Coreless Rolls of a Tissue Paper Product and Methods of Manufacturing Coreless Rolls

Technical Field

The present disclosure relates to coreless rolls of a tissue paper product, such as toilet paper, made of a spirally wound continuous web of tissue paper product. The disclosure also relates to methods of manufacturing coreless rolls of a tissue paper product, such as toilet paper.

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.

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, 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.

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. 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 of 25 to 100 dots per cm2, preferably 35 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.

It has become known to produce rolls of tissue paper products, such as toilet paper, without a core (e.g., without an additional cardboard core), so-called coreless rolls. This is appealing as a reduction of waste is achieved (as the cores of used rolls were a waste product). However, the coreless rolls are not always as satisfying for customers as rolls with a core, e.g., due to a reduced stability in comparison to the rolls with a core.

There is, hence, a need for improved coreless rolls, improving customer satisfaction while nevertheless allowing to reduce waste (by avoiding, in particular, the need of providing cores which usually end up as waste). Specifically, such coreless rolls should address at least one of the above-mentioned shortcomings. Moreover, there is a need for manufacturing methods for improved coreless rolls that address at least one of the above-mentioned shortcomings.

Summary

One aspect of the above-mentioned object is achieved by a coreless roll of a tissue paper product, such as toilet paper, with two plies, in accordance with the present disclosure. The coreless roll is made of a spirally wound continuous web of tissue paper product having 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 coreless roll and such that the first end is located on the outer side of the coreless roll and the second end is located at the inner hole.

The coreless roll has an outer diameter in the range of 95 to 150 mm. A diameter of the inner hole is in the range of 20 to 50 mm. The diameter of the inner hole, as referred to in this text, is to be understood to be an "average diameter" obtained by dividing the perimeter of the inner hole by π (π may, of course, be approximated, e.g., by 3.14). The actual distance between opposing surfaces of the inner hole may vary as one moves along the perimeter, as the inner hole does not need to have a round cross-sectional shape, but will typically vary a bit (depending, e.g., on the orientation which the roll had during transportation etc.). A density of the coreless roll is in a range of 80 to 160 kg/m^3. The roll density is defined (throughout this text) as the ratio between the weight of the roll and the volume of tissue paper product. The expression "volume of the tissue paper product" is used to refer to the difference between the external volume of the coreless roll and the volume of the inner cylinder defined by the inner hole.

A caliper ratio of the roll is in a range of 30% to 80%. If the caliper ratio is lower than 30%, the radial compression strength of the coreless roll may not be satisfactory. If the caliper ratio is higher than 80%, the embossing load needed to manufacture the coreless roll may have a negative impact

on the tensile strength of the tissue paper product.

The caliper ratio $(c_S-c_t)/c_t$ is obtained by dividing a difference between a standard caliper c_S of the tissue paper product as defined by the standard ISO-12625-3 and a theoretical caliper c_t of the tissue paper product by the theoretical caliper c_t. The theoretical caliper c_t is defined as a ratio between a grammage (e.g., in g/m^2) of the tissue paper product and the density of the roll (e.g., in kg/m^3).

The tissue paper product comprises two plies of Conventional Wet Press paper (CWP). 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 two plies are ply-bonded. According to some embodiments, they may be ply-bonded with an adhesive, such as lamination glue. According to some embodiments, the plies may be ply-bonded through mechanical bonding, such as edge embossing.

The grammage of the tissue paper product may be in a range of 24 g/m^2 to 50 g/m^2, optionally 30 g/m^2 to 45 g/m^2.

The coreless rolls with a tissue paper product made of two plies described above may have a particularly high radial compression strength. Specifically, the radial compression strength of such rolls may be 20 N or more, or even 25N or more, or even 30N. These are robust and meet the requirements, e.g., for toilet paper rolls. Thus, they may achieve customer satisfaction.

Whenever reference is made to the radial compression strength

in this document, reference is made to the radial compression strength measured as follows. A sample coreless roll is inserted into a standard dynamometer with two parallel plates, a top plate and a bottom plate (which are large enough to sandwich a coreless roll and to apply pressure to contact surfaces), the plates, e.g., being metallic plates. The coreless roll is put on the bottom plate, a plastic mandrel is inserted (e.g., a mandrel with a diameter in range of 15 mm to 40 mm) in the inside hole of the coreless roll. The bottom plate and the top plate are then moved towards each other, usually by moving the upper plate towards a lower plate that is fixed and not moveable (using a compression speed of 60 mm/min and, for example, using a dynamometer with a cell of, e.g., 200 N), and it is measured how much pressure (in Newton) needs to be exerted onto the coreless roll until the inside of the coreless roll exerts pressure onto the mandrel. The pressure exerted onto the coreless roll at which in turn the exertion of pressure by the inside of the coreless roll onto the mandrel starts, is the radial compression strength of the coreless roll. A minimum number of five serial measurements may be required in order to obtain a statistically significant result/measurement. The serial measurements need to be performed on separate rolls (from the same production series), in order to obtain reliable results. The sample rolls need to be pre-conditioned, and measurements need to be carried out in accordance with the standard norm ISO187.

According to some embodiments, the (sheet) caliper of the tissue paper product is at least 0.35 mm, for some embodiments at least 0.40 mm, and for some embodiments even at least 0.45 mm. These lower thresholds on the caliper may, to an increasing degree with the increasingly larger values indicated as the lower threshold for the caliper, lead to good customer satisfaction, as customers expect a tissue paper product to have a minimum caliper in order to feel a good sensation when dealing with the tissue paper product.

The two plies of the tissue paper product will in the following be referred to as a first ply and a second ply.

The first ply may comprise first embossments with a first height (h1), the first height (h1) 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 (h2), the second height (h2) being in a range of 0.2 mm to 2.0 mm.

The first ply may comprise third embossments with a third height (h3) smaller than the first height h1 (h1>h3). In other words, adhesive may be applied to tips of the higher embossments (i.e., those with a larger embossing height).

According to some embodiments, the first embossments have been formed by a first heated embossing roll. If the embossing is performed with the first heated embossing roll, i.e., if heat-embossing is performed, this may promote higher tensile strength, and/or larger caliper of the tissue paper product without (or while hardly) lowering the softness of the tissue paper product as compared to a reference product manufactured analogously but without heat-embossing (i.e., embossing without a heated embossing roll).

Any heated or heatable embossing roll, as referred to in this text, 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.

Any heated or heatable embossing roll, as referred to in this text, may be heatable to a surface temperature in the range of 80°C to 170°C, optionally 100°C to 165°C, or 110°C to 165°C, or 120°C to 160°C, or 130°C to 155°C, . 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 any heated embossing roll(s), as referred to 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 third embossments (if present) may have been formed by the same first heated embossing roll or, alternatively, by a different (heatable or non-heatable) embossing roll.

According to some embodiments, the second embossments have been formed by a second heated embossing roll. If the embossing is performed with the second heated embossing roll, i.e., if heat-embossing is performed, this may promote higher tensile strength, and/or higher absorption capacity without (or while hardly) lowering the softness of the tissue paper product as compared to a reference product manufactured analogously but without heat-embossing (i.e., embossing without a heated embossing roll).

According to some embodiments, the third embossments have been formed by a third heated embossing roll. If the

embossing is performed with the third heated embossing roll, i.e., if heat-embossing is performed, this may promote higher tensile strength, and/or higher absorption capacity without (or while hardly) lowering the softness of the tissue paper product as compared to a reference product manufactured analogously but without heat-embossing (i.e., embossing without a heated embossing roll).

Another aspect of the above-mentioned object is achieved by a coreless roll of a tissue paper product, such as toilet paper, with three plies, in accordance with the present disclosure. The coreless roll is made of a spirally wound continuous web of tissue paper product having 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 coreless roll and such that the first end is located on the outer side of the coreless roll and the second end is located at the inner hole.

The coreless roll has an outer diameter in the range of 95 to 150 mm. A diameter of the inner hole is in the range of 20 to 50 mm. A density of the coreless roll is in a range of 110 to 170 kg/m^3.

A caliper ratio of the roll is in a range of 20% to 60%. If the caliper ratio is lower than 20%, the radial compression strength of the coreless roll may not be satisfactory. If the caliper ratio is higher than 60%, the embossing load needed to manufacture the coreless roll may have a negative impact on the tensile strength of the tissue paper product.

The caliper ratio $(c_S-c_t)/c_t$ is obtained by dividing a difference between a standard caliper c_S of the tissue paper product as defined by the standard ISO-12625-3 and a theoretical caliper c_t of the tissue paper product by the theoretical caliper c_t. The theoretical caliper c_t is defined as a ratio between a grammage of the tissue paper product and

the density of the roll.

The tissue paper product comprises three plies of Conventional Wet Press paper (CWP). 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 three plies are ply-bonded. According to some embodiments, they may be bonded with an adhesive, such as lamination glue. According to some embodiments, the plies may be bonded through mechanical bonding, such as edge embossing.

The grammage of the tissue paper product is in a range of 34 g/m^2 to 65 g/m^2, optionally 40 g/m^2 to 63 g/m^2, or 45 g/m^2 to 60 g/m^2.

The coreless rolls with a tissue paper product made of three plies described above may have a particularly high radial compression strength. Specifically, the radial compression strength of such rolls may be 20 N or more, or even 25N or more, or even 30N. These are robust and meet the requirements, e.g., for toilet paper rolls. This property may be increasingly promoted by the increasingly narrower ranges of grammage specified for the three-ply tissue paper product.

The (sheet) caliper of the tissue paper product may be at least 0.40 mm, optionally at least 0.45 mm, or at least 0.50 mm. These lower thresholds on the caliper may, to an increasing degree with the higher values for the lower threshold, lead to good customer satisfaction, as customers expect a minimum caliper.

The three plies will in the following be referred to as a first ply, a second ply, and a third ply. The third ply is positioned between the first ply and the second ply.

The first ply may comprise first embossments with a first height (h1), the first height (h1) 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 (h2), the second height (h2) being in a range of 0.2 mm to 2.0 mm.

The first ply may comprise third embossments with a third height (h3) smaller than the first height h1 (h1>h3).

According to some embodiments, the third ply is unembossed. 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.

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.

The third ply (i.e., the middle ply) may comprise fourth embossments with a fourth height (h4), the fourth height (h4)

being in a range of 0.2 mm to 2.0 mm. The third ply may have been embossed separately from the first ply and the second ply. According to some embodiments, the fourth embossments have been formed by a fourth heated embossing roll.

According to some embodiments, the first embossments have been formed by a first heated embossing roll. If the embossing is performed with the first heated embossing roll, i.e., if heat-embossing is performed, this may promote higher tensile strength, and/or larger caliper of the tissue paper product without (or while hardly) lowering the softness of the tissue paper product as compared to a reference product manufactured analogously but without heat-embossing (i.e., embossing without a heated embossing roll).

The third embossments (if present) may have been formed by the same first heated embossing roll or, alternatively, by a different (heatable or non-heatable) embossing roll.

According to some embodiments, the second embossments have been formed by a second heated embossing roll. If the embossing is performed with the second heated embossing roll, i.e., if heat-embossing is performed, this may promote higher tensile strength, and/or higher absorption capacity without (or while hardly) lowering the softness of the tissue paper product as compared to a reference product manufactured analogously but without heat-embossing (i.e., embossing without a heated embossing roll).

According to some embodiments, the third embossments have been formed by a third heated embossing roll. If the embossing is performed with the third heated embossing roll, i.e., if heat-embossing is performed, this may promote higher tensile strength, and/or higher absorption capacity without (or while hardly) lowering the softness of the tissue paper product as compared to a reference product manufactured analogously but without heat-embossing (i.e., embossing

without a heated embossing roll).

The coreless rolls with a tissue paper product made of three plies described above may have a particularly high radial compression strength. Specifically, the radial compression strength of such rolls may be 20 N or more, or even 25N or more, or even 30N. These are robust and meet the requirements, e.g., for toilet paper rolls. In particular, they may achieve customer satisfaction for coreless rolls.

Another aspect of the above-mentioned object is achieved by a coreless roll of a tissue paper product, such as toilet paper, with four plies, in accordance with the present disclosure. The coreless roll is made of a spirally wound continuous web of tissue paper product having 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 coreless roll and such that the first end is located on the outer side of the coreless roll and the second end is located at the inner hole.

The coreless roll has an outer diameter in the range of 95 to 150 mm. A diameter of the inner hole is in the range of 20 to 50 mm. A density of the coreless roll is in a range of 120 to 160 kg/m^3.

A caliper ratio of the roll is in a range of 12% to 40%. If the caliper ratio is lower than 12%, the radial compression strength of the coreless roll may not be satisfactory. If the caliper ratio is higher than 30%, the embossing load needed to manufacture the coreless roll may have a negative impact on the tensile strength of the tissue paper product.

The caliper ratio $(c_S-c_t)/c_t$ is obtained by dividing a difference between a standard caliper c_S of the tissue paper product as defined by the standard ISO-12625-3 and a theoretical caliper c_t of the tissue paper product by the

theoretical caliper c_t. The theoretical caliper c_t is defined as a ratio between a grammage of the tissue paper product and the density of the roll.

The tissue paper product comprises four plies of Conventional Wet Press paper (CWP). 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 four plies are ply-bonded. According to some embodiments, they may be bonded with an adhesive, such as lamination glue. According to some embodiments, the plies may be bonded through mechanical bonding, such as edge embossing.

The grammage of the tissue paper product is in a range of 55 g/m^2 to 95 g/m^2, or optionally 60 g/m^2 to 80 g/m^2.

The coreless rolls with a tissue paper product made of four plies described above may have a particularly high radial compression strength. Specifically, the radial compression strength of such rolls may be 20 N or more, or even 25N or more, or even 30N. These are robust and meet the requirements, e.g., for toilet paper rolls. This property may be increasingly promoted by the increasingly narrower ranges of grammage specified for the four-ply tissue paper product.

The (sheet) caliper of the tissue paper product may be at least 0.55 mm, optionally at least 0.60 mm, or at least 0.65 mm. These lower thresholds on the caliper may, to an increasing degree with the higher values for the lower

threshold, lead to good customer satisfaction, as customers expect a minimum caliper in a tissue paper product.

The four plies may be referred to as a first ply, a second ply, a third ply, and a fourth ply. The first ply and the second ply are the outermost plies of the tissue paper product. The third ply and the fourth ply are, hence, located between the first ply and the second ply.

The first ply may comprise first embossments with a first height (h1), the first height (h1) 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 (h2), the second height (h2) being in a range of 0.2 mm to 2.0 mm.

The first ply may comprise third embossments with a third height (h3) smaller than the first height h1 (h1>h3).

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 is unembossed.

According to some embodiments, the fourth ply may have been embossed separately from the first ply, the second ply, and the third ply.

According to some embodiments, the third embossments have optionally 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.

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.

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. In addition thereto or as an alternative thereto, the fourth ply and the second ply have been embossed together to form the second embossments on the fourth ply and the second ply.

According to some 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 other

embodiments, the third embossments have been formed only on the first ply but not on the third ply.

The first embossments may have been formed by a first heated embossing roll. In addition thereto or as an alternative thereto, the second embossments may have been formed by a second heated embossing roll. In addition thereto or as an alternative thereto, the third embossments may have been formed by the first heated embossing roll or a third heated embossing roll.

The coreless rolls with a tissue paper product made of four plies described above may have a particularly high radial compression strength. Specifically, the radial compression strength of such rolls may be 20 N or more, or even 25N or more, or even 30N. These are robust and meet the requirements, e.g., for toilet paper rolls.

Another aspect of the above-mentioned object is achieved by a coreless roll of a tissue paper product, such as toilet paper, with five or six plies, in accordance with the present disclosure. The coreless roll is made of a spirally wound continuous web of tissue paper product having 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 coreless roll and such that the first end is located on the outer side of the coreless roll and the second end is located at the inner hole.

The coreless roll has an outer diameter in the range of 95 to 150 mm. A diameter of the inner hole is in the range of 20 to 50 mm. A density of the coreless roll is in a range of 130 to 160 kg/m^3.

A caliper ratio of the roll is in a range of 12% to 25%. If the caliper ratio is lower than 12%, the radial compression strength of the coreless roll may not be satisfactory. If the

caliper ratio is higher than 25%, the embossing load needed to manufacture the coreless roll may have a negative impact on the tensile strength of the tissue paper product.

The caliper ratio $(c_S-c_t)/c_t$ is obtained by dividing a difference between a standard caliper c_S of the tissue paper product as defined by the standard ISO-12625-3 and a theoretical caliper c_t of the tissue paper product by the theoretical caliper c_t. The theoretical caliper c_t is defined as a ratio between a grammage of the tissue paper product and the density of the roll.

The tissue paper product comprises five or six plies of Conventional Wet Press paper (CWP). In fact, a total number of plies of the tissue paper product is five or six. Put differently, the tissue paper product consists of five or six 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 five or six. At least one of the five or six plies is an embossed ply. One, two, three, four, or five (or six, if applicable) of the five or six plies may be embossed plies.

The five or six plies are ply-bonded. According to some embodiments, they may be bonded with an adhesive, such as lamination glue. According to some embodiments, the plies may be bonded through mechanical bonding, such as edge embossing.

The grammage of the tissue paper product is in a range of 65 g/m^2 to 125 g/m^2, or optionally 65 g/m^2 to 100 g/m^2.

The coreless rolls with a tissue paper product made of five or six plies described above may have a particularly high radial compression strength. Specifically, the radial compression strength of such rolls may be 20 N or more, or even 25N or more, or even 30N. These are robust and meet the

requirements, e.g., for toilet paper rolls. This property may be increasingly promoted by the increasingly narrower ranges of grammage specified for the five- or six-ply tissue paper product.

The (sheet) caliper of the tissue paper product may be at least 0.65 mm, optionally at least 0.70 mm or at least 0.75 mm. These lower thresholds on the caliper may, to an increasing degree with the higher values for the lower threshold, lead to good customer satisfaction, as customers expect a minimum caliper.

At least one of the outermost plies of the tissue paper product may comprises first embossments with a first height (h1), the first height (h1) being in a range of 0.2 mm to 2.0 mm. An adhesive, such as lamination glue, may be applied to tips of the first embossments of the first ply. The other one of the outermost plies of the tissue paper product may comprise second embossments with a second height (h2), the second height (h2) being in a range of 0.2 mm to 2.0 mm. According to some embodiments, first embossments have been formed by a first heated embossing roll, and/or the second embossments have been formed by a second heated embossing roll.

The coreless rolls with a tissue paper product made of five or six plies described above may have a particularly high radial compression strength. Specifically, the radial compression strength of such rolls may be 20 N or more, or even 25N or more, or even 30N. These are robust and meet the requirements, e.g., for toilet paper rolls.

Any one of the above-described embodiments of a coreless roll comprising two, three, four, five, or six plies, may have a radial compression strength of 20 N or more, optionally of 25N or more, or of 30N or more.

Another aspect of this disclosure relates to a coreless roll of a tissue paper product, such as toilet paper, that is structured as follows. The coreless roll is made of a spirally wound continuous web of tissue paper product having 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 coreless roll and such that the first end is located on the outer side of the coreless roll and the second end is located at the inner hole.

The tissue paper product comprises at least two plies of Conventional Wet Press paper (CWP). A total number of plies of the tissue paper product is between 2 and 6. At least one of the plies is an embossed ply. The between 2 and 6 plies are ply-bonded, optionally with an adhesive, such as lamination glue, or with mechanical bonding, such as edge embossing.

The coreless roll has an outer diameter in the range of 95 to 150 mm. A diameter of the inner hole is in the range of 20 to 50 mm. A density of the coreless roll being in a range of 80 to 160 kg/m^3.

A caliper ratio of the roll is in a range of 30%-80% if the total number of plies is 2, the caliper ratio of the roll is in a range of 20%-60% if the total number of plies is 3, the caliper ratio of the roll is in a range of 12%-30% if the total number of plies is 4, and the caliper ratio of the roll is in a range of 10%-25% if the total number of plies is 5 or 6. The caliper ratio $(c_S-c_t)/c_t$ is obtained by dividing a difference between a standard caliper c_S of the tissue paper product as defined by the standard ISO-12625-3 and a theoretical caliper c_t of the tissue paper product by the theoretical caliper c_t. The theoretical caliper c_t is defined as a ratio between a grammage of the tissue paper product and the density of the roll.

The coreless roll has a radial compression strength of 20 N or more, optionally of 25N or more, or of 30N or more.

All of the plies of the tissue paper product are made of Conventional Wet Press (CWP) paper.

In the case of any embodiment (or any combination of embodiments, in so far the features of the different embodiments are not incompatible) of a tissue paper product described above (irrespective of the number of plies, etc., and irrespective of which of all of the above-described aspects is chosen), at least a part of an innermost circumvolution, optionally the entire innermost circumvolution, of the absorbent material of the coreless roll at the second end may comprise a stabilizing coating composition. This may aid in promoting good radial and/or axial stability of the coreless roll.

The coating composition may comprise at least one of the following list: a polymer including oxygen and/or nitrogen atoms, a non-ionic polymer such as a non-ionic cellulose ether, polyether polyol.

The coating composition may comprise water.

When the coating composition comprises a nonionic polymer, the ionic demand may be in a range of from -1000 to +100 µeq/g, or -500 to +50 µeq/g, or -50 to 0 µeq/g.

The coating composition may be applied to only one side of the innermost turn. This one side may be side oriented towards the axially extending inner hole.

Another aspect of this disclosure relates to a method of manufacturing a coreless roll of a tissue paper product, such

as toilet paper, the tissue paper product being made of two plies. The method comprises the steps of:

- providing two plies of Conventional Wet Press paper (CWP) and embossing at least one of the two plies;
- ply-bonding the two plies, optionally with an adhesive, such as a lamination glue, or with mechanical bonding, such as edge embossing, to form a tissue paper product with a grammage in a range of 24 g/m^2 to 50 g/m^2, optionally 30 g/m^2 to 45 g/m^2, and a caliper ratio in a range of 30% to 80%;
- spirally winding up the tissue paper product on a mandrel to form a coreless roll and to define an axially extending inner hole facing the mandrel, with a first end of the tissue paper product being located on the outer side of the coreless roll and the second end being located at the inner hole; and
- withdrawing the mandrel;
  wherein the coreless roll comprises an outer diameter in the range of 95 to 150 mm and a diameter of the inner hole is in the range of 20 to 50 mm, and the density of the coreless roll lies in a range of 80 to 160 kg/m^3.

The caliper ratio may be adjusted by adjusting the embossing pressure during the manufacturing process.

The coreless rolls manufactured by the method may have the same benefits as the coreless rolls with two plies described above. In other words, features of the coreless rolls of any of the embodiments described above translate into corresponding features of an embodiment of the method, and vice versa. For the sake of conciseness, benefits which may be associated with particular features of an embodiment of the product will not be discussed for the corresponding method claims, but reference is instead made on a general basis now to the respective passage of the description relating to embodiments of the product.

The caliper of the manufacture tissue paper may be at least 0.35 mm, or at least 0.40 mm, or at least 0.45 mm.

The two plies which are processed by the method will in the following be referred to as a first ply and a second ply.

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

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

Another aspect of this disclosure relates to a method of manufacturing a coreless roll of a tissue paper product, such as toilet paper, the tissue paper product being made of three plies. The method comprises the steps of:

- providing three plies of Conventional Wet Press paper (CWP) and embossing at least one of the three plies;
- ply-bonding the three plies, optionally with an adhesive, such as a lamination glue, or with mechanical bonding, such as edge embossing, to form a tissue paper product with a grammage in a range of 34 g/m^2 to 65 g/m^2, optionally 40 g/m^2 to 63 g/m^2, or 45 g/m^2 to 60 g/m^2 and a caliper ratio in a range of 20% to 60%;
- spirally winding up the tissue paper product on a mandrel to form a coreless roll and to define an axially extending inner hole facing the mandrel, with a first end of the tissue paper product being located on the outer side of the coreless roll and the second end being located at the inner hole; and
- withdrawing the mandrel;

wherein the coreless roll comprises an outer diameter in the range of 95 to 150 mm and a diameter of the inner hole is in the range of 20 to 50 mm, and the density of the coreless roll lies in a range of 110 to 170 kg/m^3.

The caliper ratio may be adjusted by adjusting the embossing pressure during the manufacturing process.

The tissue paper products manufactured by the method may have analogous benefits as the tissue paper products with three plies described above. In other words, features of the tissue paper products of any of the embodiments described above translate into corresponding features of an embodiment of the method, and vice versa. For the sake of conciseness, benefits which may be associated with particular features of an embodiment of the product will not be discussed for the corresponding method claims, but reference is instead made on a general basis now to the respective passage of the

description relating to embodiments of the product.

The caliper of the manufactured tissue paper may be at least 0.40 mm, or at least 0.45 mm, or at least 0.50 mm.

The three plies which are processed by the method will in the following be referred to as a first ply, a second ply, and a third ply.

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

- embossing the first ply with a first embossing roll with first embossing protrusions to form first embossments with a first height (h1) in a range of 0.2 mm to 2.0 mm; and
- embossing the second ply with a second embossing roll with second embossing protrusions to form second embossments with a second height (h2) in a range of 0.2 mm to 2.0 mm;
- wherein the first, second, and third plies are ply-bonded such that the third ply is located between the first ply and the second ply.

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 third 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 ply may, according to some embodiments, not be embossed. In other words, the third ply may be a flat ply in the sense of not being (pre-)embossed by an embossing roll prior to the ply-bonding taking place. It need not be flat after the ply-bonding in the sense that the ply-bonding may remove flatness of the third ply.

The first ply and the third ply may be embossed together using the first embossing roll to form the first embossments on 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 embossments on the first ply may be formed by a first heated embossing roll.

The second embossments on the second ply may be formed by a second heated embossing roll.

The third embossments may be formed by the first heated embossing roll or a third heated embossing roll.

The method may comprise a step of forming fourth embossments with a fourth height (h4) on the third ply with a fourth embossing roll, the fourth height (h4) being in a range of 0.2 mm to 2.0 mm, wherein the third ply is embossed separately from the first ply and the second ply.

The fourth embossments may be formed by a fourth heated embossing roll.

Another aspect of this disclosure relates to a method of manufacturing a coreless roll of a tissue paper product, such as toilet paper, the tissue paper product being made of four plies. The method comprises the steps of:

- providing four plies of Conventional Wet Press paper (CWP) and embossing at least one of the four plies;
- ply-bonding the four plies, optionally with an adhesive, such as a lamination glue, or with mechanical bonding, such as edge embossing, to form a tissue paper product with a grammage in a range of 55 g/m^2 to 95 g/m^2, or optionally 60 g/m^2 to 80 g/m^2, and a caliper ratio in a range of 12% to 40%;
- spirally winding up the tissue paper product on a mandrel to form a coreless roll and to define an axially extending inner hole facing the mandrel, with a first end of the tissue paper product being located on the outer side of the coreless roll and the second end being located at the inner hole; and
- withdrawing the mandrel;

wherein the coreless roll comprises an outer diameter in the range of 95 to 150 mm and a diameter of the inner hole is in the range of 20 to 50 mm, and the density of the coreless roll lies in a range of 120 to 160 kg/m^3.

The caliper ratio may be adjusted by adjusting the embossing pressure during the manufacturing process.

The tissue paper products manufactured by the method may have the same benefits as the tissue paper products with four plies described above. In other words, features of the tissue paper products of any of the embodiments described above translate into corresponding features of an embodiment of the method, and vice versa. For the sake of conciseness, benefits which may be associated with particular features of an embodiment of the product will not be discussed for the

corresponding method claims, but reference is instead made on a general basis now to the respective passage of the description relating to embodiments of the product.

The caliper of the manufacture tissue paper may be at least at least 0.55 mm, or at least 0.60 mm, or at least 0.65 mm

The four plies which are processed by the method will in the following be referred to as a first ply, a second ply, a third ply, and a fourth ply.

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

- embossing the first ply with a first embossing roll with first embossing protrusions to form first embossments with a first height (h1) in a range of 0.2 mm to 2.0 mm; and
- embossing the second ply with a second embossing roll with second embossing protrusions to form second embossments with a second height (h2) in a range of 0.2 mm to 2.0 mm;
- wherein the first ply, the second ply, the third ply, and the fourth ply are ply-bonded such that the third ply and the fourth ply are located between the first ply and the second ply.

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 third 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 method may comprise the step of embossing the first ply and third ply together using the first embossing roll to form the first embossments on 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 and the third ply may be embossed together to form the first embossments on the first ply and the third ply.

According to some embodiments, the fourth ply is not embossed. According to other embodiments, the fourth ply is embossed separately from the first ply, the third ply, and the second ply.

The third embossments may be formed only on the first ply but not on the third ply. Alternatively, the first ply and the third ply may be 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.

According to some embodiments, the third embossments are formed on the first ply and the third ply, but not on the

fourth ply.

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

The third ply and the fourth ply may be embossed together separately from the first ply and the second ply.

One of the third ply and the fourth ply may be separately embossed from the first ply and the second ply, and the method may not comprise a step of embossing the other one of the third ply and the fourth ply.

The method may not comprise a step of embossing the third ply and may not comprise a step of embossing the fourth ply.

According to some embodiments, the first ply and the third ply are embossed together to form the first embossments on the first ply and the third ply, wherein the fourth ply and the second ply are embossed together to form the second embossments on the fourth ply and the second ply.

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

The first embossments on the first ply may be formed by a first heated embossing roll.

The second embossments on the second ply may be formed by a second heated embossing roll.

The third embossments may be formed by the first heated embossing roll or a third heated embossing roll.

Any embodiment of the method in accordance with the present disclosure may comprise a step of coating at least a part of an innermost circumvolution, optionally the entire innermost circumvolution, of the tissue paper product of the coreless roll at the second end with a stabilizing coating composition. The coating step may be carried out prior to the step of winding up the tissue paper product on a mandrel.

Another aspect of this disclosure relates to a method of manufacturing a coreless roll of a tissue paper product, such as toilet paper, the tissue paper product being made of five or six plies. The method comprises the steps of:

- providing five or six plies of Conventional Wet Press paper (CWP) and embossing at least one of the five or six plies;
- ply-bonding the five or six plies, optionally with an adhesive, such as a lamination glue, or with mechanical bonding, such as edge embossing, to form a tissue paper product with a grammage in a range of 65 g/m^2 to 125 g/m^2, optionally a range of 65 g/m^2 to 100 g/m^2, and a caliper ratio in a range of 10% to 25%;
- spirally winding up the tissue paper product on a mandrel to form a coreless roll and to define an axially extending inner hole facing the mandrel, with a first end of the tissue paper product being located on the outer side of the coreless roll and the second end being located at the inner hole; and
- withdrawing the mandrel;

wherein the coreless roll comprises an outer diameter in the range of 95 to 150 mm and a diameter of the inner hole is in the range of 20 to 50 mm, and the density of the coreless roll lies in a range of 130 to 160 kg/m^3.

The caliper ratio may be adjusted by adjusting the embossing

pressure during the manufacturing process.

The tissue paper products manufactured by the method may have the same benefits as the tissue paper products with five or six plies described above. In other words, features of the tissue paper products of any of the embodiments described above translate into corresponding features of an embodiment of the method, and vice versa. For the sake of conciseness, benefits which may be associated with particular features of an embodiment of the product will not be discussed for the corresponding method claims, but reference is instead made on a general basis now to the respective passage of the description relating to embodiments of the product.

The caliper of the manufacture tissue paper may be at least 0.65 mm, or at least 0.70 mm, or at least 0.75 mm.

In accordance with any one of the above-described embodiments (or any combination thereof, in so far not incompatible) of the method, irrespective of the total number of plies of the tissue paper product of the coreless roll manufactured, at least a part of the first ply or the second ply, or, more generally, the tissue paper product which is to be an innermost circumvolution of the coreless roll, or even the entire innermost circumvolution, of the tissue paper product of the coreless roll at the second end is provided with a stabilizing coating composition. This may aid in promoting good radial and/or axial stability of the coreless roll.

The coating composition may comprise at least one of the following list: a polymer including oxygen and/or nitrogen atoms, a non-ionic polymer such as a non-ionic cellulose ether, polyether polyol. The coating composition may comprise water. When the coating composition comprises a nonionic polymer, the ionic demand may be in a range of from -1000 to +100 µeq/g, or -500 to +50 µeq/g, or -50 to 0 µeq/g.

The coating composition may be applied to only one side of the innermost turn. This one side may be side oriented towards the axially extending inner hole.

In accordance with any one of the above-described embodiments (or any combination thereof, in so far not incompatible) of the method, an embossing load of 1 to 50 kg/cml, or optionally of 5 to 40 kg/cml may be used for heat-embossing a ply.

In accordance with any one of the above-described embodiments (or any combination thereof, in so far not incompatible) of the method, a ply may be micro-embossed (and, in particular, micro-heat-embossed with embossments heights in a range of 0.2 mm to 2.0 mm.

In accordance with any one of the above-described embodiments (or any combination thereof, in so far not incompatible) of the method, the first ply may be moistened, prior to being embossed, with a liquid, such as water optionally provided with 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. Analogous statements hold with respect to the second ply.

According to other embodiments, the first ply has not been moistened with a liquid prior to having been embossed. An analogous statement holds with respect to the second ply.

This disclosure also relates to coreless rolls of a tissue paper product manufactured according to any one (or any combination of, in so far not incompatible) embodiments 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:

Fig. 1 is a perspective view of a coreless roll in accordance with the present disclosure;

Fig. 2 is a schematic representation of (a part of) and embodiment of a manufacturing apparatus for manufacturing a coreless roll in accordance with the present disclosure with a first embodiment of a method in accordance with the present disclosure;

Fig. 3 is a schematic representation of (a part of) and embodiment of a manufacturing apparatus for manufacturing a coreless roll in accordance with the present disclosure with a second embodiment of a method in accordance with the present disclosure;

Fig. 4 is a schematic representation of (a part of) and embodiment of a manufacturing apparatus for manufacturing a coreless roll in accordance with the present disclosure with a third embodiment of

a method in accordance with the present disclosure; and

Figs. 5-25 depict embodiments of tissue paper products which are constituents of coreless rolls in accordance with the present disclosure.

Fig. 1 is a schematic representation of a coreless roll 1 in accordance with the present disclosure.

The coreless roll 1 of Fig. 1 represents different embodiments with a different tissue paper products with two, three, four, five, or six plies. All of the plies of these embodiments are made of Conventional Wet Press (CWP) paper).

The embodiments of Fig. 1 are toilet paper rolls comprising a tissue paper product that comprises different sheets 2a, 2b which can be easily separated along a perforation line 3. However, other embodiments may not comprise such perforation lines.

The coreless roll 1 of Fig. 1 is made of a spirally wound continuous web of tissue paper product having a first end and a second end, the web of tissue paper product being wound such as to define an axially extending inner hole centrally positioned relative to the coreless roll 1 and such that the first end is located on the outer side of the coreless roll 1 and the second end is located at the inner hole.

The outer diameter D1 of the coreless roll 1 is in a range of 95 to 150 mm. The diameter D2 of the inner hole of the roll 1 is in a range of 20 to 50 mm. The density of the coreless roll 1 is in a range of 80 to 160 kg/m^3 (narrower ranges for the respective numbers of plies of the tissue paper products are indicated above).

The tissue paper product of the embodiments of Fig. 1 is ply-bonded using an adhesive (a lamination glue). However, this is by no means limiting. In the case of other embodiments, the plies may, e.g., be ply-bonded using mechanical bonding, such as edge embossing. In other words, there is no need to use an adhesive, and other embodiments may be "glueless".

The grammage of the tissue paper products depends on the numbers of plies. It is in a range of 24 to 125 g/m^2 (narrower ranges for the respective numbers of plies are indicated above).

A a caliper ratio of the roll is in a range of 10% to 80% (narrower ranges for the respective numbers of plies are indicated above), wherein the caliper ratio $(c_S-c_t)/c_t$ is obtained by dividing a difference between a standard caliper c_S of the tissue paper product as defined by the standard ISO-12625-3 and a theoretical caliper c_t of the tissue paper product by the theoretical caliper c_t, and the theoretical caliper c_t being defined as a ratio between a grammage of the tissue paper product and the density of the roll. The caliper ratio can be varied conveniently by varying the embossing pressure during manufacturing of the respective tissue paper product.

The radial compression strength of the coreless rolls 1 of Fig. 1 is at least 30 N or more. However, according to other embodiments, it is at least 20 N or more or at least 25 N or more. This provides robustness to a toilet paper roll (e.g., to achieve customer satisfaction, but also for packing purposes, etc.) and is achieved despite the fact the roll 1 is coreless. As the roll is coreless, waste is reduced, and the roll in question may be considered as environment-friendly.

The (sheet) caliper of the roll 1 is at least 0.35mm.

Fig. 2 is a schematic representation of (a part of) and embodiment of a manufacturing apparatus for manufacturing a coreless roll in accordance with the present disclosure using a first embodiment of a method in accordance with the present disclosure.

The box 200 in Fig. 2 schematically represents any constituents of the manufacturing apparatus that are used prior to the later stages illustrated in Fig. 2 in more detail. For example, the box 200 may involve unwinding rolls for unwinding a first ply 15 and a second ply 25.

According to an embodiment of the method in accordance with the present disclosure relying on the manufacturing apparatus of Fig. 2, the first ply 15 is supplied at a processing speed D1, and the second ply 25 is supplied at a processing speed D2.

The apparatus of Fig 2. comprises a pre-embossing station 300 with rolls 301, 302, 303, and 304. In fact, the pre-embossing station 300 allows for heat-embossing, as one of the rolls 301 and 302 is a heatable embossing roll and one of the rolls 303 and 304 is a heatable embossing roll.

The first ply 15 may be pre-embossed between the rolls 303 and 304, one of which being an embossing roll, the other being a counter roll. The embossing roll is a heatable embossing roll and may be used to heat-emboss the first ply 15.

The second ply 25 may be pre-embossed between the rolls 301 and 302, one of being an embossing roll, the other being a counter roll. The embossing roll is a heatable embossing roll and may be used to heat-emboss the second ply 25.

The first ply 15 is then conveyed towards the rolls 35 and 40 and may be embossed once more. In particular, the roll 40 may be a non-heatable embossing roll (but according to other embodiment, it may be a heatable roll). An adhesive supplying unit with a glue chamber 80 is provided adjacent to the roll 40. An applicator roll 105 is used to homogeneously transfer adhesive (dosed by cavities engraved in an anilox roll positioned between the glue chamber 80 and the applicator roll 105) to the first ply 15 prior to ply-bonding being carried out.

The second ply 25 is conveyed towards the rolls 50 and 60 and may be embossed once more. In particular, the roll 60 may be a non-heatable embossing roll. However, according to other embodiments, it may be a heatable embossing roll.

Ply-bonding of the first ply 15 and the second ply 25 is carried out between the embossing roll 40 and a marrying roll 70. The ply-bonded tissue paper product 110 comprising (at least two plies) is then conveyed further at a processing speed D3.

The box 400 represents any components of the manufacturing apparatus of Fig. 2 used subsequently to the steps described so far. In particular, the box 400 may comprise a winding unit for winding up the manufactured tissue paper product 110.

Fig. 3 is a schematic representation of (a part of) and embodiment of a manufacturing apparatus for manufacturing a coreless roll in accordance with the present disclosure using a second embodiment of a method in accordance with the present disclosure.

The box 200 in Fig. 3 schematically represents any constituents of the manufacturing apparatus that are used

prior to the later stages illustrated in more detail. For example, the box 200 may involve unwinding rolls for unwinding a first ply 10 and a second ply 20.

According to an embodiment of the method in accordance with the present disclosure relying on the apparatus of Fig. 3, the first ply 10 is supplied at a processing speed D1, and the second ply 20 is supplied at a processing speed D2.

The apparatus of Fig 3 does not comprise a pre-embossing station.

The first ply 10 is conveyed towards the rolls 35 and 40 and can be heat-embossed. The roll 35 is a counter roll, whereas the roll 40 is a heatable embossing roll. An adhesive supplying unit with a glue chamber 80 is provided adjacent to the roll 40. An applicator roll 105 is used to homogeneously transfer adhesive (dosed by cavities engraved in an anilox roll positioned between the glue chamber 80 and the applicator roll 105) to the first ply 10 prior to ply-bonding being effected.

The second ply 20 is conveyed towards the rolls 50 and 60 and can be heat-embossed between the counter roll 50 and the heatable embossing roll 60.

Ply-bonding of the first ply 15 and the second ply 25 is carried out between the embossing roll 40 and a marrying roll 70. The ply-bonded tissue paper product 110 is then conveyed further at a processing speed D3.

The box 400 represents any components of the manufacturing apparatus of Fig. 3 used later on. In particular, the box 400 may comprise a winding unit for winding up the produced tissue paper product 110.

A main difference between the methods carried using the

apparatus of Fig. 2 and the one of Fig. 3 is that the heat-embossing of plies is carried out in the pre-embosser in the case of Fig. 2, whereas the heat-embossing is carried out in the ply-bonding unit (i.e., the main embosser) in the case of Fig. 3. However, according to a modification a mixed-type of heat-embossing may be carried out in the sense of one ply being heat-embossed in the pre-embosser and the other ply may be heat-embossed in the main embosser.

Fig. 4 depicts an apparatus used for carrying out a method in accordance with the present disclosure for manufacturing a coreless roll including a tissue paper product comprising (at least) three plies.

Most of what is shown is analogous to what was explained above with respect to Fig. 2. Reference is thus made to the corresponding explanations. A difference is that a third ply 120 (represented by a dotted line in Fig. 4) is supplied to the main embosser. It is received and conveyed by another roll 130 and is then led to the embossing roll 40, where it is conveyed further together with the first ply 15. The first ply 15 and the third ply 120 are then ply-bonded together with the second ply 25 between the embossing roll 40 and the marrying roll 70.

In each of the cases of Figs. 2 to 4, embossing rolls may either be heatable or non-heatable embossing rolls. Each of the embodiments may comprise zero heatable embossing rolls (and exclusively comprise non-heatable embossing rolls instead), one heatable embossing roll in total (which may be located in the pre-embosser, if applicable, or in the main embosser), two heatable embossing rolls (which may both be located in the pre-embosser, if present, both be located in the main embosser, or distributed onto the main embosser and the pre-embosser, if present), or three or more heatable embossing rolls (distributed in any chosen way onto the pre-embosser, if present, and the main embosser).

Figs. 5 to 25 depict a number of embodiments of tissue paper products which are spirally wound up to form coreless rolls in accordance with the present disclosure.

The tissue paper product of Fig. 5 comprises a first ply 1 that has been embossed without heat-embossing (i.e., with a non-heatable embossing roll or with non-heatable embossing rolls). It comprises two types of embossments, i.e., embossments with different heights. These may have been created using the same embossing roll or different embossing rolls.

The tissue paper product of Fig. 5 further comprises a second ply 2′ that has been heat-embossed (i.e., embossed using a heated embossing cylinder). To distinguish between a ply that was heat-embossed and one that was embossed without heat, the heat-embossed ply 2′ is drawn with a thicker line in Fig. 5 than the ply 1. This distinction between thicker and thinner lines will be maintained throughout the figures. The thicker lines represent plies that were heat-embossed, whereas the thinner lines represent plies that were embossed without heating.

Region 4 of Fig. 5 illustrates is a region where the first ply 1 and the second ply 2′ are ply-bonded to each other using an adhesive. The adhesive is present in tips of the embossments of the first ply 1 with a larger height (amongst two types of embossments of the double-embossed ply 1).

The embodiment of a tissue paper product of Fig. 6 is similar to the embodiment of Fig. 5. The difference is that the first ply 1′ was heat-embossed, whereas the second ply 2 has been embossed with a non-heated embossing roll. Again, the ply-bonding has been effected at regions including tips of the higher (deeper) embossments of the double-embossed first ply 1.

Fig. 7 shows an embodiment of a tissue paper with a heat-embossed first ply 1′ as well as a heat-embossed second ply 2′.

The grammage of the tissue paper products of Figs. 5, 6, and 7 is in a range of 24 g/m^2 to 50 g/m^2.

Figs. 8, 9, and 10 depict embodiments of tissue paper products comprising three plies. At least one of the outermost plies 1, 1′, 2, 2′ has been heat-embossed, whereas the middle ply 3 of each of the embodiments was not embossed (and was more or less flat prior to the ply-bonding).

All three plies of each of the embodiments of Figs. 8, 9, and 10 are made of Conventional Wet Press (CWP) paper.

In the case of Fig. 8, the first ply 1 was embossed with a non-heated roll, whereas the second ply 2′ was heat-embossed, i.e., embossed using a heated embossing roll. The middle ply 3 is, as already mentioned, a so-called flat ply in the sense of being a non-pre-embossed ply. The corrugation in the region 6 (where the tips of the larger embossments on the first ply 1 are situated) is a result from the ply-bonding.

In the case of Fig. 9, the first ply 1′ was heat-embossed with a heated embossing roll, whereas the second ply 2 was embossed with a non-heated embossing roll. The middle ply 3 is, as already mentioned, a so-called flat ply in the sense of being a non-pre-embossed ply. The corrugation in the region 6 (where the tips of the larger embossments on the first ply 1 are situated) is a result from the ply-bonding.

Fig. 10 depicts an embodiment with a heat-embossed first ply 1′ as well as a heat-embossed second ply 2′. The middle ply 3 is, as already mentioned, a so-called flat ply in the sense of being a non-pre-embossed ply. The corrugation in the

region 6 (where the tips of the larger embossments on the first ply 1 are situated) is a result from the ply-bonding.

Fig. 11, 12, and 13 depict further embodiments with three plies. In these cases, the first ply 10, 10′ and the middle ply 11, 11′ have been embossed together.

All three plies of each of the embodiments of Figs. 11, 12, and 13 are made of Conventional Wet Press (CWP) paper.

In the case of Fig. 11, the first ply 10 and the middle ply 11 were double-embossed together with a non-heated roll, whereas the second ply 2′ was heat-embossed, i.e., embossed using a heated embossing roll. The three plies are ply-bonded at tips of the embossments with larger height of the two types of embossments on the first ply 10 and the middle ply 11. Region 6 illustrates a region where the three plies 10, 11, and 2′ are ply-bonded.

In the case of Fig. 12, the first ply 10′ and the middle pl 11′ were double embossed together using heat-embossing, i.e., with a heated embossing roll, whereas the second ply 2 was embossed with a non-heated embossing roll. The three plies are ply-bonded at tips of the embossments with larger height of the two types of embossments on the first ply 10′ and the middle ply 11′. Region 6 illustrates a region where the three plies 10′, 11′, and 2 are ply-bonded.

Fig. 13 depicts an embodiment, wherein the first ply 10′ and the middle ply 11′ have been double-embossed with a heated embossing roll (i.e., heat-embossed) together and wherein also the second ply 2′ was heat-embossed. The three plies are ply-bonded at tips of the embossments with larger height of the two types of embossments on the first ply 10′ and the middle ply 11′. Region 6 illustrates a region where the three plies 10′, 11′, and 2′ are ply-bonded.

The grammage of the tissue paper products of Figs. 8 to 13 is in a range of 34 g/m^2 to 65 g/m^2, and, more specifically, it may even be in a range of 40 g/m^2 to 63 g/m^2 or of 45 g/m^2 to 60 g/m^2.

Figs. 14, 15, and 16 depict embodiments of a tissue paper product with four plies.

All four plies of each of the embodiments of Figs. 14, 15, and 16 are made of Conventional Wet Press (CWP) paper.

In the case of Fig. 14, the first ply 10 and the third ply 11 were double-embossed (with two types of embossments) together with a non-heated embossing roll. The fourth ply 3 is a flat middle ply in the sense of not having been pre-embossed prior to the final ply-bonding. Finally, the second ply 2' of the embodiment of Fig. 14 has been embossed by a heated embossing roll (i.e., heat-embossed).

The embodiment of Fig. 15 differs from the one of Fig. 14 in that the first ply 10' and the adjacent third ply 11' have been double-embossed together with a heated embossing roll, whereas the second ply 2 was embossed with a non-heated embossing roll.

In the case of Fig. 16, the first ply 10' and the adjacent third ply 11' have been double-embossed together with a heated embossing roll, and also the second ply 2 was embossed with a heated embossing roll (i.e., heat-embossed).

Figs. 17, 18, and 19 show further embodiments of tissue paper products with four plies. The difference with respect to the ones of Figs. 17, 18, and 19, is that the two middle plies 30 and 31 were in each case not embossed (i.e., they are flat plies in the sense of not having been pre-embossed prior to the final ply-bonding).

All four plies of each of the embodiments of Figs. 17, 18, and 19 are made of Conventional Wet Press (CWP) paper.

The embodiment of Fig. 17 has a first ply 1 that was double-embossed using a non-heated embossing roll and a second ply 2′ that was heat-embossed with a heated embossing roll.

The embodiment of Fig. 18 has a first ply 1′ that was double-embossed using a heated embossing roll (heat-embossed) and a second ply 2 that was embossed with a non-heated embossing roll.

Moreover, the embodiment of Fig. 19 comprises both a first ply 1′ that was double-embossed using a heated embossing roll (heat-embossed) as well as a second ply 2′ that was heat-embossed with a heated embossing roll.

The embodiments of Figs. 20, 21, and 22 comprise a first ply 1, 1′, a flat middle ply 3, and a second ply 20, 20′ that was embossed together with another ply 21, 21,′.

All four plies of each of the embodiments of Figs. 20, 21, and 22 are made of Conventional Wet Press (CWP) paper.

The first ply 1 of the embodiment of Fig. 20 was embossed using a non-heated embossing roll. The second ply 20′ and the adjacent ply 21′ were embossed together using a heated embossing roll (i.e., heat-embossed).

The first ply 1′ of the embodiment of Fig. 21 was embossed using a heated embossing roll (i.e., heat-embossed). The second ply 20 and the adjacent ply 21 were embossed together using a non-heated embossing roll.

In the case of the embodiment of the tissue paper product of Fig. 22, the first ply 1′ was embossed using a heated embossing roll (i.e., heat-embossed), and also the second ply

20’ and the adjacent ply 21’ were embossed together using a heated embossing roll (i.e., heat-embossed)

Moreover, the embodiments of the tissue paper products of Figs. 23, 24, and 25 also comprise four plies. However, in these cases, the first three plies were double-embossed together.

All four plies of each of the embodiments of Figs. 23, 24, and 25 are made of Conventional Wet Press (CWP) paper.

The first ply 10 and the two adjacent plies 11 and 12 of the embodiment of Fig. 23 were double-embossed together using a non-heated embossing roll. The second ply 2’ was embossed using a heated embossing roll (i.e., heat-embossed).

The first ply 10’ and the two adjacent plies 11’ and 12’ of the embodiment of Fig. 24 were double-embossed together using a heated embossing roll (heat-embossed). The second ply 2 was embossed using a non-heated embossing roll.

In the case of the embodiment of Fig. 25, the first ply 10’ and the two adjacent plies 11’ and 12’ were double-embossed together using a heated embossing roll (heat-embossed), and also the second ply 2’ was embossed using a heated embossing roll (i.e., heat-embossed).

The grammage of the tissue paper products of Figs. 14 to 25 is in a range of 55 g/m^2 to 95 g/m^2, and, more specifically, it may even be in a range of 60 g/m^2 to 80 g/m^2.

In the following, a number of experimental results obtained on the basis of coreless rolls according to an embodiment of the present disclosure will be discussed.

EXAMPLES OF CORELESS ROLLS MADE OF TWO-PLY TISSUE PRODUCT

Coreless rolls of a tissue paper product with two plies made of CWP were manufactured with an outer diameter of 128mm. The two plies were both embossed using a non-heated embossing roll.

The following table 1 summarizes the number of sheets, the roll length, the roll density, the theoretical caliper, the grammage (the units gsm stands for g/m^2), the (sheet) caliper the radial compression strength (in Newton), and the caliper ratio of the manufactured coreless rolls. Respective comparative examples are compared to two examples in accordance with the present disclosure.

Example	#sheets	Roll length (m)	Roll density (kg/m3)	Th. Caliper (mm)	Grammage (gsm)	1-sheet caliper (mm)	Radial compression (N)	Caliper ratio
Comp. 1	225	28.13	**97**	**0.38**	37.2	**0.42**	**2.5**	**11%**
1	225	28.13	**86**	**0.43**	36.8	**0.56**	**27**	**31%**
Comp. 2	350	43.75	**132**	**0.28**	36.9	**0.35**	**18.6**	**27%**
2	350	43.75	**133**	**0.28**	36.7	**0.42**	**41.2**	**53%**

table 1

As can be seen from table 1, examples 1 and 2 have radial compression strengths above 25 N (27N and 41.2N, respectively). The comparative examples (which have a caliper ratio lower than 30%, namely of 11% and 27%, respectively) have a lower radial compression strength of2.5N or 18.6N.

Another set of examples of coreless rolls with tissue paper products manufactured using heated-embossing on the bottom ply was examined as well. The roll diameter was in each case 128 mm. The results are summarized in table 2.

Example	#sheets	Roll length (m)	Roll density (kg/m3)	Th. Caliper (mm)	Grammage (gsm)	1-sheet caliper (mm)	Radial compression (N)	Caliper ratio
3	285	35.625	**109**	**0.34**	35.38	**0.46**	**42.6**	**36%**
4	350	43.75	**134**	**0.27**	34.42	**0.4**	**53.7**	**45%**

table 2

EXAMPLES OF CORELESS ROLLS MADE OF THREE-PLY TISSUE PRODUCT

Coreless rolls of a tissue paper product with three plies made of CWP were manufactured with an outer diameter of 128mm. In each case, the bottom ply was heat-embossed (i.e., embossed using a heated embossing roll). The roll diameter was in each case 128 mm.

The following table 3 summarizes the number of sheets, the roll length, the roll density, the theoretical caliper, the grammage (the units gsm stands for g/m^2), the (sheet) caliper the radial compression strength (in Newton), and the caliper ratio. Table 3 shows two examples accordance with the present disclosure.

Example	#sheets	Roll length (m)	Roll density (kg/m3)	Th. Caliper (mm)	Grammage (gsm)	1-sheet caliper (mm)	Radial compression (N)	Caliper ratio
5	230	28.75	**114**	**0.42**	46.4	**0.52**	**21.1**	**24%**
6	230	28.75	**113**	**0.42**	46.6	**0.55**	**28.5**	**31%**

table 3

EXAMPLES OF CORELESS ROLLS MADE OF FOUR-PLY TISSUE PRODUCT

Coreless rolls of a tissue paper product with four plies made of CWP were manufactured with an outer diameter of 128mm. In each case, the bottom ply was heat-embossed (i.e., embossed using a heated embossing roll). The roll diameter was in each case 128 mm.

The following table 4 summarizes the number of sheets, the roll length, the roll density, the theoretical caliper, the grammage (the units gsm stands for g/m^2), the (sheet) caliper the radial compression strength (in Newton), and the caliper ratio. Two examples in accordance with the present disclosure are shown.

Example	#sheets	Roll length (m)	Roll density (kg/m3)	Th. Caliper (mm)	Grammage (gsm)	1-sheet caliper (mm)	Radial compression (N)	Caliper ratio
7	210	26.25	**135**	**0.49**	63.7	**0.58**	**41.1**	**18%**
8	225	28.125	**145**	**0.46**	63.6	**0.56**	**47.5**	**22%**

table 4

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.

Claims

1. A coreless roll of a tissue paper product, such as toilet paper, made of a spirally wound continuous web of tissue paper product having a first end and a second end, the web of tissue paper product being wound such as to define an axially extending inner hole centrally positioned relative to the coreless roll and such that the first end is located on the outer side of the coreless roll and the second end is located at the inner hole,
wherein the tissue paper product comprises two plies of Conventional Wet Press paper (CWP), a total number of plies of the tissue paper product is two, at least one of the plies is an embossed ply, and
wherein the two plies are ply-bonded, optionally with an adhesive, such as lamination glue, and/or with mechanical bonding, such as edge embossing,
wherein the grammage of the tissue paper product is in a range of 24 g/m^2 to 50 g/m^2, optionally 30 g/m^2 to 45 g/m^2,
wherein the coreless roll has an outer diameter in the range of 95 to 150 mm, a diameter of the inner hole is in the range of 20 to 50 mm, and a density of the coreless roll is in a range of 80 to 160 kg/m^3,
wherein a caliper ratio of the roll is in a range of 30% to 80%,
the caliper ratio $(c_S-c_t)/c_t$ being obtained by dividing a difference between a standard caliper c_S of the tissue paper product as defined by the standard ISO-12625-3 and a theoretical caliper c_t of the tissue paper product by the theoretical caliper c_t, and
the theoretical caliper c_t being defined as a ratio between a grammage of the tissue paper product and the density of the roll,
the two plies being a first ply and a second ply,
wherein the first ply comprises first embossments with a first height (h1), the first height (h1) being in a range

of 0.2 mm to 2.0 mm,
wherein the first embossments have been formed by a first heated embossing roll.

2. The coreless roll of a tissue paper product of claim 1, wherein the caliper of the tissue paper product is at least 0.35 mm, optionally at least 0.40 mm, or at least 0.45 mm.

3. The coreless roll of a tissue paper product of claim 1 or 2,
wherein the adhesive, such as lamination glue, is optionally applied to tips of the first embossments of the first ply,
wherein the second ply comprises second embossments with a second height (h2), the second height (h2) being in a range of 0.2 mm to 2.0 mm, and
wherein the first ply optionally comprises third embossments with a third height (h3) smaller than the first height (h1) (h1>h3).

4. The coreless roll of a tissue paper product of claim 3,
wherein the third embossments have been formed by the first heated embossing roll,
and/or wherein the second embossments have been formed by a second heated embossing roll,
and/or wherein the third embossments have been formed by a third heated embossing roll,
and/or wherein, optionally, the first ply has been moistened, prior to having been embossed, with an amount of liquid, such as water, 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, wherein the liquid optionally is provided with one or several additives, or wherein the first ply has not been moistened with a liquid prior to having been embossed.

5. A coreless roll of a tissue paper product, such as toilet paper, made of a spirally wound continuous web of tissue paper product having a first end and a second end, the web of tissue paper product being wound such as to define an axially extending inner hole centrally positioned relative to the coreless roll and such that the first end is located on the outer side of the coreless roll and the second end is located at the inner hole,

wherein the tissue paper product comprises three plies of Conventional Wet Press paper (CWP), a total number of plies of the tissue paper product is three, at least one of the plies is an embossed ply, and

wherein the three plies are ply-bonded, optionally with an adhesive, such as lamination glue, and/or with mechanical bonding, such as edge embossing,

wherein the grammage of the tissue paper product is in a range of 34 g/m^2 to 65 g/m^2, optionally 40 g/m^2 to 63 g/m^2, or 45 g/m^2 to 60 g/m^2,

wherein the coreless roll has an outer diameter in the range of 95 to 150 mm, a diameter of the inner hole is in the range of 20 to 50 mm, and a density of the coreless roll is in a range of 110 to 170 kg/m^3,

wherein a caliper ratio of the roll is in a range of 20% to 60%,

the caliper ratio $(c_S-c_t)/c_t$ being obtained by dividing a difference between a standard caliper c_S of the tissue paper product as defined by the standard ISO-12625-3 and a theoretical caliper c_t of the tissue paper product by the theoretical caliper c_t, and

the theoretical caliper c_t being defined as a ratio between a grammage of the tissue paper product and the density of the roll,

the three plies being a first ply, a second ply, and a third ply, wherein the third ply is positioned between the first ply and the second ply,

wherein the first ply comprises first embossments with a first height (h1), the first height (h1) being in a range

of 0.2 mm to 2.0 mm,
wherein the first embossments have been formed by a first heated embossing roll.

6. The coreless roll of a tissue paper product of claim 5, wherein the caliper of the tissue paper product is at least 0.40 mm, optionally at least 0.45 mm, or at least 0.50 mm.

7. The coreless roll of a tissue paper product of claim 5 or 6,
wherein the adhesive, such as lamination glue, is optionally applied to tips of the first embossments of the first ply,
wherein the second ply comprises second embossments with a second height (h2), the second height (h2) being in a range of 0.2 mm to 2.0 mm, and
wherein the first ply optionally comprises third embossments with a third height (h3) smaller than the first height (h1) (h1>h3).

8. The coreless roll of a tissue paper product of claim 7, wherein the third ply is unembossed.

9. The coreless roll of a tissue paper product of claim 7 or 8, wherein the first ply and the third ply have been embossed together to form the first embossments on the first ply and the third ply, and
wherein, optionally, the third embossments have been formed only on the first ply but not on the third ply, or,
wherein, optionally, the first ply and the third ply have been embossed together to form the third embossments on the first ply and the third ply.

10. The coreless roll of a tissue paper product of claim 7,
wherein the third ply comprises fourth embossments with a fourth height (h4), the fourth height (h4) being in a

range of 0.2 mm to 2.0 mm, and wherein the third ply has been embossed separately from the first ply and the second ply,
wherein, optionally, the fourth embossments have been formed by a fourth heated embossing roll.

11. The coreless roll of a tissue paper product of any one of the claims 7 to 10,
wherein the second embossments have been formed by a second heated embossing roll, and/or,
wherein the third embossments have been formed by the first heated embossing roll or a third heated embossing roll, and/or
wherein, optionally, the first ply has been moistened, prior to having been embossed, with an amount of liquid, such as water, 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, wherein the liquid optionally is provided with one or several additives, or wherein the first ply has not been moistened with a liquid prior to having been embossed.

12. A coreless roll of a tissue paper product, such as toilet paper, made of a spirally wound continuous web of tissue paper product having a first end and a second end, the web of tissue paper product being wound such as to define an axially extending inner hole centrally positioned relative to the coreless roll and such that the first end is located on the outer side of the coreless roll and the second end is located at the inner hole,
wherein the tissue paper product comprises four plies of Conventional Wet Press paper (CWP), a total number of plies of the tissue paper product is four, at least one of the plies is an embossed ply, and
wherein the four plies are ply-bonded, optionally with an adhesive, such as lamination glue, and/or with mechanical bonding, such as edge embossing,

the grammage of the tissue paper product is in a range of 55 g/m^2 to 95 g/m^2, or optionally 60 g/m^2 to 80 g/m^2,
wherein the coreless roll has an outer diameter in the range of 95 to 150 mm, a diameter of the inner hole is in the range of 20 to 50 mm, and a density of the coreless roll is in a range of 120 to 160 kg/m^3,
wherein a caliper ratio of the roll is in a range of 12% to 40%,
the caliper ratio $(c_S-c_t)/c_t$ being obtained by dividing a difference between a standard caliper c_S of the tissue paper product as defined by the standard ISO-12625-3 and a theoretical caliper c_t of the tissue paper product by the theoretical caliper c_t, and
the theoretical caliper c_t being defined as a ratio between a grammage of the tissue paper product and the density of the roll,
the four plies being a first ply, a second ply, a third ply, and a fourth ply, wherein the first ply and the second ply are outermost plies of the tissue paper product,
wherein the first ply comprises first embossments with a first height (h1), the first height (h1) being in a range of 0.2 mm to 2.0 mm,
wherein the first embossments have been formed by a first heated embossing roll.

13. The coreless roll of a tissue paper product of claim 12, wherein the caliper of the tissue paper product is at least 0.55 mm, optionally at least 0.60 mm, or at least 0.65 mm.

14. The coreless roll of a tissue paper product of claim 12 or 13,
wherein the adhesive, such as lamination glue, is optionally applied to tips of the first embossments of the first ply,
wherein the second ply comprises second embossments with a

second height (h2), the second height (h2) being in a range of 0.2 mm to 2.0 mm, and
wherein the first ply optionally comprises third embossments with a third height (h3) smaller than the first height (h1) (h1>h3).

15. The coreless roll of a tissue paper product of claim 14, wherein the first ply and the third ply have been embossed together to form the first embossments on the first ply and the third ply,
wherein the fourth ply is unembossed or has been embossed separately from the first ply, the second ply, and the third ply to form fourth embossments, the fourth embossments optionally having been embossed by a fourth heated embossing roll, and
wherein the third embossments have optionally been formed only on the first ply but not on the third ply, or wherein the first ply and the third ply have been embossed together to form the third embossments on the first ply and the third ply.

16. The coreless roll of a tissue paper product of claim 14, wherein 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, and
wherein, optionally, 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, or
wherein, optionally, the third embossments have been formed on the first ply and the third ply, but not on the fourth ply, or
wherein, optionally, the third embossments have been formed on the first ply, but not on the third ply and the fourth ply.

17. The coreless roll of a tissue paper product of claim 14,

wherein the third ply and the fourth ply have been embossed together separately from the first ply and the second ply, or
wherein 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, or
wherein the third ply and the fourth ply are unembossed.

18. The coreless roll of a tissue paper product of claim 14,
wherein the first ply and the third ply have been embossed together to form the first embossments on the first ply and the third ply,
wherein the fourth ply and the second ply have been embossed together to form the second embossments on the fourth ply and the second ply, and
wherein, optionally, the first ply and the third ply have been embossed together to form the third embossments on the first ply and the third ply, or wherein the third embossments have been formed only on the first ply but not on the third ply.

19. The coreless roll of a tissue paper product of any one of the claims 14 to 18,
wherein the second embossments have been formed by a second heated embossing roll, and/or,
wherein the third embossments have been formed by the first heated embossing roll or a third heated embossing roll, and/or,
wherein, optionally, the first ply has been moistened, prior to having been embossed, with an amount of liquid, such as water, 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, wherein the liquid optionally is provided with one or several additives, or wherein the first ply has not been moistened with a liquid prior to having been embossed.

20. A coreless roll of a tissue paper product, such as toilet paper, made of a spirally wound continuous web of tissue paper product having a first end and a second end, the web of tissue paper product being wound such as to define an axially extending inner hole centrally positioned relative to the coreless roll and such that the first end is located on the outer side of the coreless roll and the second end is located at the inner hole,
wherein the tissue paper product comprises five or six plies of Conventional Wet Press paper (CWP), a total number of plies of the tissue paper product is five or six, at least one of the plies is an embossed ply, and
wherein the five or six plies are ply-bonded, optionally with an adhesive, such as lamination glue, and/or with mechanical bonding, such as edge embossing,
wherein the grammage of the tissue paper product is in a range of 65 g/m^2 to 125 g/m^2, or optionally 65 g/m^2 to 100 g/m^2,
wherein the coreless roll has an outer diameter in the range of 95 to 150 mm, a diameter of the inner hole is in the range of 20 to 50 mm, and a density of the coreless roll is in a range of 130 to 160 kg/m^3,
wherein a caliper ratio of the roll is in a range of 10% to 25%,
the caliper ratio $(c_S\text{-}c_t)/c_t$ being obtained by dividing a difference between a standard caliper c_S of the tissue paper product as defined by the standard ISO-12625-3 and a theoretical caliper c_t of the tissue paper product by the theoretical caliper c_t, and
the theoretical caliper c_t being defined as a ratio between a grammage of the tissue paper product and the density of the roll,
wherein at least one of the outermost plies of the tissue paper product comprises first embossments with a first height (h1), the first height (h1) being in a range of 0.2 mm to 2.0 mm,

wherein the first embossments have been formed by a first heated embossing roll.

21. The coreless roll of a tissue paper product of claim 20, wherein the caliper of the tissue paper product is at least 0.65 mm, optionally at least 0.70 mm or at least 0.75 mm.

22. The coreless roll of a tissue paper product of claim 20 or 21,
wherein the adhesive, such as lamination glue, is optionally applied to tips of the first embossments of the first ply,
wherein the other one of the outermost plies of the tissue paper product comprises second embossments with a second height (h2), the second height (h2) being in a range of 0.2 mm to 2.0 mm,
wherein, optionally, the second embossments have been formed by a second heated embossing roll,
wherein the first ply optionally comprises third embossments with a third height (h3) smaller than the first height (h1) (h1>h3).

23. The coreless roll of a tissue paper product of any one of the preceding claims,
wherein the coreless roll has a radial compression strength of 20 N or more, optionally of 25N or more, or of 30N or more.

24. A coreless roll of a tissue paper product, such as toilet paper, made of a spirally wound continuous web of tissue paper product having a first end and a second end, the web of tissue paper product being wound such as to define an axially extending inner hole centrally positioned relative to the coreless roll and such that the first end is located on the outer side of the coreless roll and the second end is located at the inner hole,

wherein the tissue paper product comprises at least two plies, wherein a total number of plies of the tissue paper product is between 2 and 6, all of the plies being plies of Conventional Wet Press paper (CWP), and wherein at least one of the plies is an embossed ply,

wherein the plies of the tissue paper product are ply-bonded, optionally with an adhesive, such as lamination glue, and/or with mechanical bonding, such as edge embossing,

wherein the coreless roll has an outer diameter in the range of 95 to 150 mm, a diameter of the inner hole being in the range of 20 to 50 mm, and a density of the coreless roll being in a range of 80 to 160 kg/m^3,

wherein a caliper ratio of the roll is in a range of 30%-80% if the total number of plies is 2, the caliper ratio of the roll is in a range of 20%-60% if the total number of plies is 3, the caliper ratio of the roll is in a range of 12%-30% if the total number of plies is 4, and the caliper ratio of the roll is in a range of 10%-25% if the total number of plies is 5 or 6, the caliper ratio $(c_S-c_t)/c_t$ being obtained by dividing a difference between a standard caliper c_S of the tissue paper product as defined by the standard ISO-12625-3 and a theoretical caliper c_t of the tissue paper product by the theoretical caliper c_t, the theoretical caliper c_t being defined as a ratio between a grammage of the tissue paper product and the density of the roll,

wherein the coreless roll has a radial compression strength of 20 N or more, optionally of 25N or more, or of 30N or more, and

wherein all of the plies of the tissue paper product are made of Conventional Wet Press (CWP) paper,

wherein at least one of the outermost plies of the tissue paper product comprises first embossments with a first height (h1), the first height (h1) being in a range of 0.2 mm to 2.0 mm,

wherein the first embossments have been formed by a first

heated embossing roll.

25. The coreless roll of a tissue paper product of any one of the preceding claims, wherein at least a part of an innermost circumvolution, optionally the entire innermost circumvolution, of the absorbent material of the coreless roll at the second end comprises a stabilizing coating composition.

26. A method of manufacturing a coreless roll of a tissue paper product, such as toilet paper, the tissue paper product being made of two plies, the method comprising the steps of:
- providing two plies of Conventional Wet Press paper (CWP) and embossing at least one of the two plies;
- ply-bonding the two plies, optionally with an adhesive, such as a lamination glue, and/or with mechanical bonding, such as edge embossing, to form a tissue paper product with a grammage in a range of 24 g/m^2 to 50 g/m^2, optionally 30 g/m^2 to 45 g/m^2, and a caliper ratio in a range of 30% to 80%;
- spirally winding up the tissue paper product on a mandrel to form a coreless roll and to define an axially extending inner hole facing the mandrel, with a first end of the tissue paper product being located on the outer side of the coreless roll and the second end being located at the inner hole; and
- withdrawing the mandrel;
wherein the coreless roll comprises an outer diameter in the range of 95 to 150 mm and a diameter of the inner hole is in the range of 20 to 50 mm, and the density of the coreless roll lies in a range of 80 to 160 kg/m^3,
a caliper of the formed tissue paper product optionally being at least 0.35 mm, or at least 0.40 mm, or at least 0.45 mm,
the two provided plies being a first ply and a second ply, and the method comprising the step of:

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

27. The method of manufacturing a coreless roll of a tissue paper product of claim 26, the method comprising the steps of:
- embossing the second ply with a second embossing roll with second embossing protrusions to form second embossments with a second height (h2) in a range of 0.2 mm to 2.0 mm; and
- wherein, optionally, the first embossing roll also comprises third embossing protrusions and the step of embossing the first ply forms first and third embossments on the third ply,
or, wherein the method optionally comprises a step of embossing the first ply with a third embossing roll with third embossing protrusions to form third embossments.

28. A method of manufacturing a coreless roll of a tissue paper product, such as toilet paper, the tissue paper product being made of three plies, the method comprising the steps of:
- providing three plies of Conventional Wet Press paper (CWP) and embossing at least one of the three plies;
- ply-bonding the three plies, optionally with an adhesive, such as a lamination glue, and/or with mechanical bonding, such as edge embossing, to form a tissue paper product with a grammage in a range of 34 g/m^2 to 65 g/m^2, optionally 40 g/m^2 to 63 g/m^2, or 45 g/m^2 to 60 g/m^2 and a caliper ratio in a range of 20% to 60%;
- spirally winding up the tissue paper product on a mandrel to form a coreless roll and to define an axially extending inner hole facing the mandrel, with a first end of the tissue paper product being located on the outer side of the coreless roll and the second end being located

at the inner hole; and
- withdrawing the mandrel;
wherein the coreless roll comprises an outer diameter in the range of 95 to 150 mm and a diameter of the inner hole is in the range of 20 to 50 mm, and the density of the coreless roll lies in a range of 110 to 170 kg/m^3,
a caliper of the formed tissue paper product optionally being at least 0.40 mm, optionally at least 0.45 mm, or at least 0.50 mm,
the three provided plies being a first ply, a second ply, and a third ply, and the method comprising the step of:
- embossing the first ply with a first heated embossing roll with first embossing protrusions to form first embossments with a first height (h1) in a range of 0.2 mm to 2.0 mm.

29. The method of manufacturing a coreless roll of a tissue paper product of claim 28, the method comprising the steps of:

- embossing the second ply with a second embossing roll with second embossing protrusions to form second embossments with a second height (h2) in a range of 0.2 mm to 2.0 mm;
- wherein the first, second, and third plies are ply-bonded such that the third ply is located between the first ply and the second ply; and
- wherein, optionally, the first embossing roll also comprises third embossing protrusions and the step of embossing the first ply forms first and third embossments on the third ply, or
wherein the method optionally comprises a step of embossing the first ply with a third embossing roll with third embossing protrusions to form third embossments.

30. The method of manufacturing a coreless roll of a tissue paper product of claim 29, wherein the third ply is not

embossed.

31. The method of manufacturing a coreless roll of a tissue paper product of claim 29, wherein the first ply and third ply are embossed together using the first embossing roll to form the first embossments on the first ply and the third ply,

wherein the third embossments are optionally formed only on the first ply but not on the third ply, or wherein the first ply and the third ply are embossed together to form the third embossments on the first ply and the third ply.

32. The method of manufacturing a coreless roll of a tissue paper product of claim 29, the method comprising a step of forming fourth embossments with a fourth height (h4) on the third ply with a fourth embossing roll, the fourth height (h4) being in a range of 0.2 mm to 2.0 mm, and wherein the third ply is embossed separately from the first ply and the second ply,

wherein, optionally, the fourth embossments are formed by a fourth heated embossing roll.

33. The method of manufacturing a coreless roll of a tissue paper product of any one of the claims 28 to 32,
wherein the second embossments are formed by a second heated embossing roll, and/or,
wherein the third embossments are formed by the first heated embossing roll or a third heated embossing roll.

34. A method of manufacturing a coreless roll of a tissue paper product, such as toilet paper, the tissue paper product being made of four plies, the method comprising the steps of:
- providing four plies of Conventional Wet Press paper (CWP) and embossing at least one of the four plies;
- ply-bonding the four plies, optionally with an adhesive,

such as a lamination glue, and/or with mechanical bonding, such as edge embossing, to form a tissue paper product with a grammage in a range of 55 g/m^2 to 95 g/m^2, or optionally 60 g/m^2 to 80 g/m^2, and a caliper ratio in a range of 12% to 40%;

- spirally winding up the tissue paper product on a mandrel to form a coreless roll and to define an axially extending inner hole facing the mandrel, with a first end of the tissue paper product being located on the outer side of the coreless roll and the second end being located at the inner hole; and

- withdrawing the mandrel;

wherein the coreless roll comprises an outer diameter in the range of 95 to 150 mm and a diameter of the inner hole is in the range of 20 to 50 mm, and the density of the coreless roll lies in a range of 120 to 160 kg/m^3,

a caliper of the formed tissue paper product optionally being at least 0.55 mm, or at least 0.60 mm, or at least 0.65 mm,

the four provided plies being a first ply, a second ply, a third ply, and a fourth ply, the method comprising the step of:

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

35. The method of manufacturing a coreless roll of a tissue paper product of claim 34, the method comprising the steps of:

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

- wherein the first ply, the second ply, the third ply, and the fourth ply are ply-bonded such that the third ply and the fourth ply are located between the first ply and

the second ply; and

- wherein, optionally, the first embossing roll optionally also comprises third embossing protrusions and the step of embossing the first ply forms first and third embossments on the third ply, or

wherein the method optionally comprises a step of embossing the first ply with a third embossing roll with third embossing protrusions to form third embossments.

36. The method of manufacturing a coreless roll of a tissue paper product of claim 35, the method comprising the step of embossing the first ply and third ply together using the first embossing roll to form the first embossments on the first ply and the third ply,

wherein the third embossments are optionally formed only on the first ply but not on the third ply, or wherein the first ply and the third ply are optionally embossed together to form the third embossments on the first ply and the third ply.

37. The method of manufacturing a coreless roll of a tissue paper product of claim 35,

wherein the first ply and the third ply are embossed together to form the first embossments on the first ply and the third ply,

wherein the fourth ply is unembossed or embossed separately from the first ply, the third ply, and the second ply, and

wherein the third embossments are optionally formed only on the first ply but not on the third ply, or wherein the first ply and the third ply are optionally embossed together to form the third embossments on the first ply and the third ply.

38. The method of manufacturing a coreless roll of a tissue paper product of claim 35,

wherein the first ply, the third ply, and the fourth ply

are embossed together to form the first embossments on the first ply, the third ply, and the fourth ply, and

wherein, optionally, the first ply, the third ply, and the fourth ply are embossed together to form the third embossments on the first ply, the third ply, and the fourth ply, or

wherein, optionally, the third embossments are formed on the first ply and the third ply, but not on the fourth ply, or

wherein, optionally, the third embossments are optionally formed on the first ply, but not on the third ply and the fourth ply.

39. The method of manufacturing a coreless roll of a tissue paper product of claim 35,

wherein the third ply and the fourth ply are embossed together separately from the first ply and the second ply, or

wherein one of the third ply and the fourth ply is separately embossed from the first ply and the second ply, and the method does not comprise a step of embossing the other one of the third ply and the fourth ply, or

wherein the method does not comprise a step of embossing the third ply and does not comprise a step of embossing the fourth ply.

40. The method of manufacturing a coreless roll of a tissue paper product of claim 35,

wherein the first ply and the third ply are embossed together to form the first embossments on the first ply and the third ply,

wherein the fourth ply and the second ply are embossed together to form the second embossments on the fourth ply and the second ply, and

wherein, optionally, the first ply and the third ply are embossed together to form the third embossments on the first ply and the third ply, or wherein the third

embossments are optionally formed only on the first ply but not on the third ply.

41. The method of manufacturing a coreless roll of a tissue paper product of claim 35,
wherein the second embossments are formed by a second heated embossing roll, and/or,
wherein the third embossments are formed by the first heated embossing roll or a third heated embossing roll.

42. A method of manufacturing a coreless roll of a tissue paper product, such as toilet paper, the tissue paper product being made of five or six plies, the method comprising the steps of:
- providing five or six plies of Conventional Wet Press paper (CWP) and embossing at least one of the five or six plies;
- ply-bonding the five or six plies, optionally with an adhesive, such as a lamination glue, and/or with mechanical bonding, such as edge embossing, to form a tissue paper product with a grammage in a range of 65 g/m^2 to 125 g/m^2, optionally a range of 65 g/m^2 to 100 g/m^2, and a caliper ratio in a range of 10% to 25%;
- spirally winding up the tissue paper product on a mandrel to form a coreless roll and to define an axially extending inner hole facing the mandrel, with a first end of the tissue paper product being located on the outer side of the coreless roll and the second end being located at the inner hole; and
- withdrawing the mandrel;
wherein the coreless roll comprises an outer diameter in the range of 95 to 150 mm and a diameter of the inner hole is in the range of 20 to 50 mm, and the density of the coreless roll lies in a range of 130 to 160 kg/m^3,
a caliper of the formed tissue paper product optionally being at least 0.65 mm, or at least 0.70 mm, or at least 0.75 mm,

the method comprising the step of:
- embossing one of the outermost plies with a first heated embossing roll with first embossing protrusions to form first embossments with a first height (h1) in a range of 0.2 mm to 2.0 mm.

43. The method of manufacturing a coreless roll of a tissue paper product of any one of the claims 26 to 42,
wherein the method comprises the step of coating at least a part of an innermost circumvolution, optionally the entire innermost circumvolution, of the tissue paper product of the coreless roll at the second end with a stabilizing coating composition.