A device and a method for bending panels

A plywood forming method for manufacturing a plywood product. The method comprises arranging available a panel comprising a first surface and a second surface; a first layer and a second layer arranged in between the first surface and the second surface and comprising wood-based material; and a thermoplastic adhesive layer in between the first layer and the second layer. The method further comprises arranging available a device comprising a tubular body extending in a longitudinal direction and having a surface. The method further comprises heating the panel such that the thermoplastic material at least locally melts, connecting the panel to the tubular body, winding the panel around the tubular body such that the panel becomes bent, letting the bent panel to cool to solidify the thermoplastic material, and removing the bent panel from the device. In addition, a device for bending a panel is disclosed. In addition, an arrangement comprising the device and the panel is disclosed. Moreover, a product obtainable by the method is disclosed.

Fig. 4b

- Sz
- Sy
- 413b
- 410
- 416
- 100
- 120
- 110a
- 110b
- 420
- 438
- 440
Description

Field of the Invention

[0001] The invention relates to a method for manufacturing a curvilinear panel. The invention relates to a curvilinear panel obtainable by the method. A product comprises such a curvilinear panel. The invention relates to a device for manufacturing a curvilinear panel. The invention relates to an arrangement comprising the device and a panel.

Background of the Invention

[0002] Various kinds of panels are known. In particular, plywood panels are known and widely used. Plywood panels are used e.g. in construction, in vehicles, and in furniture. In furniture, curvilinear plywood panels are sometimes used. However, curvilinear plywood panels may be hard to manufacture.

Summary of the Invention

[0003] It has been found that curvilinear panels may be manufactured by winding, i.e. rolling, a panel onto a tubular body. The results of such a process is a product. An embodiment of the product comprises

- a first surface and a second surface,
- a first layer in between the first surface and the second surface, comprising wood-based material, and optionally comprising the first surface or the second surface,
- a second layer in between the first surface and the second surface, comprising wood-based material, and optionally comprising the first surface or the second surface,
- an adhesive layer in between the first layer and the second layer, the adhesive layer comprising thermoplastic material, wherein
  - the first surface is at least partly convex,
  - the first surface comprises a first point and a first surface normal at the first point,
  - the first surface comprises a second point and a second surface normal at the second point,
  - the first surface comprises a path from the first point to the second point, and
  - the angle between the first surface normal and the second surface normal is at least 45 degrees, wherein the angle is measured along the path.

[0004] In some embodiments, the angle is at least 90 degrees, at least 180 degrees, at least 270 degrees or at least 330 degrees. The angle may be more than 360 degrees, as will be discussed.

[0005] In an embodiment

- the layer that is closest to the first surface or comprises the first surface comprises wood at a location, wherein the wood has a grain orientation at the location, wherein the wood has a grain orientation at the location,
  - the location defines a tangent plane for the first surface, and
  - the grain orientation is parallel to the tangent plane and perpendicular to a longitudinal direction of the first surface, wherein the longitudinal direction is defined by the intersection of the tangent plane and the first surface.

[0006] Such a product may be manufactured using a device. An embodiment of the device comprises

- a tubular body extending in a longitudinal direction and having a surface,
- means for connecting a panel to the tubular body, and
- means for detaching the panel from the tubular body.

[0007] An embodiment of the device comprises a cooler arranged to cool a bent panel.

[0008] In embodiment of the device, at least one end of the tubular body is detached or detachable from a support such that a bent panel is removable from the device. In the embodiment, the tubular body is arranged to rotate about an axis, wherein the axis is parallel to the longitudinal direction. In addition, the embodiment comprises a sheet attached to the tubular body, wherein the sheet is bendable such that the may be wound around the tubular body, whereby the sheet forms the means for connecting a panel to the tubular body. In an embodiment the bendability of the sheet is at least 0.0003/Nm, wherein the bendability is defined by 1/(Es×Hs^2), wherein Hs is the thickness of the sheet and Es is the elastic constant of the sheet.

[0009] When using the device to produce a product, an arrangement is formed. An embodiment of the arrangement comprises a device as disclosed in this specification and a panel comprising

- a first surface and a second surface,
- a first layer arranged in between the first surface and the second surface, comprising wood-based material, and optionally comprising the first surface or the second surface,
- a second layer arranged in between the first surface and the second surface, comprising wood-based material, and optionally comprising the first surface or the second surface, and
- an adhesive layer in between the first layer and the second layer, the adhesive layer comprising thermoplastic material.

[0010] In an arrangement the panel comprises plywood that comprises thermoplastic adhesive.

[0011] In an arrangement, the layer that is closest to the first surface of the panel or comprises the first surface
of the panel comprises wood, wherein the wood has a grain orientation, and the grain orientation is directed towards the means for connecting a panel to the tubular body.

[0012] In an arrangement
- the panel comprises N layers,
- the panel has a thickness of H, and
- the tubular body has a radius or curvature of r, and
- the sheet has a tensile line strength of at least 10 \( \text{MPa} \times N \times (H/N)^{3/2} \).

[0013] The product may be manufactured with a method. An embodiment of the method comprises
- arranging available a panel comprising
  - a first surface and a second surface,
  - a first layer arranged in between the first surface and the second surface and comprising wood-based material,
  - a second layer arranged in between the first surface and the second surface and comprising wood-based material, and
  - an adhesive layer in between the first layer and the second layer, the adhesive layer comprising thermoplastic material,
- arranging available a device comprising
  - a tubular body extending in a longitudinal direction and having a surface,
  - means for connecting the panel to the tubular body, and
  - means for detaching the panel from the tubular body,
- heating the panel such that the thermoplastic material at least locally melts,
- connecting the panel to the tubular body,
- winding the panel around the tubular body such that the panel becomes bent,
- letting the bent panel to cool to solidify the thermoplastic material, and
- removing the bent panel from the device.

[0014] In an embodiment, the panel is heated to a temperature from 80 °C to 200 °C to melt the thermoplastic material.

[0015] In an embodiment, the panel is cooled or let to cool to a low temperature, wherein the low temperature is lower than the melting point of the thermoplastic material by at least 10 °C, preferably at least 30 °C, and more preferably at least 40 °C degrees.

[0016] In an embodiment,
- the layer of the panel that is closest to the first surface of the panel or comprises the first surface of the pan-
embodiment of a device for manufacturing a product from the panel,
Figure 4c shows, in a top view, a panel and an embodiment of a device for manufacturing a product from the panel,
Figure 4d shows, in an end view, a panel and an embodiment of a device for manufacturing a product from the panel,
Figure 4e shows, in an end view, the detail IVe of Fig. 4d,
Figure 4f shows, in an end view, a panel and an embodiment of a device for manufacturing a product from the panel,
Figure 5 shows, in an end view, a panel and an embodiment of a device for manufacturing a product from the panel,
Figure 6a shows, in an end view, a panel and an embodiment of a device for manufacturing a product from the panel,
Figure 6b shows, in an end view, a panel and an embodiment of a device for manufacturing a product from the panel,
Figure 6c shows, in an end view, a panel and an embodiment of a device for manufacturing a product from the panel,
Figure 7a shows, in an end view, an embodiment of a device for manufacturing a product from the panel,
Figure 7b shows, in an end view, an embodiment of a device for manufacturing a product from the panel,
Figure 7c shows, in an end view, an embodiment of a device for manufacturing a product from the panel,
Figure 7d shows, in an end view, an embodiment of a product having been made by the device of Fig. 7c,
Figure 8a shows, in a top view, an embodiment of a device for manufacturing a product from the panel,
Figure 8b shows, in a top view, an embodiment of a device for manufacturing a product from the panel,
Figure 8c shows, in a top view, an embodiment of a device for manufacturing a product from the panel,
Figure 9a shows, in an end view, a panel and an embodiment of a device for manufacturing a product from the panel,
Figure 9b shows, in an end view, a panel and an embodiment of a device for manufacturing a product from the panel,
Figure 9c1 shows, in a bottom view, a tubular body of a device for manufacturing a product from the panel,
Figure 9c2 shows, in a side view, a clamp,
Figure 9d shows, in an end view, a panel and an embodiment of a device for manufacturing a product from the panel,
Figure 9e shows, in an end view, a panel and an embodiment of a device for manufacturing a product from the panel,
Figure 9f shows, in an end view, a panel and an embodiment of a device for manufacturing a product from the panel,
Figure 9g1 shows, in an end view, a panel and an embodiment of a device for manufacturing a product from the panel,
Figure 9g2 shows, in a bottom view, a tubular body of the device of Fig. 9g1 for manufacturing a product from the panel; and
Figure 9g3 shows, in a bottom view, a panel to be bent with the device of Figs. 9g1 and 9g2.

[0020] In some of the figures, the directions Sx, Sy, and Sz are depicted for clarity. These directions are orthogonal.

Detailed Description of the Invention

[0021] A purpose of the present invention is to provide a method by which a product that has a curvilinear shape can efficiently be manufactured. The product is manufactured from a panel. The panel may have a uniform or essentially uniform thickness. The panel may be planar or essentially planar. However, the method is applicable also for initially curvilinear panels. Moreover, the method is applicable also for a panel having a non-uniform thickness. These issues apply also for a device for manufacturing such a product.

[0022] Examples of such products 300 are shown in Figs. 3a to 3f and will be discussed in more detail below.

[0023] As discussed, a product 300, may be manufactured from a panel 100. Figure 1a shows in a perspective view a panel 100. The panel has a length L, a width W, and a thickness H. The length may be e.g. from 10 mm to 10 m. The width may be e.g. from 10 mm to 10 m. The thickness H will be discussed later. Directions Sx, Sy, and Sz are defined as shown in the figure. The directions are orthogonal. Generally, the direction Sz may refer to a vertical direction. However, verticality does not have a special technical function. Sx may thus refer to a horizontal direction. When a product has the form of an extending profile, the direction of extension is referred to as ±Sx. Naturally, the direction of extension need not be horizontal. Moreover, the device comprises an extending tubular body. The direction of the (longitudinal) extension is also referred to as ±Sx.

[0024] It has been noticed that layers 110 that are relatively thin may be bendable even if a thick objects, such as a panel 100, of the same material a not bendable, e.g. break under bending, or require excessive force to bend. According to an aspect of the invention, the panel 100 comprises layers 110 of material. As the product 300 is made using a panel 100, also the final product 300 comprises such layers 110. Referring to Fig. 1b, the panel 100 comprises the layers 110.

[0025] In an embodiment, the panel 100 is a solid object. Thereby the layers 110 are attached to each other. However, to facilitate bending of the panel 100, the layers 110 are attached to each other using thermoplastic material 120. When the panel 100 is heated, the thermo-
A layer 110 may comprise multiple sub-layers. These sub-layers are attached to each other. However, as for terminology, the layers 110 are separated from each other by the thermoplastic layer 120. Moreover, the sub-layers comprised by a layer 110 may be attached to each other using thermoset adhesive.

It is known that the flexural stiffness of an object in general depends on the thickness as $H^3$, wherein $H$ is the thickness. Thus, the flexural stiffness of a panel 100 is also proportional to $H^3$, wherein $H$ is the thickness of the panel. Therefore, thick objects are stiff and hard to bend. The problem of stiff objects has been solved by using a panel, wherein the panel 100 comprises multiple (say N) layers 110, each having a smaller thickness. The thickness of the layers 110 may be equal, and e.g. about (H/N). Thus the flexural stiffness of the pile of layers is only N x (H/N)$^3$. This applies, when the layers 110 can slide with respect to each other, e.g. when the thermoplastic material 120 in between the layers 110 allow for sliding. The thermoplastic material 120 allows for sliding e.g. when the temperature of the thermoplastic is above the melting point.

After cooling down the object (e.g. the panel 100), the thermoplastic material 120 hardens, and the object re-gains its rigidity.

As shown in the figures 1a and 1b, the panel 100 comprises
- a first surface 132 and a second surface 134,
- a first layer 110a in between the first surface 132 and the second surface 134, comprising wood-based material, and optionally comprising the first surface 132 or the second surface 134,
- a second layer 110b in between the first surface 132 and the second surface 134, comprising wood-based material, and optionally comprising the first surface 132 or the second surface 134, and
- an adhesive layer 120 in between the first layer 110a and the second layer 110b, the adhesive layer 120 comprising thermoplastic material.

The term “in between” is to be interpreted in terms of volume or mass. Therefore, even if one layer 110a, 110b forms part of the surface 132, 134, the surface itself has no volume, and therefore no mass. Thus, even if the layer 110a, 110b is a surface layer, the layer is completely in between the surfaces.

As discussed above, the first layer 110a may be, but is not necessarily, a surface layer of the panel. In case the first layer 110a is a surface layer, the first layer comprises the first surface 132 or the second surface 134.

As discussed above, the second layer 110b may be, but is not necessarily, a surface layer of the panel. In case the second layer 110b is a surface layer, the second layer comprises the first surface 132 or the second surface 134.

Moreover, as depicted in Figs. 1a to 1c, the first layer 110a is arranged in between the second layer 110b and the first surface 132. In addition, the second layer 110b is arranged in between the first layer 110b and the second surface 134.

As shown in Fig. 1c the panel 100 may comprise a surface layer 130. The surface layer 130 does not necessarily comprise wood based material. The surface layer 130 may be e.g. a protective film, such as paint or lacquer. The surface layer 130 may be attached to the panel (e.g. by adhesive 122 such as thermoplastic adhesive). The surface layer may be otherwise arranged onto the panel 100, e.g. by spraying or brushing. The panel 100 may further comprise another surface layer on another surface not shown. However, the surface layer 130 may comprise wood, and may be attached to the topmost layer 110a e.g. by thermoset adhesive. Thereby, the topmost layer 110a comprises the surface layer 130.

In a preferred embodiment (of a method or of an arrangement, as will be discussed), the panel 100 comprises plywood that comprises thermoplastic adhesive.

Fig. 2a shows, in a side view, a plywood panel 200 with three plywood layers 210, 220 and 230. These layers may serve as the layers 110 of the panel 100. As is evident to a person skilled in the art, a plywood panel may comprise several plywood layers. Typically the number of plywood layers is odd (i.e. 2 x N + 1, wherein N is an integer at least one). The number may be even. Typically a plywood panel 200 comprises from 2 to 30, preferably from 3 to 15, and most preferably from 5 to 10 plywood layers. The plywood layers are attached to each other using suitable adhesive. In plywood comprising thermoplastic adhesive, the plywood layers are attached to each other using thermoplastic adhesive. Fig. 2b shows, in a perspective exploded view, the plywood panel of Fig. 2a; in particular the plywood layers 210, 220, and 230.

Referring to Fig. 2c, each plywood layer, e.g. the lowest plywood layer 230, comprises at least one veneer 231, 232, 233. The plywood layer 230 of Fig. 2c comprises three veneers 231, 232 and 233. The veneers are attached onto a plywood layer, e.g. onto the plywood layer 220, using suitable adhesive. The term veneer refers to thin slice of wood. A veneer usually has a thickness of at most 5 mm. Veneer is usually produced from wood by turning or cutting. Alternatively a veneer may be produced from wood by sawing. Such veneers may be referred to as lamellae or lignum. Plywood comprising such lamellae are used e.g. for furniture.

Fig. 2d shows, in a perspective view, an example of a veneer 234 and its grain direction 243. The veneer 234 could be used as the veneer 231, 232 or 233, or, as
the plywood layer 210, 220 or 230. As the veneer 234 is turned from wood, the veneer comprises wood grains. As the veneer is a thin slice, it may be considered to be planar. The term grain refers to the alternating regions of relatively darker and lighter wood resulting from the differing growth parameters occurring in different seasons. Typically the different grains of a veneer are more or less parallel.

[0039] The grains define a grain direction for the veneer. The grain direction represents an average direction of the individual grains of the veneer. The grain direction is parallel with a direction of the plane of the veneer. The grain direction of the veneer 234 is shown with the arrow 243 in Fig. 2d. The grain direction may be referred to as the fibre direction, since the wood fibres are aligned more or less parallel to the grain direction. Moreover, the grain direction may be referred to also as grain orientation. The terms "grain direction" and "grain orientation" are used in this specification interchangeably.

[0040] A plywood layer may consist of one veneer. More typically, a plywood layer may comprise at least two veneers. As illustrated in Fig. 2c, the veneers of a plywood layer are so aligned that the grain directions of different veneers in the plywood layer are parallel. Therefore, each plywood layer has a grain direction. The grain direction is parallel to a direction of the plane of the plywood layer, and therefore also parallel to a direction in the surface of the plywood panel 200 (or the surface 132, 134 of the panel 100, cf. Fig. 1 a). Referring to Fig. 2b, a plywood panel is formed in such a way that the grain direction of each plywood layer is essentially perpendicular to the grain direction of an adjacent plywood layer. For example, the grain direction 242 of the second plywood layer 220 is essentially perpendicular to the grain direction 241 of the first plywood layer 210 and to the grain direction 243 of the third plywood layer 230. The term "essentially perpendicular" means an angle of at least 75 degrees, preferably more than 85 degrees, or e.g. an angle of about 90 degrees (e.g. at least 88 degrees). Therefore, the grain directions of every second plywood layers are essentially parallel. For example, the grain direction 241 of the first plywood layer 210 is parallel to the grain direction 243 of the third plywood layer 230. Referring to Fig. 2a, the grain direction of the plywood layers are shown with the arrows 241 and 243, when the grain direction is in the plane of the figure. When the grain direction is perpendicular to the plane of the figure, e.g. the grain direction 242, the direction is shown with the cross-mark.

[0041] A plywood layer has anisotropic mechanical properties, meaning that these properties are different in the grain direction and in the direction perpendicular to the grain direction. As the adjacent layers have perpendicular grain directions, the plywood panel 200 as a whole has more or less isotropic properties, at least in the directions of the plane of the plywood panel 200. Therefore, bending of the plywood panel 200 to a curvilinear shape can be done in any direction such that the bending axis as parallel to a direction of the plane of the plywood panel 200. In an embodiment, the mechanical properties of the panel 100 are independent of the direction, provided that the direction is in the plane of the panel 100. More specifically, in an embodiment, the mechanical properties of the panel are transversely isotropic. In an embodiment, the thermal properties of the panel are transversely isotropic. In an embodiment, the panel 100 is transversely isotropic. This is the case for a plywood panel 200, due to the alternating grain orientations of the layers. A transversely isotropic panel may be bended equally as easily, regardless of the orientation of the bending axis around which the panel is bent. (The bending axis being in the plane of the panel 100).

[0042] The panel 100 does not necessarily consist of plywood. At least one layer 110 of the panel may comprise at least one of glass, metal, fiberglass, carbon fibers, natural fibres, textile, cloth, and polymer material. If strength, light weight an recyclability are required, the layers 110 may comprise natural fibers, e.g. in the form of wood or paper. All the layers 110 are not necessarily of the same material. At least one layer 110 may comprise at least one of natural fibers, glass, and polymer material.

[0043] In a preferred embodiment, at least one layer 110 of the panel 100 comprises organic natural fibers. In a preferred embodiment, at least one layer 110 of the panel 100 comprises wood. The thickness of the layer that comprises wood may be from 0.1 mm to 5 mm. Layers of other materials may have different thickness.

[0044] The layer (or layers) 110 that comprises wood may have been manufactured by one of sawing (as discussed above), rotary cutting, flat slicing, quarter slicing, half-round slicing, and rift cutting. These methods are known as such in plywood manufacturing, and different methods result in a slightly different visual appearance of the layer. Rotary cutting may also be referred to as turning or rotary turning. In an embodiment, a layer that comprises wood has been manufactured by rotary cutting. In an embodiment, all the layers that comprise wood have been manufactured by rotary cutting. In an embodiment, a layer that comprises wood has been manufactured by sawing. Layers of a plywood panel 200 may comprise veneers. A layer 110 comprising fibrous material may have a fiber orientation in the plane 110 comprising the fibrous material. In this way, the layer is easily flexible in at least one direction, e.g. the direction perpendicular to the fiber orientation, whereby the fiber orientation is parallel to the bending axis. This is particularly true for a layer 110 comprising wood, e.g. a wooden veneer.

[0045] The plywood panel 200 may be e.g. a panel made using hardwood. Therefore, the panel 100 may comprise veneers made of hardwood. The term “hardwood” will be defined in more detail in connection with the product 300.

[0046] The total thickness, H (Fig. 1a), of the panel 100 is preferably at most 50 mm to facilitate bending on the
panel 100. More preferably the thickness is at most 30 mm, and even more preferably the thickness is at most 20 mm. However, a preferred embodiment of the method is applied to form structural material for furniture. Such structural material needs to have sufficient strength for the purpose. Therefore, preferably the total thickness of the panel 100 is at least 0.5 mm, or more preferably at least 1 mm or at least 2 mm.

[0047] The material of the layers 110 of the panel 100 have a higher melting point (temperature) than the thermoplastic 120 material of the panel. The material of the layers 110 of the panel 100 is resistant to a temperature that is higher than the melting point of the thermoplastic 120 material of the panel. For example, wooden layers of plywood typically can resist temperatures up to about 200 °C. The melting point of the thermoplastic material 120 may therefore be e.g. at most or less than 200 °C. The melting point of the thermoplastic material 120 may be e.g. less than 180 °C. The melting point of the thermoplastic material 120 may be e.g. less than 150 °C.

[0048] The thermoplastic material 120 may comprise at least one of polyvinyl alcohol, polyolefin, lignin, polyethylene, polypropylene, and a co-polymer comprising ethylenes and propylenes. In an embodiment, the thermoplastic material comprises polyethylene. The melting point of thermoplastic comprising polyethylene may be from 100 °C to 120 °C.

[0049] The panel 100 or the plywood panel 200 may be bent using a device 400 for bending the panel 100. As the panel 100 is bent, a product 300 may formed. Alternatively, a bent panel can be further processed, e.g. machined and/or coated to obtain the product 300.

[0050] Figures 4, 5, 6, 8, and 9 show arrangements comprising a panel 100 and a device 400 for bending the panel. Referring to the figures 4a, 4c, and 9a an embodiment of device 400 comprises

- a tubular body 410 extending in a longitudinal direction ±Sx and having a surface 412,
- means (418, 420) for connecting a panel 100 to the tubular body 410, and
- means for detaching the panel 100 from the tubular body 410.

[0051] Referring to Fig. 4c, in an embodiment,

- at least one end of the tubular body 410 is detached or detachable from a support 424 such that a bent panel is removable from the device 400.

[0052] Even if not shown in Figs. 9a - 9g3, also in those embodiments an end of the tubular body may be detached or detachable from a support.

[0053] Figure 4a shows a preferred arrangement comprising a panel 100 and a preferred embodiment of a device 400 for bending the panel 100. The device 400 is shown in an end view. The respective directions Sy and Sz are indicated. The device 400 comprises

- a sheet 420, attached to the tubular body.

[0054] The sheet 420 forms the means for connecting a panel 100 to the tubular body 410. Moreover, the sheet 420 forms the means for detaching the panel 100 from the tubular body 410; e.g. by loosen the sheet 420.

[0055] As depicted in the figure 4a, the sheet 420 is bendable. The sheet 420 is bendable such that the sheet 420 may be wound around the tubular body 410. The sheet 420 may be wound such that a panel 100 in between the sheet 420 and the surface 412 of the tubular body 410 becomes bent during the winding. The winding is depicted with the arrow 413a.

[0056] Generally the stiffness of the sheet 420 is determined by the thickness Hs of the sheet and the modulus of elasticity Es of the sheet 420. The stiffness is proportional to Es×Hs. Therefore, the bendability (or the flexibility) of the sheet 420 is related to 1/(Es×Hs). In some embodiments, the bendability of the sheet 420 is at least 0.0003/Nm (in which case the stiffness Es×Hs is at most about 3000 Nm). In some of these embodiments, the bendability of the sheet 420 is at least 0.005/Nm. In some of these embodiments, the bendability of the sheet 420 is at least 0.04/Nm.

[0057] However, the bendability is the sheet 420 may be selected according to the radius of curvature of the tubular body 410. In this case the bendability of the sheet 420 related to the tubular body 410 may be defined by r2/(Es×Hs3), wherein r is the radius of curvature of the tubular body 410. In case the tubular body 410 has multiple different radii of curvature, the smallest value (or smallest absolute value, if negative radii are present) may be used as r. In some embodiments, the bendability of the sheet 420 related to the tubular body 410 is at least 0.00001 m/N. In some embodiments the bendability of the sheet 420 related to the tubular body 410 is at least 0.00003 m/N. In some embodiments the bendability of the sheet 420 related to the tubular body 410 is at least 0.0001 m/N.

[0058] Referring to Fig. 4c, at least one end of the tubular body 410 is detached or detachable from a support 424. The tubular body is detached or detachable such that a bent panel is removable from the device 400. The tubular body may be detached or detachable such that a panel 100 may be slid out from the device in the longitudinal direction 402. Alternatively or in addition, the tubular body 410 may be moved so that the panel is slid out from the device. Figure 4c shows, in a dot line, a support 424 that is detachable from the body 410. The support 424 can be arranged in two positions, wherein in a first position the support 424 is arranged to support the tubular body 410, and in the second position, the support 424 is detached from the tubular body 410 such that the panel 100 may be slid out from the device in the longitudinal direction 402. As will be discussed, the support 424 is not necessarily needed. In this case the tubular body 410 is detached from a support.

[0059] Figure 4b shows a more preferred embodiment.
In this embodiment, the tubular body 410 is arranged to rotate about an axis 416, wherein the axis is parallel to the longitudinal direction ±Sx. The direction of rotation is depicted with the arrow 413b. The axis 416 may be only an axis of rotation, not necessarily of physical object.

[0060] Referring to Fig. 4c, a support 422 may be arranged to support the tubular body 410. In an embodiment, the tubular body 410 is attached to a support 422 using at least one bearing 428. In an embodiment, the tubular body 410 comprises an axis 426, and the axis 426 is attached to the support 422 using the bearing 428 (Fig. 4c). In an embodiment, the support 422 comprises an axis 426, and the axis 426 is attached to the tubular body 410 using the bearing 428 (not shown). In the figure, the axis 426 is parallel to the axis of rotation 416 (cf. Fig. 4b).

[0061] In order to bend the panel 100, the sheet 420 has a tensile line strength of at least 0.2 kN/m. In some embodiments, the sheet 420 has a tensile line strength of at least 0.5 kN/m. In some embodiments, the sheet 420 has a tensile line strength of at least 2 kN/m. The maximum tensile strength of the sheet is not critical, however, as discussed above, the sheet should be bendable. Thus, in some embodiments the tensile line strength is at most 1.3 MN/m. The term "line strength" refers to the strength (i.e. maximum load) of the sheet, as divided by the width Ws of the sheet. Conversely, if the sheet material has a tensile strength, as commonly given in units MPa (e.g. GN/m²), the line strength of the sheet 420 is the tensile strength of the sheet material, multiplied by the thickness of the sheet. This tensile line strength is beneficial for some panels, since the sheet should bear the load needed to bend a panel in between the sheet and the surface of the tubular body. The tensile line strength is needed for tensioning the sheet 420, as depicted with the arrow 440 (Fig. 4b).

[0062] As for the tubular body 410, the strength of the tubular body 410 should be selected such that the tubular body 410 is arranged to support the sheet 420. In particular, both

- the tubular body 410 and
- the attachment between the tubular body 410 and the sheet 420 should withstand the line tension to which the sheet 420 is tensioned. For example, in an embodiment the tubular body 410 and the attachment between the tubular body 410 and the sheet 420 are arranged to withstand a line tension of the sheet corresponding to the line strength of the sheet 420.

[0063] The size of the device 400 determines the size of the product 300 that may be made using the device. Referring to Fig. 4a, the tubular body 410 has a cross section, wherein the cross section is taken along a plane having a surface normal parallel to the longitudinal direction ±Sx. It is further noted that the tubular body extends in the longitudinal direction ±Sx. The cross section has a first dimension d₁ in a first direction perpendicular to the longitudinal direction ±Sx. Furthermore, the cross section has a second dimension d₂ in a second direction perpendicular to the longitudinal direction ±Sx and perpendicular to the first direction. In Fig. 4a the dimensions are equal. However, in general these dimensions need not to be equal (cf. Figs. 7a and 7c).

[0064] In an embodiment, the smaller of the first and the second dimension (i.e. min(d₁,d₂)) is at least 4 mm. In another embodiment, the smaller of the first and the second dimension (i.e. min(d₁,d₂)) is at least 8 mm. In this or another embodiment, the larger of the first and the second dimension (i.e. max(d₁,d₂)) is at most 2.5 m. In this or another embodiment, the larger of the first and the second dimension (i.e. max(d₁,d₂)) is at most 2 m.

[0065] Referring to Fig. 4c, the tubular body has a length Lb in the longitudinal direction. In an embodiment, the length Lb is from 10 mm to 20 m.

[0066] Figures 4d to 4f describe in more detail how to support the panel 100 with the sheet 420, and how an edge 142 of the panel does not deform by sliding during bending. These issues will be discussed in more detail in connection with the arrangement comprising the device 400 and the panel 100.

[0067] The panel 100 may be heated before arranging the panel 100 into the device 400. The panel may be heated to melt the thermoplastic material 120 and facilitate bending. The device 400 may be arranged to cool the panel 100. When the panel 100 is cooled, it regains its rigidity. However, the panel 100 is not a part of the device 400.

[0068] An embodiment of the device 400 comprises a cooler arranged to cool the panel 100. An embodiment of the device 400 comprises a cooler arranged to cool the tubular body 410. As the tubular body 410 cools, also the panel 100 cools. The cooler may be arranged to cool the tubular body 410 using a heat transfer medium. The heat transfer medium may comprise liquid, such as water. Figure 5 shows heat transfer pipes 450 arranged in the tubular body 410, to cool the tubular body 410. One heat transfer pipe 450 may be arranged parallel and concentric with the axis of rotation 416. One heat transfer pipe 450 may form an axis 426 for the tubular body 410 (Fig. 4c).

[0069] Referring to Fig. 5, an embodiment of the device 400 comprises a heater 460. The heater 460 is arranged to heat the sheet 420. Thereby the heater is arranged to heat the panel 100. However, the panel 100 is not a part of the device 400. The heater 460 may be arranged in a planar support 465. Referring to Fig. 5, an embodiment of the device 400 comprises

- a support 465, wherein a surface normal of the support 465 forms an angle with the horizontal plane, wherein the angle is at least 60 degrees; preferably at least 80 degrees; or about 90 degrees (as in the embodiment of Fig. 5; the term "about 90" meaning e.g. at least 85 degrees);
- a heater 460 arranged to heat the support 465, and
- the sheet 420 is arranged on the support 465.

[0070] The support 465 may be planar, as depicted in Fig. 5. The upper surface of the support may be planar. In this way, the heater is arranged to heat the sheet 420. Moreover, as the panel 100 may be arranged on the sheet 420, the heater is arranged to heat the panel 100.

[0071] As depicted in Fig. 5, the device 400 may comprise another heater 466. The other heater 466 may be arranged to heat the panel directly. In direct heating, heat from the heater 466 is transferred directly to the panel 100, i.e. not through the sheet 420. The panel 100 may be directly heated e.g. with infra-red radiation or with convection. The panel 100 may be heated from both sides. E.g. the panel 100 may be heated from a first side with a first heater 460 arranged to heat the sheet 420. In addition or alternatively, the panel 100 may be heated from a second side with a second heater 466 arranged to heat the panel 100 directly. The device 400 may comprise at least one heater, e.g. both the heaters 460, 466. Alternatively, the heaters may be arranged, as separate heaters, to the arrangement comprising the device 400, the panel 100, and the heater(s).

[0072] Referring to Fig. 6a, an embodiment of the device 400 comprises
- a second tubular body 470 extending in a second longitudinal direction and having a second surface 472, wherein
- the second longitudinal direction is parallel to the longitudinal direction \( \pm S_x \), and
- the second surface 472 is arranged within a distance from the first surface 412 such that the second surface 472, in combination with the sheet 420, is arranged to press a panel 100 in between the sheet 420 and the surface 412 of the tubular body 410.

[0073] In the device of Fig. 6a the second tubular body 470 has a second cross section, wherein the second cross section is taken along a plane having a surface normal parallel to the longitudinal direction, and the second cross section is circular. Even if cross section of the tubular body 410 is not circular (e.g. Fig. 7c), a second tubular body 470 having a circular cross section may be used to press the panel as discussed.

[0074] Moreover, the tubular body 410 may be larger than the second tubular body 470. More specifically, in an embodiment
- the tubular body 410 has a cross section, wherein the cross section is taken along a plane having a surface normal parallel to the longitudinal direction \( \pm S_x \),
- the cross section has a first dimension \( d_1 \) in a first direction perpendicular to the longitudinal direction \( \pm S_x \), and
- the cross section has a second dimension \( d_2 \) in a second direction perpendicular to the longitudinal direction \( \pm S_x \) and perpendicular to the first direction, wherein
- the larger of the first and the second dimension (i.e. \( \max(d_1, d_2) \)) is larger than the diameter of the second tubular body 470.

[0075] As depicted in Fig. 6b, the device 400 may comprise multiple tubular bodies 470a, 470b, and 470c. These tubular bodies may be arranged to press the panel 100; directly as depicted in Fig. 9d, or through the sheet 420 as depicted in Fig. 6b. In this way, the requirement for the tensile line strength of the sheet 420 may be reduced, since at least part of the load needed to bend the panel 100 is generated by the tubular bodies 470. Moreover, in such an embodiment, a physical axis 426 for the tubular body 410 is not needed. However, the tubular body 410 is arranged to rotate about an axis of rotation 416. The other tubular bodies 470a, 470b, 470c may be used to rotate the tubular body 410. The tubular body 410 is arranged to remain in its location because of the supporting forces by the other tubular bodies 470a, 470b, 470c.

[0076] Referring to Fig. 6c, the device may comprise a sheet 420 that has the form of a closed loop. The device may further comprise an object 430 arranged to press the panel 100 against the tubular body 410. Still further, the device may comprise a cylinder 480 arranged to pull the sheet 420 to rotate the tubular body 410. Conversely, in another embodiment the sheet 420 may be used to rotate the cylinder 480.

[0077] Figures 7a to 7c show embodiments of devices 400. As shown in the figures, the cross section of the tubular body 410 is not necessarily circular. In Fig. 7a the cross section is oval. In Fig. 7b the cross section has the shape of a square having rounded corners.

[0078] Referring to Fig. 7c, in an embodiment, the surface 412 of the tubular body 410 comprises a concave area 414. In this way, a part of the panel 100 may be pressed into the concave area 414, thereby bending the panel 100 to another direction. As depicted in Fig. 7c, the device 400 comprises pressing part 416 arranged to press a panel 100 against the concave area 414. Moreover, the shape of the pressing part 416 is adapted to the shape of the concave area 414. In an embodiment, the sheet 420 comprises the pressing part 416. In another embodiment, a separate pressing part 416 is used to bend the panel into the concave area 414.

[0079] Figure 7d shows a product 300 that is obtainable with the device of Fig. 7c.

[0080] Referring to Figs. 8a to 8c, the sheet 420 may be used to locate the panel 100 on the sheet 420. Referring to Fig. 8a, in an embodiment, the sheet 420 of the device 400 comprises at least one marking 432 for locating a panel 100 with respect to the sheet 420. In an embodiment, the sheet 420 of the device 400 comprises at least one projection 434 for locating a panel 100 with respect to the sheet 420. An edge of the panel 100, such
The sheet 420 may comprise a continuous layer of material. The sheet 420 may comprise a mesh of material. In an embodiment, the sheet 420 comprises a continuous metal layer. In an embodiment, the sheet 420 comprises a continuous layer of steel. In an embodiment, the sheet 420 comprises a continuous stainless steel layer. The tensile strength of stainless steel is from 250 MPa to 500 MPa (as measured by the yield stress, and depending on the steel quality). Thereby, some metals deform easily plastically, whereby those deformations are irreversible. The change from elastic to plastic deformation is characterized e.g. by the yield strength. For example, the yield strength of steel may be of the order of 250 MPa, in contrast to aluminium having the yield stress of only 95 MPa. In an embodiment, the material of the tubular body 410 has a yield strength of at least 150 MPa, preferably at least 200 MPa. Some stainless steels have the yield strength of about 500 MPa. In an embodiment, the tubular body 410 comprises ductile material.

The sheet 420 may also have the form of a mesh. The mesh may comprise metal. The mesh may comprise stainless steel. The mesh may comprise steel. The mesh may comprise stainless steel. The friction between the sheet 420 and the panel 100 should preferably be reasonably high. Preferably the coefficient of friction in between the panel 100 and the sheet 420 is at least 0.17, and even more preferably at least 0.2. Moreover, the friction between the tubular body 410 and the panel 100 should preferably be reasonably high. Preferably the coefficient of friction in between the panel 100 and the tubular body 410 is at least 0.15. More preferably the coefficient of friction in between the panel 100 and the tubular body 410 is at least 0.17, and even more preferably at least 0.2. These values are obtainable e.g. using a metal sheet 420 and/or a metal tubular body 410 in connection with a panel comprising wood.

However, the moisture content affects the coefficients of friction. A well-defined moisture content affects the coefficient of friction between (1) the panel 100 and the sheet 420 and/or (2) the panel 100 and the surface 412 of the tubular body 410. In case the moisture content could vary within a large range, the frictional properties of the arrangement would not be as well designed as for reasonably dry panels. Moreover, the moisture affects the adhesion between the layers 110 and the adhesive layer 120. In an arrangement the panel comprises wood having the moisture content at most 5 % by weight. Preferably, the moisture content of the wood is at most 3 % by weight. Preferably, the moisture content of the panel 100 is at least 0.01 % by weight. In an arrangement the moisture content of the panel 100 is at most 5 % by weight. Preferably, the moisture content of the panel 100 is at least 0.01 % by weight. When the moisture content is within this limit, the coefficient of friction between a wooden surface of a panel 100 and a steel sheet 420 is from 0.2 to 0.4. Preferably, the coefficient of friction is within this range. When the moisture content is within this limit, the coefficient of friction between a wooden surface of a panel 100 and a steel tubular body 410 is from 0.2 to 0.4. Preferably, the coefficient of friction is within this range.

Moreover, to ensure reasonably high friction, the sheet 420 may comprise elastomer. In an embodiment, the sheet 420 comprises a first sheet layer comprising an elastomer, and the sheet 420 comprises a second sheet layer comprising a support, wherein

- the second sheet layer is attached to the first sheet
In an embodiment the first sheet layer comprises rubber. The first sheet layer may comprise hard rubber. Hard rubber has a shore hardness of 70. The shore hardness of the elastomer may be e.g. at most 70. Preferably, the shore hardness of the elastomer, such as rubber, may be e.g. at most 50. The shore hardness of the elastomer may be e.g. at least 15. Preferably, the shore hardness of the elastomer, such as rubber, may be e.g. at least 25.

The support, i.e. the second sheet layer, may comprise fibrous material. The second sheet layer may comprise cloth, glass fibres, or carbon fibres. The support, i.e. the second sheet layer, may comprise metal. The second sheet layer may comprise a metal mesh.

The sheet 420 should be resistant to the temperature of the heated panel 100. Therefore, in an embodiment, the sheet 420 is mechanically stable in the temperatures from -10 °C to 200 °C. Thereby the sheet 420 can tolerate a temperature needed to melt the thermoplastic layer 120 in between the layers 110 of a panel 100. For example, the melting point of a material comprised by the sheet 420 may be greater than the melting point of the thermoplastic material 120. For example, the melting point of a material comprised by the sheet 420 may be greater than 200 °C.

In an embodiment, the sheet 420 is elastic up to at least some point of deformation. In this embodiment, when the tensioning 440 of the sheet 420 is released, the sheet 420 contracts. As the product 300 (the product 300 being made from the panel 100) is not tensioned in the same way, the product 300 does not contract upon the release of the sheet 420. Therefore, the sheet 420 detaches from the product 300. Moreover, this enables the easy release of the product 300 from the device 400. The sheet 420 should contract e.g. at least 1 degree, preferably about 5 degrees, and preferably at most 90 degrees upon its release. These values refer to the winding of a full circle. The term about 5 degrees may refer to values from 3 to 30 degrees. These values correspond to an elastic strain of (1/360), (5/360), and (90/360), i.e. 0.28 %, 1.4 %, and 25 %, respectively. The contraction is due to the release of the elastic stress, whereby elastic strain in the sheet 420 is also released. Thus, the sheet should be able to withstand reasonable high elastic strain. Mechanically, the yield strain defines the point (strain-wise), wherein the material starts to deform plastically, and cannot bear larger elastic deformations. Therefore, the yield strain of the sheet 420 is preferably at least 0.28 %, and more preferably at least 0.83 % (corresponding to 3 degrees), and even more preferably at least 1.4 %. The yield strain of the sheet 420 may also be at most 25 %, or at most 8.3 % (corresponding to 30 degrees). Also preferably, the sheet 420 material is ductile such that the sheet 420 withstands the winding.

Referring to Figs. 9a to 9e, the device 400 shown an embodiment, wherein the means for connecting 418 a panel 100 to the tubular body 410 comprises at least one hole 502 (Fig. 9c1). The hole 502 comprises an inlet 504 part and a locking part 506. In this way, the hole 502 forms the means for connecting 418 a clamp 495 (Figs. 9a and 9b) to the tubular body 410, and the clamp 495 may be used to connect a panel 100 to the clamp 495. The clamp 495 may be attached or attachable to a panel 100.

Referring to Fig. 9c2, the clamp 495 may, correspondingly, comprise a locking head 514 and a connecting part 516. The diameter of the locking head 514 may be selected such that the diameter of the locking head 514 is smaller than the width of the inlet part 504 (of the hole 502), but greater than width of the locking part 504 (of the hole 502). The diameter of the connecting part 516 may be smaller than the width of the locking part 504. In this way, the clamp 495 may be locked to the hole 502. The whole locking head 514 and a part of the connecting part 516 may be penetrated through the inlet part 504 of the hole 502. Thereafter, the connecting part 516 may be slid to the locking part 506 of the hole. As the diameter of the locking head 514 is large, the clamp 495 is mechanically locked into the locking part 506 of the hole 502.

After thus attaching the panel 100 to the tubular body, the panel 100 may be wound around the tubular body 410 to bend the panel. The winding is depicted with the arrow 413a. Preferably the winding may be performed by rotating the tubular body, as depicted in Fig. 9d. The direction of rotation is shown with the arrow 413b. Preferably, a second tubular body 470 is used to press the panel 100. Even more preferable, particularly, if the sheet 420 is not used, a multiple of other tubular bodies 470 is used.

The panel 100 may be fixed to the tubular body 410 also by other means such as nails or screws. The tubular body 410 may comprise a groove, into which such nails or screws are arranged (Fig. 9f). The nails or screws may be slid out from the groove. The tubular body 410 may comprise a detachable support for supporting the tubular body 410 at the groove. In addition or alternatively, the device 400 may comprise a moveable rod or bar (also shown with reference 418 in Fig. 9f), to which the panel 100 may be attached by the clamp, the nail or the screw. The rod may be slid to the tubular body 410, or into the tubular body 410, in the longitudinal direction ±Sx (402, Fig. 4c).

Referring to Figs. 9g1 to 9g3, the means for connecting 418 the panel 100, comprised by the device 400, may comprise a projection 522. Correspondingly, the panel 100 may comprise a hole 532 adapted to the projection 522.

Referring to Fig. 9g1, the device 400 shown therein comprises means for connecting 418 a panel 100 to the tubular body 410. The means for connecting has the shape of a projection 522. The projection comprises locking head 524 and a connecting part 526. The projec-
tion may be arranged to be movable in the radial direction of the tubular body 410. E.g. the projection 522 may be screwed into the tubular body and/or out of the tubular body. In addition or alternatively, the projection 522 may be arranged to be movable in the radial direction of the tubular body 410 by at least one of: a spring, a pneumatic means, and a hydraulic means. In the Figure 9g1, a projection 522 is arranged to be in the second position. In the Figure 9g1 another projection 522b is arranged to protrude from the tubular body 410. The projection 522, 522b may be arranged to be in at least a first position, wherein the projection 522, 522b may be arranged to be in at least a first position, wherein the projection 522, 522b protrudes from the tubular body 410. In addition or alternatively, the projection 522 may be arranged to be movable in the radial direction of the tubular body 410. Moreover, the projection(s) 522 comprises a groove 525. The groove 525 can be used to enable screwing of the projection 522 into the tubular body and/or out of the tubular body.

Referring to Fig. 9g2, the device 400 may comprise several projections 522. In Fig. 9g2, only the locking head 524 is visible, while the connecting part 526 remains under the locking head 524. The locking head 524 may comprise a groove 525. The groove 525 may be used to turn the projection 522. The turning may engage screwing of the projection 522 into the tubular body and/or out of the tubular body.

Referring to Fig. 9g3, the panel 100 may comprise a hole 532 or holes 532. A hole 532 may comprise an inlet part 534 and a locking part 536. The panel 100 may be connected to the tubular body 410 by first moving the panel 100 such that the locking head(s) 524 and at least part of the connecting part(s) 526 penetrate through the inlet part(s) 534 of the hole(s) 532. Thereafter, the panel may be moved such that the connecting part(s) 526 moves into the locking part(s) 536 of the hole(s) 532. Moreover, before bending the panel 100, the panel 100 may be further fixed to the tubular body by tightening the projection(s) 522. More specifically, tightening the projection(s) such that the locking head(s) 524 presses the panel 100 at the regions adjacent to the locking part(s) 536 of the hole(s) 532.

After winding the panel 100 around the tubular body 410, the panel 100 is cooled to regain rigidity. Thereafter, the projection(s) 522 may be loosened. Finally, the bent panel may be turned in respect to the tubular body (in the reverse direction compared to the direction of winding) in order to locate the locking head(s) 524 and the inlet part(s) 534 such that the panel may be removed from the device 400.

As discussed above, the projection(s) 522 form the means for connecting the panel 100 to the device. Moreover, as discussed above, the projection(s) 522 form the means for detaching the panel 100 from the device. In addition, the tubular body 410 may be detached or detachable from a support 424 as discussed in connection with Fig. 4c. Thus the bent panel is removable from the device.

As depicted in Fig. 9e, the tubular body 410 may comprise angles. At the angles, the radius of curvature of the tubular body is zero. In this case, the radius of curvature of the concave part of the tubular body determines the radius of curvature of the bent panel. Moreover, preferably the tubular body 410 of Fig. 9e is used to bend a panel only to a relatively low angle variation. Otherwise, the sharp corners at the angles could break the panel 100. An embodiment of the device comprises a tubular body that does not comprise sharp corners. In such a device, the radius of curvature at each point of the surface is reasonably large. E.g. the minimum of the multiple radii of curvature is at least 1 mm, preferably at least 2 mm. Referring to Fig. 9e, in an embodiment, the tubular body 410 may be connected to supports 422, 424 from both its ends. When the angle of winding is relatively low, e.g. at most 180 degrees, the bent panel is removable from the device even if the tubular body is not detachable. In this case it suffices that the device 400 comprises means for detaching the panel 100 from the tubular body 410. For example, the clamps 495 may be detached from the tubular body 410. The angle of winding the panel may be e.g. at least 30 degrees, at least 45 degrees, or at least 90 degrees. As will be discussed later, a corresponding product comprises a first surface 332 that is at least partly convex, the first surface 332 comprises a first point 374 and a first surface normal Sn1 at the first point 374, the first surface 332 comprises a second point 376 and a second surface normal Sn2 at the second point 376, the first surface 332 comprises a path from the first point 374 to the second point 376, and the angle α between the first surface normal Sn1 and the second surface normal Sn2 is at least 45 degrees, wherein angle α is measured along the path.

When using the device 400 to bend a panel 100, an arrangement is formed. The arrangement comprises a device 400 for bending a panel 100, the device comprising the at least some of the features discussed above, and a panel 100, especially the panel 100 to be bent, comprising

- a first surface 332 that is at least partly convex,
- a first surface 332 comprises a first point 374 and a first surface normal Sn1 at the first point 374,
- a first surface 332 comprises a second point 376 and a second surface normal Sn2 at the second point 376,
- a first surface 332 comprises a path from the first point 374 to the second point 376, and
- the angle α between the first surface normal Sn1 and the second surface normal Sn2 is at least 45 degrees, wherein angle α is measured along the path.
or the second surface 134, 334, and
○ an adhesive layer 120 in between the first layer 110a and the second layer 110b, the adhesive layer comprising thermoplastic material.

[0106] The first surface is referred to as 132, 332 since the surface of the panel 100 is referred to as 132, while the surface of the product 300 is referred to as 332. In the device 400, the panel 100 may be bent or planar, depending on the state of the method. For these reasons, the second surface is referred to as 134, 334. For these issues, cf. Figs. 1a, 4e, and 3a.

[0107] The features of the panel 100 for various embodiments were discussed above in connection with the panel 100 alone. Evidently any disclosed panel 100, or plywood panel 200 may be used in the arrangement.

[0108] The device may be used to form a product 300 having a preferable grain orientation, as shown in Fig. 3g. When bending such a panel, an arrangement of the device 400 and the panel 100 is formed. In the panel 100 the layer 110a that is closest to the first surface 132 or comprises the first surface 132 comprises wood, at a location 337, wherein the wood has a grain orientation 241 at the location 337. Notice however, that unlike in Fig. 3g, the panel 100 may be planar or essentially planar before entering the device 400. The device 400 comprises an attachment, such as the contact point 438 (e.g. Fig. 4b), between the sheet 420 and the tubular body 410. In an arrangement, the panel 100 is oriented such that the grain orientation is directed towards the attachment 438. Referring to Fig. 4b, e.g. a grain orientation of the layer 110a may be directed towards the attachment 438. In case the layer 110a consist of one wooden layer having one grain orientation, the grain orientation of the layer 110a may be directed towards the attachment 438. In case the device 400 does not comprise the sheet 420. A panel can be oriented such that a grain orientation is directed towards the means for connecting a panel 100 to the tubular body.

[0109] When using the device 400, the user performs a method for bending a panel 100. A product 300 may be manufactured during the process. The method comprises arranging available a panel 100 (cf. Figs. 1a to 1c) comprising

○ a first surface 132 and a second surface 134,
○ a first layer 110a arranged in between the first surface 132 and the second surface 134, comprising wood-based material, and optionally comprising the first surface 132 or the second surface 134,
○ a second layer 110b arranged in between the first surface 132 and the second surface 134, comprising wood-based material, and optionally comprising the first surface 132 or the second surface 134, and
○ an adhesive layer 120 in between the first layer 110a and the second layer 110b, the adhesive layer 120 comprising thermoplastic material.

[0110] Moreover, as discussed above, the first layer 110a is arranged in between the second layer 110b and the first surface 132. In addition, the second layer 110b is arranged in between the first layer 110a and the second surface 132.

[0111] The method further comprises arranging available a device comprising

○ a tubular body 410 extending in a longitudinal direction and having a surface 412,
○ means (418, 420) for connecting a panel 100 to the tubular body 410, and
○ means for detaching the panel 100 from the tubular body 410.

[0112] An embodiment comprises arranging available a device comprising

○ a sheet 420 attached to the tubular body 410.

[0113] The method further comprises heating the panel 100 such that the thermoplastic material 120 at least locally melts. The whole panel 100 may be heated such that all the thermoplastic material 120 melts. The panel may be locally heated near the contact point 438 (Fig. 4d) between the sheet 420 and the tubular body 410. In the embodiment the panel 100 is connected using a sheet 420.

[0114] The method further comprises connecting the panel 100 to the tubular body 410. In an embodiment the panel 100 is connected using a sheet 420.

[0115] The method further comprises winding the panel 100 around the tubular body 410 such that the panel 100 becomes bent. An embodiment comprises winding the sheet 420 around the tubular body 410 such that the panel 100 becomes arranged in between the sheet 420 and the tubular body 410. In this way, the panel 100 is bent to a shape determined by the surface 412 of the tubular body 410.

[0116] The method further comprises letting the panel 100 to cool to solidify the thermoplastic material 120. The panel 100 may be passively let to cool. Alternatively the panel 100 may be actively cooled, whereby the panel 100 is also let to cool. A cooler may be arranged in the device 400 as discussed above. The panel may be let to cool simply by waiting a sufficient time at a reasonable low temperature.

[0117] The method further comprises removing the bent panel from the device 400. An embodiment comprises releasing the sheet to remove the bent panel from the device 400.

[0118] An embodiment comprises tensioning the sheet 420. As the sheet is tensioned, the tension of the sheet 420 bends the panel 100 around the tubular body 410.

[0119] An embodiment comprises arranging the panel 100 on one side of the sheet 420.

[0120] An embodiment comprises releasing the sheet 420. When releasing the sheet, the sheet 420 contracts. In addition, the structure comprising the sheet 420 and the bent panel (e.g. the product 300) is loosened in this
The method comprises removing the bent panel from the device. Some embodiments comprise either
- sliding the bent panel arranged in between the sheet 420 and the surface 412 of the tubular body 410 out from the device 400 in the longitudinal direction 402 (Fig. 4c) or
- moving the device 400 while keeping the bent panel in place such that the panel moves out from the device.

An embodiment comprises moving the bent panel arranged in between the sheet 420 and the surface 412 of the tubular body 410 with respect to the device 400 in the longitudinal direction 402 (Fig. 4c). In an embodiment, the bent panel is moved at least a distance corresponding to the width of the panel.

When winding the panel 100 around the tubular body 410, the layers 110 of the panel 100 slide with respect to each other. The layers 110 slide so that at one end edge (e.g., the edge 142 of Fig. 4e), essentially no sliding occurs. Therefore, when the panel is pressed, the thermoplastic adhesive 120 flows from the first end edge 142 towards a second, opposite end edge 144 (Fig. 4d). Therefore, as a result of the method, the thermoplastic layer of the final product 300 may be uneven. The thermoplastic layer 120 may be thicker at one end 144 than the other 142. Moreover, because the thermoplastic material flows more rapidly near the end edge 144, where more sliding occurs, than at the other end edge 142, the polymer chains of the layer 120 may be oriented differently at one end than the other.

Referring to Figs. 4d to 4f, in an embodiment the sheet 420 is tensioned in such a way that the contact point 438 divides the sheet into two parts. The parts are not separated from each other. At the contact point 438, the panel 100 and/or the sheet 420 detaches from the tubular body 410. A first part 420a of the sheet 420 is wound around the tubular body 410. A second part 420b of the sheet 420 forms a planar sheet, due to the tensioning 440. In Fig. 4d, the second part 420b is parallel to the tangent plane of the tubular body 410, wherein the tangent plane is taken at the contact point 438. Preferably the length of the second part 420b is greater than the length of the panel 100. In this way, the sheet 420 (i.e. the tensioned sheet 420), particularly the second part 420b of the sheet, is arranged to support the panel 100.

Figure 4f shows a device 400 and a panel 100, wherein the sheet 420 comprises the aforementioned two parts 420a and 420b. However, the length of the second part 420b is smaller than the length of the panel 100. Therefore, the second part 420b does not support the panel 100. It is noted that the sheet 420 of Fig. 4f comprises also a third part 420c. Also the third part 420c is planar and parallel to a tangent plane of the tubular body 410. However, the third part 420c is not parallel to the tangent plane of the tubular body 410, wherein the tangent plane is taken at the contact point 438.

The length of the second part 420 may also be adjustable. For example, the roller 490 can be movable. The distance between the roller 490 and the tubular body 470 can be adjustable. The distance between the surface of the roller 490 and the surface of the tubular body 470 can be adjustable between a minimum distance and a maximum distance. The minimum distance may be e.g. from 5 cm to 50 cm. The maximum distance may be e.g. from 10 cm to 10 m. In Fig. 4f, the roller 490 can be movable in the horizontal direction, whereby the sliding of the layers 110 with respect to each other can be controlled. In an embodiment, the sliding is enhanced by said controlling.
embodiment (e.g. Figs. 9g1 to 9g3), no sliding occurs at the end edge 142 due to the means of connecting 418 to the tubular body 410.

[0131] Referring to Figs. 3g and 4b, an embodiment of the method comprises arranging the panel 100 on one side of the sheet 420 such that a grain orientation of a layer 110 of the panel 100 is directed towards the attachment 438. In the embodiment, the layer 110 is the layer that is closest to the first surface 132 or comprises the first surface 132 and the layer comprises wood, wherein the wood has the grain orientation. Moreover, the device 400 comprises the attachment 438 between the sheet 420 and the tubular body 410. An embodiment comprises arranging the panel on one side of the sheet such that during the winding the grain orientation is perpendicular to the longitudinal direction of the tubular body 410 of the device 400.

[0132] In an embodiment of the method, the sheet 420 of the device has a bendability of at least 0.0003/Nm. In an embodiment of the method, the bendability of the sheet 420 related to the tubular body 410 is at least 0.00001 m/N. Other possible values have been recited above.

[0133] In an embodiment, the panel 100 is heated to a high temperature $T_h$, wherein the high temperature $T_h$ is higher than the melting point $T_m$ of the thermoplastic material 120. In an embodiment, the panel 100 is heated to a high temperature $T_h$, wherein the high temperature $T_h$ is higher than the melting point $T_m$ of the thermoplastic material by at least 5 °C, preferably at least 10 °C, and more preferably at least 15 °C degrees. In other words, the difference $T_h - T_m$ may be e.g. at least 5 °C, at least 10 °C, or at least 15 °C.

[0134] In an embodiment, the panel 100 is heated to a high temperature $T_h$, wherein the high temperature $T_h$ is higher than the melting point $T_m$ of the thermoplastic material 120 by at least 65 °C, preferably at most 45 °C, and more preferably at most 20 °C degrees. In other words, the difference $T_h - T_m$ may be e.g. at most 65 °C, at most 45 °C, or at most 20 °C.

[0135] In an embodiment the panel 100 is heated to a high temperature $T_h$, wherein the high temperature $T_h$ is higher than the melting point $T_m$ of the thermoplastic material 120 by at least 65 °C, preferably at most 45 °C, and more preferably at most 20 °C degrees. In other words, the difference $T_h - T_m$ may be e.g. at most 65 °C, at most 45 °C, or at most 20 °C.

[0136] In some embodiments, the panel 100 is heated to a temperature from 80 °C to 200 °C to melt the thermoplastic material. In some of these embodiments, the panel 100 is heated to a temperature from 120 °C to 180 °C to melt the thermoplastic material.

[0137] In an embodiment, the panel 100 (i.e. the bent panel, e.g. the product 300) is cooled or let to cool to a low temperature $T_l$, wherein the low temperature $T_l$ is lower than the melting point $T_m$ of the thermoplastic material 120 by at least 10 °C, preferably at least 30 °C, and more preferably at least 40 °C degrees. In other words, the difference $T_m - T_l$ may be e.g. at least 10 °C, at least 30 °C, or at least 40 °C.

[0138] In an embodiment, the panel 100 (i.e. the bent panel, i.e. the product 300) is cooled or let to cool to a low temperature $T_l$, wherein the low temperature $T_l$ is lower than the melting point $T_m$ of the thermoplastic material 120 by at least 10 °C, preferably at least 30 °C, and more preferably at least 40 °C degrees. In other words, the difference $T_m - T_l$ may be e.g. at least 10 °C, at least 30 °C, or at least 40 °C.

[0139] In an embodiment, the panel 100 (i.e. the bent panel, e.g. the product 300) is cooled or let to cool to a low temperature $T_l$, wherein the low temperature $T_l$ is lower than the melting point $T_m$ of the thermoplastic material 120 by at most 80 °C, preferably at most 60 °C, and more preferably at most 50 °C degrees. In other words, the difference $T_m - T_l$ may be e.g. at most 120 °C, at most 80 °C, or at most 60 °C.

[0140] In some embodiments the panel 100 (i.e. the bent panel, e.g. the product 300) is cooled or let to cool to a low temperature $T_l$, wherein the low temperature $T_l$ is from 0 °C to 90 °C. In some of these embodiments, the panel 100 (i.e. the bent panel, e.g. the product 300) is cooled or let to cool to a low temperature $T_l$, wherein the low temperature $T_l$ is from 15 °C to 40 °C.

[0141] An embodiment of the method comprises rotating the tubular body 410 around an axis 416 parallel to the longitudinal direction, to wind the panel 100 around the tubular body. An embodiment of the method comprises rotating the tubular body 410 around an axis 416 parallel to the longitudinal direction, to wind the sheet 420 around the tubular body 410. In an embodiment, the axis is not a physical axis 426, only an axis of rotation 416, as discussed in connection with Fig. 6b. The device may comprise an axis 426, which may be attached to the tubular body 410 or to the support 412 e.g. using a bearing 428.

[0142] An embodiment of the method comprises cooling the tubular body 410 to solidify the thermoplastic material 120. An embodiment of the method comprises cooling the tubular body 410 using a cooling device.

[0143] An embodiment of the method comprises cooling the tubular body 410 to a second low temperature $T_{l2}$, wherein the second low temperature $T_{l2}$ is lower than the melting point $T_m$ of the thermoplastic material by at least 10 °C, preferably at least 30 °C, and more preferably at least 40 °C degrees. In other words, the difference $T_m - T_{l2}$ may be e.g. at least 10 °C, at least 30 °C, or at least 40 °C.

[0144] An embodiment of the method comprises cooling the tubular body 410 to a second low temperature $T_{l2}$, wherein the second low temperature $T_{l2}$ is lower than the melting point $T_m$ of the thermoplastic material by at most 80 °C, preferably at most 60 °C, and more preferably at most 50 °C degrees. In other words, the difference $T_m - T_{l2}$ may be e.g. at most 80 °C, at most 60 °C, or at most 50 °C.

[0145] An embodiment of the method comprises heating the sheet 420 to keep the temperature of the panel 100 above the melting point $T_m$ of the thermoplastic material 120. In this embodiment, the panel 100 is heated elsewhere, and the heated panel 100 is arranged on one side of the sheet 420.

[0146] An embodiment of the method comprises heating the sheet 420 to heat the panel 100 above the melting point $T_m$ of the thermoplastic material 120. In this embodiment, the panel 100, having a temperature e.g. about
the same as the ambient, is arranged on one side of the sheet 420. Thereafter, the panel 100 is heated using the sheet 420.

[0147] An embodiment of the method comprises heating the sheet to a second high temperature $T_{h2}$, wherein the second high temperature $T_{h2}$ is higher than the melting point $T_{m}$ of the thermoplastic material 120 by at least 5 °C, preferably at least 10 °C, and more preferably at least 15 °C degrees. In other words, the difference $T_{h2} - T_{m}$ may be e.g. at least 5 °C, at least 10 °C, or at least 15 °C.

[0148] An embodiment of the method comprises heating the sheet to a second high temperature $T_{h2}$, wherein the second high temperature $T_{h2}$ is higher than the melting point $T_{m}$ of the thermoplastic material 120 by at most 65 °C, preferably at most 45 °C, and more preferably at at most 20 °C degrees. In other words, the difference $T_{h2} - T_{m}$ may be e.g. at most 5 °C, at most 10 °C, or at most 15 °C.

[0149] In an embodiment, the panel 100, having a temperature e.g. about the same as the ambient, is arranged on one side of the sheet 420. Thereafter, the panel 100 is heated using a heating device. The heating device may be arranged to heat the panel 100 directly. This is shown in Fig. 5, wherein the heater 466 arranged to heat the panel 100 directly. This embodiment the heat from the heating device is transferred directly to the panel 100, i.e. not through the sheet 420. The panel 100 may be directly heated e.g. with infra-red radiation or with convection.

[0150] In an embodiment, before the panel 100 is wound around the tubular body 410, the contact point 438 is used for locating the panel 100. In this embodiment, the device 400 comprises an attachment between the sheet 420 and the tubular body 410. The embodiment comprises locating the panel using the attachment.

[0151] The method comprises tensioning the sheet 420. An embodiment comprises tensioning the sheet 420 to a line tension of at least 0.2 kN/m. An embodiment comprises tensioning the sheet 420 to a line tension of at least 0.5 kN/m. An embodiment comprises tensioning the sheet 420 to a line tension of at least 1 kN/m. The sheet is tensioned in a direction, wherein the direction is perpendicular to the longitudinal direction ±Sx, as depicted in Fig. 4b with the arrow 440. The sheet 420 of the corresponding device 400 may have a line strength of at least the aforementioned line tension.

[0152] An embodiment comprises choosing a line tension according to the flexural stiffness of the panel and the radius or curvature of the tubular body. The embodiment further comprises tensioning the sheet 420 to the line tension.

[0153] As discussed above, the flexural stiffness of a layer i of a panel 100 is proportional to $h_i^3$, wherein $h_i$ is the thickness of the layer. Therefore, the total stiffness of a layered panel 100 is the sum of stiffnesses of all layers 110 of the panel 100. Moreover, in general, for a beam under a load, the deflection at an end of the beam is proportional to the force, proportional to third power of the length of the beam, and inversely proportional to the stiffness. As depicted in Fig. 4a, the panel 100 may be considered a beam. When bending the panel 100, the deflection about a radius of curvature $r$ may be considered to be of the order of $r$. Moreover, when bending the panel 100, the length of the bent part is of the order of $r$, wherein $r$ is the radius of curvature. In this way, the force (e.g. the line force of the sheet 420) needed to bend the panel 100 is proportional to stiffness of the panel 100 and inversely proportional to $r^2$, wherein $r$ is the radius of curvature for bending. Mathematically:

$$ F \propto \frac{1}{r^2} \sum_{i=1}^{N} E_i h_i^3 $$

where $F$ is the line tension of the sheet 420. As depicted in Figs. 7a to 7c, the tubular body may have several different radii of curvature $r$. In the method, when choosing a line tension according to the flexural stiffness of the panel and the radius or curvature of the tubular body, the smallest radius of curvature may be used. Also, if either concave or convex surface is considered to have a negative radius of curvature, the radius of curvature having the smallest absolute value may be used.

[0154] For example, if the panel comprises $N$ layers, each having the thickness of $H/N$, the line force may be chosen to be proportional to $N \times (H/N)^3 r^2$.

[0155] It has surprisingly been found that a line tension of at least 10 MPa $\times N \times (h/N)^3 r^2$ seems to be sufficient in most cases. This seems to apply at least to panels having the thickness up to 4 mm. For panels having the thickness of more than 4 mm, a slightly higher line tension may be applied. For the thicker panels, a line tension of at least 20 MPa $\times N \times (h/N)^3 r^2$ was seen sufficient. In some cases, a line tension of at least 50 MPa $\times N \times (h/N)^3 r^2$ was seen sufficient.

[0156] The elastic modulus of the panel may affect the advantageous line tension. In an embodiment, the elastic modulus of the layer i of the panel is $E_i$. All the layers may have the same elastic constant, or the constant may be different in different layers. An embodiment comprises choosing the line tension according to the flexural stiffness of the panel, the elastic modulus of a layer of the panel, and the radius or curvature of the tubular body. For example, if the elastic modulus of a layer i is $E_i$ the line tension $F$ of the sheet 420 may be proportional as:

$$ F \propto \frac{1}{r^2} \sum_{i=1}^{N} E_i h_i^3 $$

[0157] In an embodiment, wherein all the layers 110 have the same elastic constant $E$, the line tension of the sheet 420 is at least $0.01 \times N \times E \times r^2 \times (H/N)^3$. In an embodiment, wherein all the layers 110 have the same elas-
When the method is performed, and in an arrangement, the sheet 420 has been tensioned to the line tension. Thus, in an arrangement comprising the device 400 and the panel 100, the sheet 420 has a tensile line tension. The line tension may have e.g. one of the aforementioned values. Moreover, since the sheet 420 needs to bear the line tension, the sheet has a line strength. The line strength may have e.g. one of the aforementioned values.

In an arrangement, one end edge, e.g. the end edge 142 is at least partly cut to improve the entrance of the panel 100 to the device 400. For example, a part of the end edge 142 may be removed to increase the frictional forces fixing the panel 100 to the sheet 420.

By the method or the device 400, a product 300 may be manufactured from a panel 100. Figures 3a to 3f show examples of products 300. The products 300 of the figures 3a-3f are obtained with the described process, or the products 300 of the figures 3a-3f are obtainable with the described process.

Referring to Fig. 3a, an embodiment of a product 300 comprises
- a first surface 332 and a second surface 334,
- a first layer 110a in between the first surface 332 and the second surface 334, comprising wood-based material, and optionally comprising the first surface 332 or the second surface 334,
- a second layer 110b in between the first surface 332 and the second surface 334, comprising wood-based material, and optionally comprising the first surface 332 or the second surface 334,
- an adhesive layer 120 in between the first layer 110a and the second layer 110b, the adhesive layer 120 comprising thermoplastic material, wherein
  - the first surface 332 is at least partly convex,
  - the first surface 332 comprises a first point 374 and a first surface normal Sn1 at the first point 374,
  - the first surface 332 comprises a second point 376 and a second surface normal Sn2 at the second point 376,
  - the first surface 332 comprises a path from the first point 374 to the second point 376, and
  - the angle α between the first surface normal Sn1 and the second surface normal Sn2 is at least 45 degrees, wherein the angle is measured along the path.

Preferably the angle α between the first surface normal Sn1 and the second surface normal Sn2 is at least 90 degrees, and more preferably at least 180 degrees.

For example, in Figs. 3a, 3b, and 3c, the angle opens towards the path, i.e. the at least partly convex surface. It is evident that the surfaces of a curvilinear product can be named first and second in any order. For the sake of clarity, the naming is done such that the first surface 332 is at least partly convex.

The term "in between" is to be interpreted in terms of volume or mass. Therefore, even if one layer 110a, 110b forms part of the surface 332, 334, the surface itself has no volume, and therefore no mass. Thus, even if the layer 110a, 110b is a surface layer, the layer is completely in between the surfaces.

Moreover, as discussed above, the first layer 110a is arranged in between the second layer 110b and the first surface 332. In addition, the second layer 110b is arranged in between the first layer 110a and the second surface 334.

It is also understood that the product 300 is made by bending a panel 100. Thus, the first surface 332 of the panel does not comprise an angle. In other words, the radius of curvature of the first surface is, at all points of the surface, defined. Moreover, the radius of curvature of the first surface is, at all points of the surface, is greater than zero.

The products of Figs. 3a to 3e have the shape of an extending profile. The profile extends in a longitudinal direction ±Sx. The figures 3a to 3e show the cross section of the product in a plane having its normal parallel to the longitudinal direction. The cross section may form an open line, as in Figs. 3a, 3b, or 3d. An open line in general comprises two end points, such as the end points 374 and 376 (Figs. 3a and 3b). Alternatively, the cross section forms a closed loop, as depicted in Figs. 3c and 3e. In an embodiment, the cross section forms a circular cross section. In an embodiment, the cross section forms an oval cross section. In an embodiment, the cross section forms a cross section having the shape of a rounded rectangle. These cross sections may be open or closed. The products with closed cross sections may be used e.g. as pipes or tubes. The products with open cross sections may be used e.g. as chutes or covers.

In an embodiment, the cross section forms a closed loop that is at least essentially oval. In this embodiment, the distance between every point of the cross section and an ellipse is at most 0.125 × (R1 + R2), wherein R1 and R2 are the two radii of the ellipse. In an embodiment, the cross section forms a closed loop that is at least essentially circular. In this embodiment, the distance between every point of the cross section and a circle is at most 0.25rR, wherein R is the radius of the circle.

The product 300 may comprise a surface layer (not shown, however, for the panel, cf. Fig. 1c). The surface layer may be arranged or attached to a bent panel. The surface layer may comprise at least one of wood, paint, lacquer, stain, cloth, fabric, paper, felt, elastomer such as rubber, metal, glass, poly(methyl methacrylate) (PMMA), and phenol. The surface layer may have the form of film, veneer, laminate, or high pressure laminate. The surface layer may be attached to a bent panel or the
The angle \( \alpha \) may open towards the path, wherein the path is comprised by the first surface 332. Referring to Fig. 3b, this means that the angle \( \alpha \) may also be more than 180 degrees. For example, the angle \( \alpha \) between the first surface normal Sn1 and the second surface normal Sn2, wherein the angle opens towards the path, may be at least 270 degrees, preferably at least 330 degrees.

Referring to Fig. 3d, in an embodiment, the cross section of the product forms an open line (as discussed above). Moreover, in an embodiment, the angle \( \alpha \) between the first surface normal Sn1 and the second surface normal Sn2 is more than full circle, i.e. 360 degrees. This is, because the angle is measured along the path, and may thus be more than full circle.

Referring to Figs. 3d and 3e, some embodiments of the product comprise an overlapping area 310. The overlapping area 310 comprises
- a first part of the product 300, the first part of the product comprising a first part of the first layer 110a and a first part of the second layer 110b, and
- a second part of the product 300, the second part of the product comprising a second part of the first layer 110a and a second part of the second layer 110b.

In the overlapping area 310 the first part of the product 300 and the second part of the product 300 are arranged to overlap. The parts of the product may be arranged to overlap, e.g. such that a line perpendicular to longitudinal direction and parallel to a surface normal of the overlapping area penetrates both the first part of the product 300 and the second part of the product 300.

Referring to Fig. 3f, in an embodiment the overlapping area 310 extends in the longitudinal direction \( \pm S_x \). The overlapping area 310 may extend straight in the longitudinal direction, as shown in Fig. 3f.

When the product comprises an overlapping area 310, the thickness of the product is not constant. Therefore, when the overlapping area 310 is present, the product has a first thickness at a first location and a second thickness at a second location. The second thickness may be measured, e.g. at the overlapping area 310. Because of the overlapping area 310, and the non-uniform thickness, the second thickness is greater than the first thickness.

As discussed above, when winding the panel 100 around the tubular body 410, the layers 110 of the panel 100 slide with respect to each other differently at different locations. Thereby
- the thickness of the layer 120 may change, and/or
- the polymer chains of the layer 120 may orient during bending.

In an embodiment, wherein the product 300 does not form a closed loop
- the cross-section of the product comprises two end points and
- at a boundary area near the first end point the adhesive layer 120 has a first thickness, and
- at a boundary area near the second end point the adhesive layer 120 has a second thickness, and
- the second thickness is greater than the first thickness.

In an embodiment, the first end point is located near the end edge 142 that is perpendicular to the first surface. The term "near the end point" refers to a boundary area wherein the distance between each point of the area and the end point is less than 1/5 (on fifth) of the distance between the two end points, as measured along the product 300. In an embodiment, the second thickness is greater than the first thickness by at least 1 %, such as at least 2 %.

In another embodiment,
- the cross-section of the product forms a closed loop,
- the product comprises a seam,
- on a first side of the seam, the adhesive layer 120 has a first thickness, and
- on a second side of the seam, the adhesive layer 120 has a second thickness, and
- the second thickness is greater than the first thickness.

In an embodiment, the second thickness is greater than the first thickness by at least 1 %, such as at least 2 %.

In an embodiment, wherein the product 300 does not form a closed loop
- the cross-section of the product comprises two end points and
- at a boundary area near the first end point the adhesive layer 120 has a first polymer orientation, and
- at a boundary area near the second end point the adhesive layer 120 has a second polymer orientation, and
- the second polymer orientation is different from the first polymer orientation.

The term "near the end point" refers to a boundary area wherein the distance between each point of the area and the end point is less than 1/5 (on fifth) of the distance between the two end points, as measured along the product 300.

In another embodiment,
- the cross-section of the product form a closed loop,
- the product comprises a seam,
- on a first side of the seam, the adhesive layer 120 has a first polymer orientation, and
- on a second side of the seam, the adhesive layer 120 has a second polymer orientation, and
- the second polymer orientation is different from the first polymer orientation.

[0184] Referring to Figs. 3d, 3e, and 4e, in an embodiment, an edge 142 of the product is perpendicular to a surface 332, 334 of the product. Moreover, unless machined to a perpendicular plane, the product 300 may comprise another edge 144 that is not perpendicular to the surface 332, 334. This embodiment comprises a planar end edge 142 and an intersection of the planar end edge 142 and the first surface 332. It is noted that as the edge 142 is an end edge, the surface normal of the first surface, determined along the intersection, is constant. Thus, the end edge 142 is not curvilinear. In contrast, the product may also comprise curvilinear side edges. Also the curvilinear side edges may be perpendicular to the first surface 332. Moreover, as the end edge 142 is perpendicular to the first surface 332, the plane of the planar end edge 142 comprises the surface normal of the first surface 332 at the intersection.

[0185] Referring to Fig. 3g, in an embodiment the layer 110a that is closest to the first surface 132 or comprises the first surface 132 comprises wood. However, as discussed above, the layer 110a may comprise sub-layers being attached to each other using thermoset adhesive. The grain orientation in these sub-layers is not necessarily the same. The layer 110a comprises wood at a first location 337, wherein the wood has a grain orientation 241 at the first location 337. The term grain orientation (i.e. grain direction) was discussed in connection with Figs. 2a to 2d. The first location 337 defines a tangent plane 335 for the first surface 132. Moreover, the grain orientation 241 is parallel to the tangent plane 335 and perpendicular to a longitudinal direction of the first surface 132. The longitudinal direction of the first surface 335 is defined by the intersection of the tangent plane 335 and the first surface 132. The longitudinal direction of the first surface 335 is perpendicular to a plane of Fig. 3g. The grain orientations of the three layers 110a, 110b, and 110c are depicted in the figure. The same convention is used as in Fig. 2a.

[0186] Preferably the product 300 comprises an odd number of layers 110. In such a case, both the topmost layer and the bottommost layer comprise wood having this grain orientation. The embodiment of Fig. 3g comprises three layers 110a, 110c, and 110b. The grain orientation of both the layer 110a and the layer 110b is parallel to the tangent plane and perpendicular to the longitudinal direction. For example, the point 337 defines the tangent plane 335 for the first surface 132. The longitudinal direction of the tangent plane 335 is defined by the intersection of the tangent plane 335 and the first surface 132. The grain orientation 241 of the first layer 110a is parallel to the tangent plane 335 and perpendicular to the longitudinal direction. The same applies for the grain orientation 243 and the second surface 334, since the number of layer is odd and the grain orientations of the layers are arranged alternating.

[0187] In the product at least one layer 110 is arranged such that the layer comprises wood having a grain orientation that is perpendicular to the longitudinal direction. The shape of the product 300 is stable partly because of the adhesive material 120 and partly because at least one layer has such orientated grains. Preferably every second layer has a grain orientation perpendicular to the longitudinal direction.

[0188] In addition to structural stability, the preferred grain orientation makes the topmost and/or bottommost layer more resistant to cracking. It has been noticed that, in a bent panel, provided that the grain orientation is parallel to a bending axis, micro cracks are easily formed on the product during bending.

[0189] It is further noted that the topmost layer (e.g. 110a) may comprise two sub-layers. In the topmost sub-layer the grain orientation may be oriented in the longitudinal direction, even if the topmost layer 110 comprises wood, wherein the grain orientation is perpendicular to the longitudinal direction. In this embodiment, the sub-layers may be attached to each other using thermoset adhesive. In this way, the sub-layers mechanically support each other even at the high temperature, since the thermoset adhesive noes not melt. In this way, the topmost sub-layer can withstand bending even if the grain orientation of the sub-layer is not as described above. However, the other sub-layer comprises grains having the orientation perpendicular to the longitudinal direction ±Sx.

[0190] Referring to Figs. 7c and 7d, the product may have different radii of curvature, depending on the location on the surface, where the radius is determined. The figure 7d shows, in an end view, an embodiment of a product 300 having been made by the device of Fig. 7c. As discussed above, the first surface 332 is at least partly convex. In Fig. 7d, the first surface 332 comprises a first area 333. The first area 333 is concave.

[0191] The radius (or radii) of curvature of the product 300 depends on the device 400. The radius of curvature is not necessarily constant. As the product 300 comprises (or is) a bent panel, the radius of curvature depends on the line of which radius of curvature is measured. In the following, the radius (or radii) of curvature is (or are) defined from the cross section of the profile. The cross section was discussed in more detail above. The cross section defines the line from which the radius (or radii) of curvature is (or are) measured.

[0192] In an embodiment the first surface 332 comprises a second area from which the radius of curvature is measured. In an embodiment, the radius of curvature of the second area is at most 2.5 m, preferably at most 1.3 m or at most 1 m. It is further noted, that the radius of curvature here is defined to be always positive. Thereby the centre for defining the radius of curvature may be located on the opposite side of the product. In some embodiments, the radius of curvature of the second area is at least 2 mm, preferably at least 3 mm or at least 5 mm.
[0193] The product 300 inherits its material properties from the corresponding panel 100. Therefore, any of the material properties discussed above for the panel is applicable also for some products 300.

[0194] In an embodiment of the product 300, the first layer 110a comprises wood and the second layer 110b comprises wood. If the product is coated on a first side, the first layer 110a may further comprise a surface layer comprising a surface 332, 334 of the product 300. The first layer 110a may also be located inside the product 300. If the product is coated from a second side, the second layer 110b may further comprise a second surface layer comprising another surface 334, 332 of the product 300.

[0195] In an embodiment, the thickness of the first layer is at least 0.1 mm. The thickness of another or all layers 110 may be in this range. Preferably the thickness of all layers is in this range.

[0196] In an embodiment, the thickness of the first layer is at most 5 mm. The thickness of another or all layers 110 may be in this range. Preferably the thickness of all layers is in this range.

[0197] Preferably the thicknesses of the wooden layers 110 are equal or substantially equal. In an embodiment, the ratio of the thickness of the thickest wooden layer 110 to the thickness of the thinnest wooden layer 110 is at most 10. In an embodiment the ratio of the thickness of the first wooden layer to the thickness of the second wooden layer is from 0.1 to 10. In an embodiment, the topmost wooden layer and the bottommost wooden layer are thinner than the other layers, while the other layers are substantially equally thick. The other layers are substantially equally thick, when the ratio of the thickness of the thickest of these layers to the thickness of the thinnest of these layers is at most 2.

[0198] In an embodiment, at least one of the layers 110 is made of hardwood. Preferably at least the topmost layer 110 is made of hardwood. Preferably also the bottommost layer 110 is made of hardwood. In an embodiment all the wooden layers 110 comprise hardwood. Hardwood is wood from angiosperm trees or from monocotyledons. Hardwood contrasts with softwood (which comes from Gymnosperm trees, also called conifers). The list of angiosperm trees (hardwood) is wide, and includes e.g. alder, apple, aspen, birch, cherry, ebony, elm, eucalyptus, hickory, mahogany, maple, oak, rosewood, teak, walnut, and willow. The list of monocotyledons (hardwood) is less wide, including bamboo and coconut. In particular, the wooden layer may comprise birch. Even if in principle possible, the visual appearance of a product 300, made by bending a softwood panel 100, could be deteriorated, because of the problem of resin flow at elevated temperatures. The elevated temperature is needed to melt the thermoplastic material 120.

[0199] The layers 110 may comprise wooden veneers, as discussed for the panels. The veneers may have been made by means discussed above. In some embodiments, at least one layer has been manufactured by one of sawing, rotary cutting, flat slicing, quarter slicing, half-round slicing, and rift cutting. In some embodiments, all the wooden layers have been manufactured by one of sawing, rotary cutting, flat slicing, quarter slicing, half-round slicing, and rift cutting.

[0200] In some embodiments, at least one wooden layer has been manufactured by rotary cutting. In some embodiments, all the wooden layers have been manufactured by rotary cutting. In some embodiments, at least one wooden layer has been manufactured by sawing. In some embodiments, all the wooden layers have been manufactured by sawing.

[0201] Some preferred fibre orientations were discussed above for the panel 100, in particular for a plywood panel 200. The same applies also for the product 300. Therefore, in an embodiment

- the first layer 110a comprises wood-based material having a first grain orientation,
- the second layer 110b is adjacent to the first layer 110a, and
- the second layer 110b comprises wood-based material having a second grain orientation, wherein
- the second grain orientation forms an angle with the first grain orientation, wherein
- the angle is at least 75 degrees, preferably at least 85 degrees.

[0202] However, another layer 110 may be arranged in between the first layer 110a and the second layer 110b. Thus, an embodiment comprises

- a second thermoplastic adhesive layer 120 attached directly to the first layer 110a, and
- a third layer 110 comprising wood based material attached directly to the second thermoplastic adhesive layer 120, wherein
- the first layer 110a comprises wood-based material having a first grain orientation,
- the third layer 110 comprises wood-based material having a second grain orientation, wherein
- the second grain orientation forms an angle with the first grain orientation, wherein
- the angle is at least 75 degrees, preferably at least 85 degrees.

[0203] The thickness of the product 300 is preferably at least 0.5 mm. The thickness of the product 300 is preferably at most 50 mm.

[0204] In an embodiment, the product 300 comprises plywood that comprises thermoplastic adhesive. Such a plywood comprises thermoplastic material 120 in between wooden layers 110. In an embodiment, the thermoplastic material 120 in between the layers 110 comprises at least one of polyvinyl alcohol, polylefin, lignin, polyethylene, polypropylene, and a co-polymer comprising ethylenes and propylenes. Preferably the thermoplastic material 120 comprises polyethylene. The melting
point of the thermoplastic material 120 may be e.g. from 100 °C to 120 °C.

Examples

[0205] In an embodiment a panel 100 consisted of 3 wooden layers. Each layer had the thickness 0.6 mm, whereby the thickness of the panel was about 2 mm. The panel 100 was bent to a radius of curvature of 10 mm. The radius of curvature corresponds to the inner radius of curvature. In this way, a product 300 was obtained.

[0206] In an embodiment a panel consisted of 3 wooden layers. Each layer had the thickness 0.4 mm, whereby the thickness of the panel was about 1.5 mm. The panel was bent to a radius of curvature of 3 mm. The radius of curvature corresponds to the inner radius of curvature.

[0207] In an embodiment a panel consisted of 3 wooden layers. Each layer had the thickness 1.5 mm, whereby the thickness of the panel was about 5 mm. The panel was bent to a radius of curvature of 20 mm. The radius of curvature corresponds to the inner radius of curvature.

Numbered examples

[0208] The following numbered examples summarise some features of the embodiments.

101. A product 300 comprising

- a first surface 332 and a second surface 334,
- a first layer 110a in between the first surface 332 and the second surface 334, comprising wood-based material, and optionally comprising the first surface 332 or the second surface 334,
- a second layer 110b in between the first surface 332 and the second surface 334, comprising wood-based material, and optionally comprising the first surface 332 or the second surface 334,
- an adhesive layer 120 in between the first layer 110a and the second layer 110b, the adhesive layer 120 comprising thermoplastic material, wherein
  - the first surface 332 is at least partly convex,
  - the first surface 332 comprises a first point 374 and a first surface normal Sn1 at the first point 374,
  - the first surface 332 comprises a second point 376 and a second surface normal Sn2 at the second point 376,
  - the first surface 332 comprises a path from the first point 374 to the second point 376, and
  - the angle $\alpha$ between the first surface normal Sn1 and the second surface normal Sn2 is at least 45 degrees, wherein the angle is measured along the path.

In some embodiments, the angle $\alpha$ between the first surface normal Sn1 and the second surface normal Sn2 is at least 90 degrees. In some embodiments, the angle $\alpha$ between the first surface normal Sn1 and the second surface normal Sn2 is at least 180 degrees.

102. The product 300 of example 101, wherein

- the angle $\alpha$ between the first surface normal Sn1 and the second surface normal Sn2, wherein the angle $\alpha$ is measured along the path, is at least 270 degrees and preferably at least 330 degrees.

103. The product 300 of example 101 or 102, wherein

- the product 300 has the shape of an extending profile, the profile extending in a longitudinal direction $\pm Sx$,
- the cross section of the product 300 in a plane having its normal parallel to the longitudinal direction $\pm Sx$ forms an open line, and
- the angle $\alpha$ between the first surface normal Sn1 and the second surface normal Sn2 is more than 360 degrees.

104. The product 300 of example 101 or 102, wherein

- the product 300 has the shape of an extending profile, the profile extending in a longitudinal direction $\pm Sx$, and
- the cross section of the product 300 in a plane having its normal parallel to the longitudinal direction $\pm Sx$ forms a closed loop.

105. The product 300 of example 104, wherein

- the product 300 comprises an overlapping area 310, wherein the overlapping area 310 comprises
  - a first part of the product 300, the first part of the product 300 comprising a first part of the first layer 110a and a first part of the second layer 110b, and
  - a second part of the product 300, the second part of the product 300 comprising a second part of the first layer 110a and a second part of the second layer 110b, wherein
  - the first part of the product 300 and the second part of the product 300 are arranged to overlap.

106. The product 300 of example 105, wherein

- the overlapping area 310 extends in the longitudinal direction $\pm Sx$. 

107. The product 300 of the example 105 or 106, wherein
- the product 300 has a first thickness at a first location and a second thickness at a second location, wherein the second location is in the overlapping area 310, and
- the second thickness is greater than the first thickness.

108. The product 300 of any of the examples 101 to 103, wherein the product comprises
- a planar end edge 142, and
- an intersection of the planar end edge 142 and the first surface 332 such that
- the surface normal of the first surface 332, determined along the intersection, is constant, and
- the plane of the planar end edge 142 comprises the surface normal of the first surface 332 at the intersection.

109. The product 300 of any of the examples 101 to 108, wherein
- the first surface 332 comprises a first area 333, wherein
- the first area 333 is concave.

110. The product 300 of any of the examples 101 to 109, wherein
- the first surface 332 comprises a second area, wherein
- the radius of curvature of the second area is at most 2.5 m, preferably at most 1.3 m or at most 1 m.

111. The product 300 of the example 110, wherein
- the radius of curvature of the second area is at least 2 mm, preferably at least 3 mm or at least 5 mm.

112. The product 300 of any of the examples 101 to 111, wherein
- the first layer 110a comprises wood, wherein
- the second layer 110b comprises wood, optionally, the first layer 110a comprises a surface layer comprising the first surface 332 of the product 300, and
- optionally, the second layer 11b comprises a second surface layer comprising the second surface 334 of the product 300.

113. The product 300 of the example 112, wherein
- the thickness of the first layer 110a is at least 0.1 mm

114. The product 300 of the example 112 or 113, wherein
- the thickness of the first layer 110a is at most 5 mm.

115. The product 300 of any of the examples 112 to 114, wherein
- the ratio of the thickness of the first layer 110a to the thickness of the second layer 110b is from 0.1 to 10.

116. The product 300 of any of the examples 112 to 115, wherein
- the first layer 110a or the second layer 110b comprises hardwood.

117. The product 300 of any of the examples 112 to 116, wherein
- at least part of the first layer 110a and/or at least part of the second layer 110b has been manufactured by one of sawing, rotary cutting, flat slicing, quarter slicing, half-round slicing, and rift cutting.

118. The product 300 of the example 117, wherein
- at least part of the first layer 110a and/or at least part of the second layer 110b has been manufactured by sawing or rotary cutting.

119. The product 300 of any of the examples 101 to 118, wherein
- the first layer 110a comprises wood-based material having a first grain orientation, wherein
- the second layer 110b is adjacent to the first layer 110a, and
- the second layer 110b comprises wood-based material having a second grain orientation, wherein
- the second grain orientation forms an angle with the first grain orientation, wherein
- the angle is at least 75 degrees, preferably at least 85 degrees.

120. The product 300 of any of the examples 101 to 118, comprising
- a second thermoplastic adhesive layer 120 attached directly to the first layer 110a, and
- a third layer 110 comprising wood based mate-
rial attached directly to the second thermoplastic adhesive layer 120, wherein
- the first layer 110a comprises wood-based material having a first grain orientation,
- the third layer 110 comprises wood-based material having a second grain orientation, wherein
- the second grain orientation forms an angle with the first grain orientation, wherein
- the angle is at least 75 degrees, preferably at least 85 degrees.

121. The product 300 of any of the examples 101 to 120, wherein
- the thickness of the product 300 is at least 0.5 mm.

122. The product 300 of any of the examples 101 to 121, wherein
- the thickness of the product 300 is at most 50 mm.

123. The product 300 of any of the examples 101 to 122, comprising
- plywood that comprises thermoplastic adhesive.

124. The product 300 of any of the examples 101 to 123, wherein
- the thermoplastic material 120 in between the layers 110 comprises at least one of polyvinyl alcohol, polyolefin, lignin, polyethylene, polypropylene, and a co-polymer comprising ethylenes and propylenes.

125. The product 300 of the example 124, wherein
- the thermoplastic material 120 comprises polyethylene.

126. The product 300 of the example 125, wherein
- the melting point of the thermoplastic material 120 is from 100 °C to 120 °C.

127. The product 300 of any of the examples 101 to 124, wherein
- the layer (110a, 110b) that is closest to the first surface 332 or comprises wood at a location 337, wherein the wood has a grain orientation at the location 337, wherein
- the location 337 defines a tangent plane 335 for the first surface 332, and
- the grain orientation is parallel to the tangent plane 335 and perpendicular to a longitudinal direction ±Sx of the first surface 332, wherein the longitudinal direction ±Sx is defined by the intersection of the tangent plane 335 and the first surface 332.

128. The product 300 of example 104, wherein
- the cross section of the product 300 at least approximately circular, whereby
- the distance between every point of the cross section and a circle is at most 0.25xR, wherein R is the radius of the circle.

129. A product having been made by the process of any of the examples 401 to 431

130. A product obtainable by the process of any of the examples 401 to 431

201. A device 400 for bending a panel 100, the device 400 comprising
- a tubular body 410 extending in a longitudinal direction ±Sx and having a surface 412, wherein
- means (418, 420) for connecting a panel 100 to the tubular body 410, and
- means for detaching the panel 100 from the tubular body 410.

202. A device 400 for bending a panel 100, the device 400 wherein
- at least one end of the tubular body 410 is detachable from a support 424 such that a bent panel is removable from the device 400.

203. The device 400 of example 201 or 202, wherein
- the tubular body 410 is arranged to rotate about an axis of rotation 416, wherein the axis of rotation 416 is parallel to the longitudinal direction ±Sx.

204. The device 400 of example 203, wherein
- the tubular body 410 is attached to a support 422 using at least one bearing 428.

205. The device 400 of any of the examples 201 to 204, comprising
- a cooler arranged to cool the tubular body 410.

206. The device 400 of the example 205, wherein
- the cooler arranged to cool the tubular body 410
using a heat transfer medium.

207. The device 400 of any of the examples 201 to 206, comprising

- a heater 466 arranged to heat a panel 100.

208. The device 400 of any of the examples 201 to 207, wherein

- the tubular body 410 has a cross section, wherein the cross section is taken along a plane having a surface normal parallel to the longitudinal direction $\pm S_x$,
- the cross section has a first dimension $d_1$ in a first direction perpendicular to the longitudinal direction $\pm S_x$, and
- the cross section has a second dimension $d_2$ in a second direction perpendicular to the longitudinal direction $\pm S_x$ and perpendicular to the first direction, wherein
- the smaller of the first and the second dimension, $\min(d_1,d_2)$, is at least 4 mm.

209. The device 400 of any of the examples 201 to 208, wherein

- the tubular body 410 has a cross section, wherein the cross section is taken along a plane having a surface normal parallel to the longitudinal direction $\pm S_x$,
- the cross section has a first dimension $d_1$ in a first direction perpendicular to the longitudinal direction $\pm S_x$, and
- the cross section has a second dimension $d_2$ in a second direction perpendicular to the longitudinal direction $\pm S_x$ and perpendicular to the first direction, wherein
- the larger of the first and the second dimension, $\max(d_1,d_2)$, is at most 2.5 m.

210. The device 400 of any of the examples 201 to 209, wherein

- the tubular body 410 has a length in the longitudinal direction, and
- the length is from 10 mm to 20 m.

211. The device 400 of any of the examples 201 to 210, comprising

- a second tubular body 470 extending in a second longitudinal direction and having a second surface 472, wherein
- the second longitudinal direction is parallel to the longitudinal direction $\pm S_x$, and
- the second surface 472 is arranged within a distance from the surface 412 of the tubular body 410 such that the second surface 472 is arranged to press a panel 100 in between the second surface and the surface 412 of the tubular body 410.

[0209] Optionally, the second surface 472 is arranged within a distance from the surface 412 of the tubular body 412 such that the second surface 472 is arranged to press a panel 100 in between a sheet 420 of the device and the surface 412 of the tubular body 410.

212. The device 400 of the example 211, wherein

- the second tubular body 470 has a second cross section, wherein the second cross section is taken along a plane having a surface normal parallel to the longitudinal direction $\pm S_x$, and the second cross section is circular.

213. The device 400 of the example 212, wherein

- the tubular body 410 has a cross section, wherein the cross section is taken along a plane having a surface normal parallel to the longitudinal direction $\pm S_x$,
- the cross section has a first dimension $d_1$ in a first direction perpendicular to the longitudinal direction $\pm S_x$, and
- the cross section has a second dimension $d_2$ in a second direction perpendicular to the longitudinal direction $\pm S_x$ and perpendicular to the first direction, wherein
- the larger of the first and the second dimension, $\max(d_1,d_2)$, is larger than the diameter of the second tubular body 470.

214. The device 400 of any of the examples 201 to 213, wherein

- the tubular body 410 comprises material having, at the temperature of 300 K, a thermal conductivity at least 15 W/mK.

215. The device 400 of any of the examples 201 to 214, wherein

- the tubular body 410 comprises metal.

216. The device 400 of the example 215, wherein

- the tubular body 410 comprises steel, such as stainless steel.

217. The device of any of the examples 201 to 216, comprising

- at least a hole 502 having an inlet 504 part and a locking part 506, wherein
the hole 502 forms means for connecting a clamp 495 to the tubular body 410, and the clamp 495 may be used to connect a panel 100 to the clamp 495.

218. The device of any of the examples 201 to 216, comprising
- a sheet 420 attached to the tubular body 410,
  wherein
- the sheet 420 is bendable such that the sheet 420 may be wound around the tubular body 410, whereby
- the sheet 420 forms the means for connecting a panel 100 to the tubular body 410.

219. The device of the example 218, comprising
- a support 465, wherein the surface normal of the support forms an angle with the horizontal plane, wherein the angle is at least 60 degrees; preferably at least 80 degrees, wherein
- the sheet 420 is arranged on the support 465.

220. The device of the example 218 or 219, comprising
- a heater 460 arranged to heat the sheet 420.

221. The device of the example 219, comprising
- a heater 460, wherein
- the heater 460 is arranged to heat the support 465.

222. The device 400 of any of the examples 218 to 221, wherein
- the surface 412 of the tubular body comprises 410 a concave area 414 and
- the device 400 comprises pressing part 416, arranged to press a panel 100 against the concave area 414, wherein
- the shape of the pressing part 416 is adapted to the shape of the concave area 414.

223. The device of the example 222, wherein
- the sheet 420 comprises the pressing part 416.

224. The device of any of the examples 218 to 223, wherein
- the sheet 420 comprises at least one marking 432 for locating a panel 100 with respect to the sheet 420.

225. The device of any of the examples 218 to 224, wherein
- the sheet 420 comprises at least one projection 434, arranged to locate a panel 100 with respect to the sheet 420, and
- the tubular body 410 comprises at least one hole, adapted to the at least one projection 434.

226. The device of any of the examples 218 to 225, wherein
- the sheet 420 comprises a hole 436, wherein the shape of the hole 436 is adapted to the shape of a panel 100, to locate a panel 100 in respect to the sheet 420.

227. The device of any of the examples 218 to 226, wherein
- the sheet 420 has a tensile line strength of at least 0.2 kN/m, whereby the sheet 420 can bear the load needed to bend a panel 100 in between the sheet 420 and the surface 412 of the tubular body 410.

228. The device of any of the examples 218 to 227, wherein
- the sheet 420 comprises a continuous layer of metal such as stainless steel.

229. The device of the example 228, wherein
- the thickness of the sheet 420 is at most 2.5 mm.

230. The device of any of the examples 218 to 229, wherein
- the sheet 420 comprises a mesh comprising metal such as stainless steel.

231. The device of any of the examples 218 to 230, wherein
- the sheet 420 comprises a first sheet layer comprising an elastomer, and
- the sheet 420 comprises a second sheet layer comprising a support, wherein
- the second sheet layer is attached to the first sheet layer.

232. The device of the example 231, wherein
- the first sheet layer comprises rubber.

233. The device of the example 231 or 232, wherein
- the second sheet layer comprises fibrous mate-
rial, such as cloth, fabric, glass fibres, or carbon fibres.

234. The device of the example 231 or 232, wherein the second sheet layer comprises a mesh comprising metal.

235. The device of any of the examples 218 to 234, wherein the sheet 420 is mechanically stable in the temperatures from -10 °C to 200 °C, whereby the sheet 420 can tolerate a temperature needed to melt a thermoplastic layer 120 in between layers 110 of a panel 100.

236. The device of any of the examples 218 to 235, wherein the sheet 240 comprises ductile material and the yield strain of the sheet 240 is at least 0.28 %.

237. The device of any of the examples 218 to 236, wherein the sheet 420 detaches from the tubular body 410 at a contact point 438, and the sheet 420 comprises a first part 420a and a second part 420b, wherein the first part 420a is wound around the tubular body 410 and the second part 420b forms a planar sheet, such that the second part 420b is parallel to the tangent plane of the tubular body 410, wherein the tangent plane is taken at the contact point 438.

238. The device of any of the examples 218 to 237, wherein the sheet 420 has a thickness Hs, and an elastic constant Es, whereby the sheet 420 has a bendability of 1/(Es×Hs²), and the bendability is at least 0.0003/Nm.

239. The device of any of the examples 218 to 238, wherein the sheet 420 has a thickness Hs, and an elastic constant Es, the tubular body 410 has a minimum radius of curvature of r, whereby the bendability of the sheet 420 related to the tubular body 410 is r²/(Es×Hs³), and the bendability of the sheet 420 related to the tubular body 410 is at least 0.00001 m/N.

301. An arrangement comprising the device 400 of any of the examples 201 to 239 and a panel 100 comprising

- a first surface 132 and a second surface 134,
- a first layer 110a arranged in between the first surface 132 and the second surface 134, comprising wood-based material, and optionally comprising the first surface 132 or the second surface 134,
- a second layer 110b arranged in between the first surface 132 and the second surface 134, comprising wood-based material, and optionally comprising the first surface 132 or the second surface 134, and
- an adhesive layer 120 in between the first layer 110b and the second layer 110b, the adhesive layer 120 comprising thermoplastic material.

302. The arrangement of the example 301 or 302, wherein the coefficient of friction in between the panel 100 and the tubular body 410 is at least 0.15, preferably from 0.2 to 0.4.

303. The arrangement of any of the example 301 or 302, wherein the panel 100 comprises the technical features derivable from the examples 112 - 126.

304. The arrangement of any of the examples 301 to 303, wherein the first layer 110a of the panel 100 comprises wood, and the second layer 110b of the panel 100 comprises wood.

305. The arrangement the example 304, wherein the thickness of the first layer 110a is at least 0.1 mm.

306. The arrangement of the example 304 or 305, wherein the thickness of the first layer is 110a at most 5 mm.

307. The arrangement of any of the examples 304 to 306, wherein the ratio of the thickness of the first layer 110a to the thickness of the second layer 110b is from
0.1 to 10.

308. The arrangement of any of the examples 304 to 307, wherein
- the first layer 110a or the second layer 110b comprises hardwood.

309. The arrangement of any of the examples 304 to 308, wherein
- at least part of the first layer 110a and/or at least part of the second layer 110b has been manufactured by one of sawing, rotary cutting, flat slicing, quarter slicing, half-round slicing, and rift cutting.

310. The arrangement of any of the examples 304 to 309, wherein
- at least part of the first layer 110a and/or at least part of the second layer 110b has been manufactured by rotary cutting or sawing.

311. The arrangement of any of the examples 301 to 310, wherein
- the first layer 110a of the panel 100 comprises wood-based material having a first grain orientation,
- the second layer 110b of the panel 100 is adjacent to the first layer 110a, and
- the second layer 1110b comprises wood-based material having a second grain orientation, wherein
- the second grain orientation forms an angle with the first grain orientation, wherein
- the angle is at least 75 degrees, preferably at least 85 degrees.

312. The arrangement of any of the examples 301 to 310, wherein the panel 100 comprises
- a second thermoplastic adhesive layer 120 attached directly to the first layer 110a, and
- a third layer 110 comprising wood based material attached directly to the second thermoplastic adhesive layer 120, wherein in the panel 100,
- the first layer 110a comprises wood-based material having a first grain orientation,
- the third layer 110 comprises wood-based material having a second grain orientation, wherein
- the second grain orientation forms an angle with the first grain orientation, wherein
- the angle is at least 75 degrees, preferably at least 85 degrees.

313. The arrangement of any of the examples 301 to 312, wherein
- the thickness of the panel 100 is at least 0.5 mm.

314. The arrangement of any of the examples 301 to 313, wherein
- the thickness of the panel 100 is at most 50 mm.

315. The arrangement of any of the examples 301 to 314, wherein
- the panel 100 comprises plywood that comprises thermoplastic adhesive.

316. The arrangement of any of the examples 301 to 315, wherein
- the thermoplastic material 120 in between the layers 110 of the panel 100 comprises at least one of polyvinyl alcohol, polyolefin, lignin, polyethylene, polypropylene, and a co-polymer comprising ethylenes and propylenes.

317. The arrangement of any of the examples 301 to 316, wherein
- the thermoplastic material 120 of the panel 100 comprises polyethylene.

318. The arrangement of any of the examples 301 to 317, wherein
- the melting point of the thermoplastic material 120 of the panel 110 is from 100 °C to 120 °C.

319. The arrangement of any of the examples 301 to 318, wherein
- the layer 110 of the panel 100 that is closest to the first surface 132 of the panel 100 or comprises the first surface 132 of the panel 100 comprises wood, wherein the wood has a grain orientation, and
- the grain orientation is directed towards the means (418, 420) for connecting a panel 100 to the tubular body 410.

320. The arrangement of any of the examples 301 to 319, wherein
the device 400 comprises
- a sheet 420 attached to the tubular body 410, wherein
- the sheet 420 forms the means for connecting a panel 100 to the tubular body 410.

321. The arrangement of the example 320, wherein
- the coefficient of friction in between the panel 100 and the sheet 420 is at least 0.15, preferably from 0.2 to 0.4.

322. The arrangement of example 320 to 321, wherein
- the panel 100 comprises N layers, and
- the panel 100 has a thickness of H, whereby
- the flexural stiffness of the panel 100 is proportional to $N \times (H/N)^3$, and
- the tubular body 410 has a radius or curvature of r, and
- the sheet 420 has a tensile line strength of at least 10 MPa $\times N \times (H/N)^3/r^2$.

323. The arrangement of any of the examples 320 to 322, wherein
- the panel 100 comprises N layers, and
- the panel 100 has a thickness of H, whereby
- the flexural stiffness of the panel 100 is proportional to $N \times (H/N)^3$, and
- the tubular body 410 has a radius or curvature of r, and
- the sheet 420 has a tensile line strength of at least 0.01 $\times E \times N \times (H/N)^3/r^2$.

324. The arrangement of any of the examples 320 to 323, wherein
- the panel 100 comprises N layers, and
- the panel 100 has a thickness of H, whereby
- the flexural stiffness of the panel 100 is proportional to $E \times N \times (H/N)^3$, and
- the tubular body 410 has a radius or curvature of r, and
- the sheet 420 has a line tension of at least 10 MPa $\times N \times (H/N)^3/r^2$.

325. The arrangement of any of the examples 320 to 324, wherein
- the panel 100 comprises N layers, and
- the panel 100 has a thickness of H, whereby
- the flexural stiffness of the panel 100 is proportional to $E \times N \times (H/N)^3$, and
- the tubular body 410 has a radius or curvature of r, and
- the sheet 420 has a line tension of at least 0.01 $\times E \times N \times (H/N)^3/r^2$.

326. The arrangement of any of the examples 320 to 325, wherein
- the width $W_s$ of the sheet 420 is at least 75 % of the width $W$ of the panel 100.

327. The arrangement of any of the examples 320 to 326, wherein
- the width $W_s$ of the sheet 420 is at least the width $W$ of the panel 100.

328. The arrangement of any of the examples 320 to 327, wherein
- the sheet 420 supports the panel 100.

329. The arrangement of any of the examples 320 to 328, wherein
- in the device 400
- the sheet 420 detaches from the tubular body 410 at a contact point 438, and
- the sheet 420 forms a first part 420a and a second part 420b, wherein
- the first part 420a is wound around the tubular body 410 and
- the second part 420b forms a planar sheet, such that the second part 420b is parallel to the tangent plane of the tubular body 410, wherein the tangent plane is taken at the contact point 438, and in the arrangement,
- the length of the second part 420b is greater than the length of the panel 100.

330. The arrangement of any of the examples 320 to 329, wherein
- in the panel 100 the layer 110 that is closest to the first surface 132 or comprises the first surface 132 comprises wood, at a first location, wherein the wood has a grain orientation,
- the device 400 comprises an attachment 438 between the sheet 420 and the tubular body 410, and
- in the arrangement the grain orientation is directed towards the attachment 438.

331. The arrangement of any of the examples 301 to 330, wherein
- the panel 100 comprises wood having the moisture content of at most 5 % by weight.

401. A method for manufacturing a product 300 of any of the examples 101 to 130, the method comprising
- arranging available a panel 100 comprising
○ a first surface 132 and a second surface 134,  
○ a first layer 110a arranged in between the first surface 132 and the second surface 134 and comprising wood-based material,  
○ a second layer 110b arranged in between the first surface 132 and the second surface 134 and comprising wood-based material, and  
○ an adhesive layer 120 in between the first layer 110a and the second layer 100b, the adhesive layer 120 comprising thermoplastic material,  
- arranging available a device 400 comprising  
○ a tubular body 410 extending in a longitudinal direction ±Sx and having a surface 412,  
○ means for connecting (418, 420) the panel 100 to the tubular body 410, and  
○ means for detaching the panel 100 from the tubular body 410,  
- heating the panel 100 such that the thermoplastic material 120 at least locally melts,  
- connecting the panel 100 to the tubular body 410,  
- winding the panel 100 around the tubular body 410 such that the panel 100 becomes bent,  
- letting the bent panel 100 to cool to solidify the thermoplastic material 120, and  
- removing the bent panel from the device 400.

402. The method of example 401, wherein  
- the panel 100 is heated to a high temperature wherein the high temperature is higher than the melting point of the thermoplastic material 120.

403. The method of example 402, wherein  
- the panel 100 is heated to a high temperature wherein the high temperature is higher than the melting point of the thermoplastic material 120 by at least 5 °C, preferably at least 10 °C, and more preferably at least 15 °C degrees.

404. The method of example 402 or 403, wherein  
- the panel 100 is heated to a high temperature wherein the high temperature is higher than the melting point of the thermoplastic material 120 by at most 65 °C, preferably at most 45 °C, and more preferably at most 20 °C degrees.

405. The method of any of the examples 402 to 404, wherein  
- the panel 100 is heated to a temperature from 80 °C to 200 °C to melt the thermoplastic material 120.

406. The method of example 405, wherein  
- the panel 100 is heated to a temperature from 120 °C to 180 °C to melt the thermoplastic material 120.

407. The method of any of the examples 401 to 406, wherein  
- the panel 100 is cooled or let to cool to a low temperature, wherein the low temperature is lower than the melting point of the thermoplastic material 120.

408. The method of the example 407, wherein  
- the panel 100 is cooled or let to cool to a low temperature, wherein the low temperature is lower than the melting point of the thermoplastic material 120 by at least 10 °C, preferably at least 30 °C, and more preferably at least 40 °C degrees.

409. The method of the example 408, wherein  
- the panel 100 is cooled or let to cool to a low temperature, wherein the low temperature is lower than the melting point of the thermoplastic material 120 by at most 80 °C, preferably at most 60 °C, and more preferably at most 50 °C degrees.

410. The method of any of the examples 401 to 407, wherein  
- the panel 100 is cooled or let to cool to a low temperature, wherein the low temperature is from 0 °C to 90 °C.

411. The method of the example 410, wherein  
- the panel 100 is cooled or let to cool to a low temperature, wherein the low temperature is from 15 °C to 40 °C.

412. The method of any of the examples 401 to 411, comprising  
- rotating the tubular body 410 around an axis 416 parallel to the longitudinal direction ±Sx, to wind the panel around the tubular body 410.

413. The method of any of the examples 401 to 412, comprising
- cooling the tubular body 410 to solidify the thermoplastic material 120.

414. The method of the example 413, comprising

- cooling the tubular body 410 to a second low temperature, wherein
- the second low temperature is lower than the melting point of the thermoplastic material 120 by at least 10 °C, preferably at least 30 °C, and more preferably at least 40 °C degrees.

415. The method of the example 414 or 415, wherein

- the second low temperature is lower than the melting point of the thermoplastic material 120 by at most 80 °C, preferably at most 60 °C, and more preferably at most 50 °C degrees.

416. The method of any of the examples 401 to 415, comprising

- heating the panel 100 directly.

417. The method of any of the examples 401 to 416, wherein

- in the panel 100, the layer 110 that is closest to the first surface 132 or comprises the first surface 132, comprises wood, wherein the wood has a grain orientation, and the method comprises
- arranging the panel 100 such that the grain orientation is directed towards the means for connecting 418 the panel 100 to the tubular body 410.

418. The method of any of the examples 401 to 417, wherein

- the layer 110 of the panel 100 that is closest to the first surface 132 of the panel 100 or comprises the first surface 132 of the panel 100, comprises wood, wherein the wood has a grain orientation, and the method comprises
- bending the panel 100 with the tubular body 410 such that the grain orientation is perpendicular to the longitudinal direction ±Sx of the tubular body 410.

419. The method of any of the claims 401 to 418 comprising

- attaching the panel 100 to a clamp 495, and
- connecting the panel 100 to the tubular body 410 using the clamp 495.

420 The method of any of the claims 401 to 418, wherein

- the device comprises a sheet 420 attached to the tubular body 410, and the method further comprises
- tensioning the sheet 420,
- arranging the panel 100 on one side of the sheet 420,
- winding the panel 100 around the tubular body 410 by winding the sheet 420 around the tubular body 410, and
- releasing the sheet 420.

421. The method of any of the example 420, comprising

- heating the sheet 420 to keep the temperature of the panel 100 above the melting point of the thermoplastic material 120.

422. The method of example 420 or 421, comprising

- heating the sheet 420 to heat the panel 100 above the melting point of the thermoplastic material 120.

423. The method of any of the examples 420 to 422, comprising

- heating the sheet 420 to a second high temperature, wherein
- the second high temperature is higher than the melting point of the thermoplastic material 120 by at least 5 °C, preferably at least 10 °C, and more preferably at least 15 °C degrees.

424. The method of any of the examples 420 to 423, comprising

- heating the sheet 420 to a second high temperature, wherein
- the second high temperature is higher than the melting point of the thermoplastic material 120 by at most 65 °C, preferably at most 45 °C, and more preferably at most 20 °C degrees.

425. The method of any of the examples 420 to 424, wherein

- the device 420 comprises an attachment 438 between the sheet 420 and the tubular body 410, and the method comprises
- locating the panel 100 using the attachment 438.

426. The method of any of the examples 420 to 425, comprising
427. The method of any of the examples 420 to 426, wherein
- the panel 100 comprises N layers 110, and
- the panel 100 has a thickness of H, whereby
- the flexural stiffness of the panel is proportional to N(h/N)^3, and
- the tubular body 410 has a radius or curvature of r, and the method comprises
  - choosing a line tension according to the flexural stiffness of the panel, and the radius or curvature of the tubular body, and
  - tensioning the sheet 420 to a line tension of at least 0.2 kN/m.

428. The method of the example 427, wherein
- the line tension is at least 10 MPa × N × (H/N)^3/r^2.

426. The method of the example 427, wherein
- the elastic modulus of the layers 110 of the panel 100 is E, and the method comprises
  - choosing the line tension according to the flexural stiffness of the panel, the elastic modulus of the layers of the panel, and the radius or curvature of the tubular body.

427. The method of the example 426, wherein
- the line tension is at least 0.01 × N × E/r^2 × (H/N)^3.

428. The method of any of the examples 420 to 427, comprising
- supporting the panel 100 with the sheet 420.

429. The method of any of the examples 420 to 428, wherein in the device 400
- the sheet 420 has a thickness Hs, and an elastic constant Es, whereby
- the sheet 420 has a bendability of 1/(Es × Hs^3), and
- the bendability is at least 0.0003/Nm.

430. The method of any of the examples 401 to 433, wherein in the device 400
- the sheet 420 has a thickness Hs, and an elastic constant Es, and
- the tubular body 410 has a minimum radius of curvature of r, whereby
- the bendability of the sheet 420 related to the tubular body 410 is r^2/(Es × Hs^3), and
- the bendability of the sheet 420 related to the tubular body 410 is at least 0.00001 m/N.

431. The method of the example 401, comprising
- forming the arrangement of any of the examples 301 to 331.

Claims

1. A plywood forming method for manufacturing a plywood product, the method comprising
   - arranging available a panel comprising
     ○ a first surface and a second surface,
     ○ a first layer arranged in between the first surface and the second surface and comprising wood-based material,
     ○ a second layer arranged in between the first surface and the second surface and comprising wood-based material, and
     ○ an adhesive layer in between the first layer and the second layer, the adhesive layer comprising thermoplastic material,
   - arranging available a device comprising
     ○ a tubular body extending in a longitudinal direction and having a surface, and
     ○ means for connecting the panel to the tubular body,
   - heating the panel such that the thermoplastic material at least locally melts,
   - connecting the panel to the tubular body,
   - winding the panel around the tubular body such that the panel becomes bent,
   - letting the bent panel to cool to solidify the thermoplastic material, and
   - removing the bent panel from the device.

2. The method of any of claim 1, wherein
   - the panel is heated to a temperature from 80 °C to 200 °C to melt the thermoplastic material.

3. The method of claim 1 or 2, wherein
   - the panel is cooled or let to cool to a low temperature, wherein the low temperature is lower than the melting point of the thermoplastic material by at least 10 °C, preferably at least 30 °C, and more preferably at least 40 °C degrees.

4. The method of any of the claims 1 to 3, wherein
- the layer of the panel that is closest to the first surface of the panel or comprises the first surface of the panel comprises wood, wherein the wood has a grain orientation, and the method comprises
- bending the panel with the tubular body such that the grain orientation is perpendicular to the longitudinal direction of the tubular body.

5. The method of any of the claims 1 to 4, wherein
- the device comprises a sheet attached to the tubular body, and the method further comprises
- tensioning the sheet,
- arranging the panel on one side of the sheet,
- winding the panel around the tubular body by winding the sheet around the tubular body, and
- releasing the sheet.

6. The method of claim 5, comprising
- tensioning the sheet to a line tension of at least 0.2 kN/m.

7. A plywood forming device for bending a panel, the device comprising
- a tubular body extending in a longitudinal direction and having a surface,
- means for connecting a panel to the tubular body, and
- means for detaching the panel from the tubular body.

8. The device of claim 7, comprising
- a cooler arranged to cool the tubular body.

9. The device of claim 7 or 8, comprising
- a sheet attached to the tubular body, wherein
- the sheet is bendable such that the sheet may be wound around the tubular body, whereby the sheet forms the means for connecting a panel to the tubular body,
- at least one end of the tubular body is detachable from a support such that a bent panel is removable from the device, and
- the tubular body is arranged to rotate about an axis of rotation, wherein the axis of rotation is parallel to the longitudinal direction.

10. The device of claim 9, wherein
- the sheet has a tensile line strength of at least 0.2 kN/m, whereby the sheet can bear the load needed to bend a panel in between the sheet and the surface of the tubular body.

11. A plywood forming arrangement, comprising
- the device of any of the claims 7 to 10 and
- a panel comprising
  - a first surface and a second surface,
  - a first layer arranged in between the first surface and the second surface, comprising wood-based material, and optionally comprising the first surface or the second surface,
  - a second layer arranged in between the first surface and the second surface, comprising wood-based material, and optionally comprising the first surface or the second surface, and
  - an adhesive layer in between the first layer and the second layer, the adhesive layer comprising thermoplastic material.

12. The arrangement of the claim 11, wherein
- the layer of the panel that is closest to the first surface of the panel or comprises the first surface of the panel comprises wood, wherein the wood has a grain orientation, and
- the grain orientation is directed towards the means for connecting a panel to the tubular body.

13. The arrangement of claim 11 or 12, wherein
- the device comprises a sheet attached to the tubular body, wherein the sheet is bendable such that the may be wound around the tubular body, and in the arrangement
- the panel comprises N layers,
- the panel has a thickness of H,
- the tubular body has a radius or curvature of r, and
- the sheet has a tensile line strength of at least $10 \text{ MPa} \times N \times (H/N)^3/r^2$.

14. A plywood product comprising
- a first surface and a second surface,
- a first layer in between the first surface and the second surface, comprising wood-based material, and optionally comprising the first surface or the second surface,
- a second layer in between the first surface and the second surface, comprising wood-based material, and optionally comprising the first surface or the second surface,
- an adhesive layer in between the first layer and the second layer, the adhesive layer comprising thermoplastic material, wherein
- the first surface is at least partly convex,
- the first surface comprises a first point and a first surface normal at the first point,
- the first surface comprises a second point and a second surface normal at the second point,
- the first surface comprises a path from the first point to the second point, and
- the angle between the first surface normal and the second surface normal is at least 45 degrees, wherein the angle is measured along the path.

15. The product of claim 14, wherein

- the layer that is closest to the first surface or comprises the first surface comprises wood at a location, wherein the wood has a grain orientation at the location,
- the location defines a tangent plane for the first surface, and
- the grain orientation is parallel to the tangent plane and perpendicular to a longitudinal direction of the first surface, wherein the longitudinal direction is defined by the intersection of the tangent plane and the first surface.
Fig. 5

Fig. 6a

Fig. 6b
### DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document with indication, where appropriate, of relevant passages</th>
<th>Relevant to claim</th>
<th>CLASSIFICATION OF THE APPLICATION (IPC)</th>
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### CATEGORY OF CITED DOCUMENTS

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