	94	136	12.5	1.7

Exemplary products D4, D5, and D6 have similar physical characteristics as the exemplary products D1 D2, and D3.

It will be apparent to those skilled in the art that various modifications and variations can be made in the disclosed devices and systems without departing from the scope of the disclosure. Other aspects of the disclosure will be apparent to those skilled in the art from consideration of the specification and practice of the features disclosed herein. It is intended that the specification and examples be considered as exemplary only. Many additional variations and modifications are possible and are understood to fall within the framework of the disclosure.