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(71) Applicant: SCA FOREST PRODUCTS AB [SE/SE]; S-851 88 Sundsvall (SE).

(72) Inventors: ENARSSON, Lars-Erik; Sallyhillsvägen 9 B, S-853 53 Sundsvall (SE). ANDREASSON, Ulrika; Parkgatan 29, S-852 38 Sundsvall (SE). MALMGREN, Kent; Harmonigatan 11 C, S-854 63 Sundsvall (SE). GERDSDORFF, Tomas; Östermalmsgatan 33, S-854 60 Sundsvall (SE). GÄRDLUND, Linda; c/o SCA Forest Products AB, S-851 88 Sundsvall (SE).

(74) Agents: ZACCO SWEDEN AB et al.; P.O Box 5581, S-114 85 Stockholm (SE).

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(54) Title: DRY-LAID COMPOSITE WEB FOR THERMOFORMING OF THREE-DIMENSIONALLY SHAPED OBJECTS, A PROCESS FOR ITS PRODUCTION, THERMOFORMING THEREOF, AND A THERMOFORMED THREE-DIMENSIONALLY SHAPED OBJECT

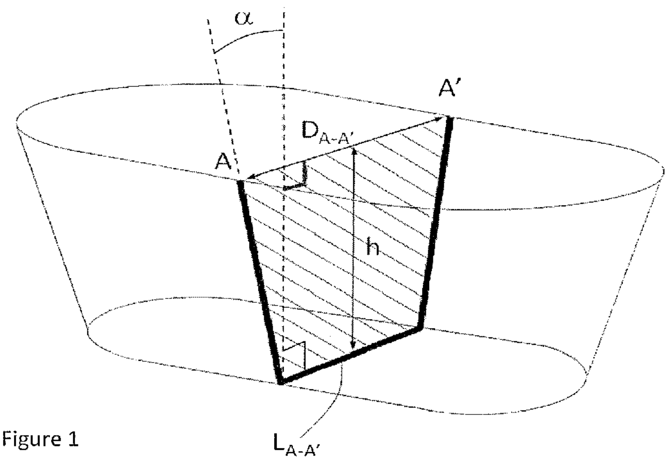

Figure 1

(57) Abstract: A dry-laid composite web being an intermediate product for thermoforming of three- dimensionally shaped objects, comprising 40-95 wt-% CTMP fibres, 5-50 wt-% thermoplastic material, and 0-10 wt-% additives, the dry-laid composite web having been impregnated with a dispersion, an emulsion, or a solution containing the thermoplastic material and dried, obtaining a density of 50-250 kg/m^3, or, if compressed by calendaring 400-1000 kg/m^3, and a process for producing web comprising the steps of: forming a dry-laid web comprising CTMP fibres; adding thermoplastic material to the web by impregnation, wherein the thermoplastic material is added in the form of a dispersion, an emulsion, or a solution in an amount to reach 5-50 wt-% thermoplastic material based on the total dry weight of the web; drying; and making rolls or sheets thereof, and a process for producing 3D-object from the intermediate web comprising the steps: optionally, in the case of the composite intermediate web being calendared, swelling of the web by means of wetting with water, followed by drying; heating and introducing the web into a thermoforming tool having the desired shape; forming the web in the thermoforming tool by pressing at a pressure of 1-200 MPa, or by utilizing a vacuum pressure; releasing the thereby obtained three-dimensionally shaped object from the thermoforming tool, and a thermoformed 3D object.

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DRY-LAID COMPOSITE WEB FOR THERMOFORMING OF THREE-DIMENSIONALLY SHAPED OBJECTS, A PROCESS FOR ITS PRODUCTION, THERMOFORMING THEREOF, AND A THERMOFORMED THREE-DIMENSIONALLY SHAPED OBJECT

TECHNICAL FIELD

The invention relates to a dry-laid composite web being an intermediate for thermoforming of three-dimensionally shaped objects, including a process for its production. Furthermore, the invention relates to a process for thermoforming a three-dimensional object from the intermediate product, and such thermoformed three-dimensionally shaped object. Such three-dimensionally objects may for example be utilized for packaging purposes.

BACKGROUND ART

There are many situations where it is desirable to provide 3D shaped objects made of sustainable materials. One such situation relates to packaging of sensitive goods, such as electronic equipment, cellular phones and other household and hardware items, that need protective packaging in order to avoid damage of the sensitive goods, due to for example mechanical shock, vibrations, compression, or extreme temperatures during transport, storage, or other handling. Such packages typically require a protective insert that has a shape adapted to the goods contained, and thus securely holds the goods in the package. Such inserts are commonly made of expanded polystyrene (EPS), which is a lightweight petroleum derived material and is not regarded as a sustainable material.

There are methods for forming three-dimensional objects by crinkling paper around a forming tool. However, crinkles may be undesirable from an appearance point of view and since the use of crinkled objects is limited.

A low price material commonly used for packaging inserts is moulded pulp. Moulded pulp has the advantage of being considered as a sustainable packaging material, since it is produced from biomaterials and can be recycled after use. As a consequence moulded pulp has been quickly increasing in popularity for both primary and secondary packaging applications (packaging next to the article and assembly of such packages). Moulded pulp articles are generally formed by immersing a suction mould into a pulp suspension, while suction is applied, whereby a body of pulp is formed with the shape of the desired article by fibre deposition. The suction mould is then withdrawn from the suspension and the suction is generally continued to compact the deposited fibres while exhausting residual liquid.

Lately, new fibre-based materials have been developed, such as Durapulp® (Södra Cell AB) which is a wet-laid material composed of pulp fibres and thermoplastic polylactide (PLA) fibres. A common disadvantage with all wet-forming techniques is the need for drying of the moulded product, which is a time and energy consuming step. Another drawback is that strong inter-fibre bonds, often explained as hydrogen bonds, are formed between the fibres in the material, which restrict the flexibility of the material.

Beside wet-forming, pulp fibres may also be dry-laid to a web, having virtually no bonding between the individual fibres. Normally, such dry-laid webs comprising pulp fibres are used in hygiene care products, in particular as absorbing articles of various kinds. However, such dry-laid webs are typically of limited use for forming three dimensional shapes, such as packaging inserts, because of the low web strength.

There is still a need for three dimensional objects made of sustainable material that can be effectively manufactures from a time and energy point of view. The objective of the present invention is thus to provide a way to produce advanced three dimensionally shaped products mainly consisting of pulp fibres in an efficient way with respect to time and energy consumption. This object is achieved by the present invention as defined in the appended claims.

SUMMARY OF THE INVENTION

The present invention relates to a dry-laid composite web being an intermediate product for thermoforming of three-dimensionally shaped objects, said web comprising 40-95 wt-% CTMP fibres, 5-50 wt-% thermoplastic material, and 0-10 wt-% additives, wherein the dry-laid composite web has been impregnated with a dispersion, an emulsion, or a solution containing the thermoplastic material and dried, obtaining a density of 50-250 kg/m^3, or, if compressed by calendaring 400-1000 kg/m^3. The CTMP fibres in combination with the thermoplastic material and the low density of the web allow thermoforming of three-dimensionally shaped object. The thermoplastic material preferably comprises a first polymer material having a glass transition temperature, Tg, of -60°C - +80°C, preferably -30°C - +50°C; more preferred -10°C - +25°C, and a second polymer material having Tg of 45°C - 130°C, and the composite web has then been subjected to a temperature of above Tg of the first polymer, but not above Tg of the second polymer after impregnation, so that the first polymer binds to the CTMP fibres, while the CTMP fibres remain unbonded to the second polymer. This allows the dry-laid web to be sufficiently bonded to allow convenient handling and transport, and at the same time the web remains extensible enough to allow thermoforming of three-dimensionally shaped objects. Bonding of the second polymer is activated by the higher temperature applied in the thermoforming process and contributes to the final strength of the thermoformed object. Preferably, the thermoplastic material comprises 5-20 wt-% of the first polymer material based on the total weight of the composite web, to ensure sufficient bonding.

The dry-laid composite web may advantageously comprise a polymer film layer positioned on at least one side of the web, preferably on both sides of the web forming a sandwich laminate, the film having a thickness of 1-500 µm, preferably 4-200 µm, in order to enhance the thermoforming properties of the composite web. The polymer film layer(s) preferably comprises polylactide.

The present invention also relates to a process for producing the above mentioned dry-laid composite intermediate web. The process comprises the following steps:

- Forming a dry-laid web comprising CTMP fibres; and preferably calendaring or compressing the dry-laid web
- Adding thermoplastic material to the web by impregnation, wherein the thermoplastic material is added in the form of a dispersion, an emulsion, or a solution in an amount to reach 5-50 wt-% thermoplastic material based on the total dry weight of the web;
- Drying the web;
- Making rolls or sheets of the dried web.

The impregnation serves two purposes in the present invention, to add the binder in a convenient way and at the same time expand the compacted airlaid sheet to a low-density web suitable for thermoforming. The latter is obtained with a liquid that makes the fibres swell significantly, in particular water. The impregnation is preferably a process where the composite web can expand freely, and is advantageously performed by spraying. In the process, the thermoplastic material added preferably comprises a first polymer material having Tg of -60 - +80 °C, preferably -30 - +50 °C; more preferred -10 - +25°C, and a second polymer material having Tg of 45 - 130 °C, the drying is performed at a temperature of above Tg of the first polymer, but preferably not above Tg of the second polymer after impregnation, so that the first polymer binds to the CTMP fibres, while the CTMP fibres remain unbonded to the second polymer.

The drying is preferably performed without applying any physical constraints to the web until the web reaches ambient humidity, and the web may be calendared subsequent to drying, obtaining a web density of 400-1000 kg/m^3.

It is preferred to include into the process a further step of applying a polymer film layer to at least one side of the dried web, said polymer film layer preferably being a polylactide film.

The invention also relates to a process for producing a three-dimensionally shaped object from a pre-manufactured dry-laid composite intermediate web as described above, said web having a density of 50-250 kg/m^3, comprising the steps:

- Optionally, in the case of the composite intermediate web being calendared, swelling of the web by means of wetting with water, followed by drying;
- Heating and introducing the web into a thermoforming tool having the desired shape;
- Forming the web in the thermoforming tool by pressing at a pressure of 1-200 MPa, preferably 1-100 MPa, or by utilizing a vacuum pressure;
- Releasing the thereby obtained three-dimensionally shaped object from the thermoforming tool.

The process preferably includes moistening of the heated web by treating it with water, preferably by spraying, to obtain a moisture content of the web of 10-30 %, more preferably 15-20 %, as the form-shaping tool is closing, and may also advantageously include cooling of the obtained object. If desired, the web may be cut into blanks before being introduced into a thermoforming tool.

The invention also relates to a thermoformed three-dimensionally shaped object obtained from the above described thermoforming process, said object having an opening in a plane perpendicular to the press direction of the thermoforming tool, at least one side wall, and a bottom, and a maximum depth area, with a maximum depth between the opening and the bottom, said shaped object having a first extensibility in at least one first direction of at least 22 %, preferably at least 26%, even more preferably 30%, said first direction coinciding with a plane perpendicular to the plane of the opening at a point of maximum depth, said extensibility being calculated as $\varepsilon_{A\text{-}A'} = (L_{A\text{-}A'}/D_{A\text{-}A'})\text{-}1) \times 100$ %, $L_{A\text{-}A'}$ is the contour length, which follows the profile of the shaped object along a cross section in said direction, and $D_{A\text{-}A'}$ is the shortest distance over the opening passing over said cross section in said direction. In general, the opening and the bottom are perpendicular to the press direction. In addition, the thermoformed three-dimensionally shaped object preferably has a second extensibility in the plane of the opening in a second direction perpendicular to the first direction, the second extensibility being calculated in the same manner as the first extensibility, and both first and second extensibilities being at least 18%, preferably at least 22%, even more preferably at least 26%. The thermoformed three-dimensionally shaped object preferably has at least one draft angle is less than 15°, preferably less than 5°.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows a thermoformed object, with an inlaid plane indicating how to evaluate the extensibility.

Figure 2 shows thermoforming test moulds with a medium draft angle, in an open position.

Figure 3 shows thermoforming test moulds with a steep draft angle, in a closed position.

DETAILED DESCRIPTION

The present invention is based on the realization that a dry-laid web of chemi-thermo-mechanical pulp (CTMP) can effectively be impregnated by thermoplastic material and dried to form a low density intermediate web, which can effectively be used for manufacturing of advanced three-dimensional objects by means of thermoforming. By three-dimensional thermoformed or pressformed object is meant an object, pressed from a planar substrate with an extension in the x-y plane and only its planar thickness in the z-direction, such that the formed object also has an additional formed extension in the z-direction. The extension in the z-direction should be at least 5 %, more preferably at least 30%, of its largest extension in the x-y plane. It has been produced from the planar substrate by irreversible stretching similar to plastic deformation in three dimensions, to produce the desired three-dimensional shape. This stretch also means that the three-dimensional object cannot revert back to its planar origin. The maximum stretch obtained during thermoforming gives a measure on the extensibility of the material.

It has been found that such dry-laid CTMP sheets impregnated with thermoplastic binder have a high extensibility in all directions at elevated temperatures, which allows advanced three-dimensionally shaped objects to be formed, which may include steep draft angles of down to 15°, or even 5°, and moulding depths in relation to cavity diameter of as much as 20:70 for a three-dimensional object with conical shape. Shapes which require high extension of the material in all directions can thus be accomplished according to the invention, which means that shapes that have hitherto only been possible to obtain by means of wet-moulding can now be obtained without the need of the time- and energy consuming drying. This improves the cycle time for the moulding as compared to moulded pulp.

The final three-dimensionally shaped object of the invention is prepared from a dry-laid composite web which is first formed as an intermediate product. The intermediate product is a substantially flat web, which comprises CTMP fibres, thermoplastic material, and possibly additives, and has a low density. The production of the intermediate product involves dry-laying of CTMP fibre to form a web, using conventional dry-laying technology, and thereafter applying a dispersion, emulsion, or solution containing a thermoplastic material to a dry-laid composite web comprising CTMP, so as to impregnate the web.

The intermediate composite web and its manufacture

It is an essential feature for the performance of the intermediate composite web product during thermoforming that the pulp is specifically CTMP as will be further described below. Dry-laid CTMP sheets have substantially isotropic fibre orientation in the lateral plane, which gives the impregnated sheets equal thermal extensibility over all lateral angles. This is an advantage over extensible papers made by wet-forming and microcreping, which often show different extensibility in the machine direction compared to the cross direction of the paper. CTMP is a wood-based pulp prepared by a combination of chemical pre-treatment and mechanical refining. Chemical pre-treatment involves impregnation of wood chips with steam and sulphite. Contrary to chemical pulping, the small sulphite charge does not remove any significant amount of lignin, but leads to a softening of the lignin content and this aids the refining process. As a result, less energy input is required for refining and the pulp contains longer fibres and less fine material than what is achieved by conventional mechanical pulping. CTMP fibres are characterized by their high stiffness and resistance to fibre collapse as compared to chemical pulps. Applied in papermaking these properties leads to sheets with lower density (higher bulk) and larger pores compared to fully delignified chemical pulps (e.g. Kraft pulp). In the present invention, substantially all fibres of the dry-laid web are preferably CTMP fibres. Dry-laid CTMP sheets are often compressed or calendared before further processing, in order to facilitate the handling thereof. When such calendared CTMP sheets are subjected to wetting, they swell to a great extent and effectively absorb the wetting liquid, and they are therefore well suited as starting materials for the present invention. The calendared CTMP sheet for use in the present invention typically has a grammage of 300-800 g/m^2, but depending on the desired final three-dimensional product a lower grammage may be preferred, such as 100-300 g/m^2. Grammage should be selected after the required mechanical properties for the thermoformed product. The highest grammages are suitable for structures that should withstand heavy loads or should be used over long time. The lowest grammages are especially suitable as packaging inserts for lightweight products.

Mechanical refining of CTMP can also be made at a high temperature exceeding 135 °C in order to achieve a further softening effect of the lignin by a thermoplastic effect, in addition to the chemical softening (see for example WO 94/16139). CTMP produced in this manner (HT-CTMP) is suitable for the intermediate composite web and allows for good uptake of colloidal binder particles, such as thermoplastic latex particles, when being impregnated with a dispersion or emulsion containing a polymeric material due to the large pores obtained in a porous dry-laid web of such CTMP fibres. When this particular type of CTMP is calendared after dry-laying, the calendared sheet swells and absorbs liquid up to 10 g/g upon wetting, and the uptake of colloidal binder dispersion is high. Also, the low refining energy required gives a pulp with little fine material and long average fibre length, which contributes to a high tensile and tear strength, as well as an good ductility of the fibre network.

The amount of CTMP in the dry-laid composite intermediate web, and consequently in the formed three-dimensional product, should be in the interval of 40-95 wt-% of the total dry weight of the web, preferably in the interval of 60-85 wt-%, and most preferably in the interval of 65-75 wt-%. If the amount of CTMP is over 95 wt-% the fibres in the dry-laid web would not be bonded well enough, and it may be difficult to thermoform the product without breaking the substrate due to inferior ductility and web strength, and the finished product might show inferior mechanical properties. The bonding and thermo-elastic properties of the sheet develop strongly when the thermoplastic content is increased from 5 to 40 wt-%, and more preferably 15-40 wt-%. The latter corresponds to a preferred amount of 60-85% CTMP in the product. It is not of interest to go to lower amount of CTMP than 40 wt-% since the aim is to accomplish a three-dimensionally shaped product based mainly on sustainable pulp fibres. If has been found that the best compromise between a high amount of sustainable CTMP, good forming and mechanical properties is found in the interval of 65-75 wt-% CTMP.

The thermoplastic material is added to the dry-laid web in the form of a polymer in a liquid carrier, of the type dispersion, emulsion, or solution. For the sake of simplicity, the thermoplastic material in the form of a dispersion, emulsion or solution is hereinafter referred to as the binder liquid.

If the dry-laid web is impregnated directly in connection with the web forming it will collapse slightly. The advantage of direct impregnation in immediate connection with the web forming is that steps for compressing or calendaring the dry-laid web can be omitted.

However, as mentioned above it may be advantageous to subject the dry-laid CTMP web to compression or calendaring before impregnation, since a calendared dry-laid web can more easily be stored and handled, and the impregnation step need not necessarily be performed at the same site as the dry-laying. A positive side-effect of using a compressed material is also that the absorbed liquid distributes more evenly in the CTMP web due to the higher capillary pressure induced by the smaller pores in the compressed web. Accordingly, the dry-laid CTMP web is preferably compressed or calendared prior to adding thermoplastic material by impregnation. The density of the compressed or calendared CTMP web before impregnation is preferably 400-1000 kg/m^3. In the following description of the invention, the dry-laid CTMP web referred to, which is subjected to impregnation is a compressed or calendared web, unless stated otherwise.

As the compressed or calendared dry-laid web comprising CTMP fibres is wetted it starts to expand via moisture-induced debonding and relaxation of built-in stresses in the fibre web. The thermoplastic material is added to the dry-laid web in the form of an aqueous dispersion, emulsion or solution, since the wetting and swelling is more effective using water than with other solvents and since water is environmentally friendly and readily available.

It is preferred that the impregnation step allows a free expansion of the web in the transversal direction seen from the plane of the web. The reason is based on the finding that if a dry-laid composite web is maximally expanded during impregnation, and is then dried at that expanded state, a lower density may be achieved which has turned out to be beneficial for a subsequent thermoforming to deep forms having steep edge angles, i.e. draft angles. If the CTMP web is allowed to expand freely during impregnation, it may expand to several times its original thickness. For example, the free expansion of dry-aid calendared HT-CTMP may lead to a six-fold increase in thickness, which is uncommon for fibre-based materials in contact with water. Important factors for large expansion of fibre webs are a combination of high fibre stiffness, a relative low degree of bonding in calendared dry-laid CTMP sheets, and a relaxation effect of curled CTMP fibres when they are softened by thorough wetting, (e.g. more than 0.7 g water/g dry-laid CTMP). One purpose of free expansion is to get an increased uptake of binder liquid using the large pores that are created during wet expansion. The expansion contributes to a sorption capacity of the CTMP web that is several times higher than what ordinary paper sheets of chemical pulp or TMP can show. The large pores created during expansion are also capable of absorbing colloidal-size latex particles, which otherwise would be restricted to the surface of a normal paper web with smaller pore radii.

The lower density of the sheet obtained by allowing free expansion leads to increased bulk, larger separation between CTMP fibres, and lower degree of bonding between them. These properties improve the stretchability of the CTMP web, and the capability of being formed into three-dimensional objects. As a comparison, an ordinary paper (made of chemical pulp) with high degree of bonding would show a brittle behaviour in stretching and three-dimensional forming against a mould with significant depth, leading to crack failure of the material. The lower degree of bonding in the impregnated CTMP web allows the web to be more extensible. CTMP fibres show a thermoplastic effect, since they are more flexible at temperatures above 130°C as the lignin softens, so it is highly beneficial to heat the CTMP web during thermoforming. The loosely bonded fibres of the low density web are able to move relative each other in the sparse fibre network and can redistribute according to the shape of the mould. The added thermoplastic material provides soft bonds between CTMP fibres and makes the sheet cohesive enough to allow stretch in the material.

The impregnation is preferably performed by spraying, although other techniques such as impregnation bath, applicator roll, printing (offset, flexo- and rotogravure, inkjet), film coating and curtain coating are also applicable.

Spray application is preferred since it provides excellent control of the applied content, for example by varying the application time and flow rate of the spray nozzle. Spraying also allows for a broad range of solid contents of the thermoplastic material in the liquid carrier, namely from 1-50 wt-% in the case of latex, and easy flowing polymer dispersions, offering a wide process window for optimizing the combination of applied liquid content and the target content of applied thermoplastic material. Another advantage with spraying is that the web can be allowed to expand freely in thickness, resting on a support without constriction.

The spraying techniques involve one or more spraying nozzles that can be moved in relation to the CTMP web, by either moving the nozzles or the web. A spraying technique suitable for small scale production may involve application with a single spray nozzle, and can be automated by moving the CTMP sheet on an x-y table, or by using an automatically traversing nozzle. In larger scale production a set of spray guns may be used under which the web is passing, preferably guided by a conveying belt. Spraying may also preferably be performed on both sides on the web, in order to obtain even coverage and effective wetting of the web.

Impregnation bath methods include immersion of the dry-laid web in a dispersion, emulsion or solution comprising the thermoplastic material. Impregnation baths have the advantage of allowing free expansion of the web. Impregnation by immersion may be performed batch-wise or continuously. In batch-wise immersion, the CTMP web may be placed into a tray and the binder liquid is poured over the web, which leads to spontaneous absorption under free expansion. The added amount of binder liquid should preferably be chosen so that the web absorbs all content, i.e. additions below saturation absorption for the CTMP web. This minimizes the recycling of excess liquid after the impregnation bath, gives a higher wet strength of the sheet, and also reduces the energy needed for drying the impregnated sheet. In the case of continuous immersion a moving CTMP web is led through a bath with binder liquid. The sheet is preferably supported by one or two wires, since the wet expanded CTMP web has a low wet strength and does not stand the tension in free drawing. Depending on the applied drawing geometry and tension, the expansion of the CTMP web might occur under some constraint.

In impregnation by applicator roll a CTMP web is passed over an applicator roll that transfers the liquid to the web surface. In its simplest form the applicator roll is partly immersed in a reservoir with binder liquid to pick up the liquid on the surface of the roll and transfer it the web passing the roll. The roll may be provided with grooves in order to control the amount of pick-up of the binder liquid. A pressure may be applied to the web to keep it in contact with the applicator roll, and the pressure is preferably kept low to allow for free expansion of the impregnated web.

Impregnation may also be performed by printing techniques to transfer the binder liquid to the CTMP web with full or partial surface coverage, such as different variants of roll applications (offset, flexo- and rotogravure techniques) as well as spraying techniques (inkjet).

In impregnation by film coating, a falling film of liquid binder falls on the applicator roll, which transfers the liquid film onto the sheet. One-sided treatment allows free expansion of the

CTMP web. A two-sided application with two applicator rolls that are pressed against each other is less preferred since it leads to impregnation with restrained expansion.

In impregnation by curtain coating, a falling film of binder liquid falls directly onto a moving CTMP web, which absorbs the binder liquid. This technique allows free expansion of the CTMP web.

The main purpose of the thermoplastic material is to bind the CTMP fibres in a desired three-dimensional shape during thermoforming, and to function as a strengthening structure component in the final product. It is beneficial if the thermoplastic material can serve a dual purpose, where it in addition to bind the CTMP fibres during thermoforming, also serves to preliminarily bind the CTMP fibres in the low density intermediate web, to facilitate handling and transport of the intermediate web. When the CTMP web expands during impregnation, the expansion of the web results in a low-density sheet with weak bonding between the CTMP fibres. Extra binder contributes by making the sheet strong enough to withstand transport and handling. Without such preliminary bonding, the web will be very difficult to manage, due to its low strength and vulnerability for rupture or material losses. The preliminary bonding weakly binds the CTMP fibre network of the expanded low-density web so that the fibres can move against each other and thereby contribute to the extensibility of the web during thermoforming. Thus in practice the thermoplastic material has two main functions in the intermediate dry-laid composite web product, firstly preliminary bonding (or pre-bonding) before the final bonding during thermoforming occurs and secondly, bonding the CTMP fibres during thermoforming to contribute to final rigidity and thermal resistance of the shaped three-dimensional object by fixation of the rearranged fibre network of the shaped structure. The combination of two polymers also makes it possible to tune the stiffness and toughness of the final product. The preliminary bonding of the CTMP fibres may be enhanced by subjecting the web to heat, during or subsequent to drying. The total amount of polymeric material added should be 5-50 wt-% based on the total dry weight of the web, in order to be able to successfully perform the thermoforming of the CTMP web. Preferably, 10-40 wt-% thermoplastic polymer is added, and most preferably 20-30 wt-%. The extensibility in thermoforming is continuously increased over the interval 5-30%. In order to reach extensibilities over 20%, a content of 20 wt% or more of thermoplastic polymer is typically needed.

Both these functions can be performed by one single thermoplastic polymer, even though it is more complicated to fulfil the functions with just one polymer. Still, a single component might be preferred for its simplicity, or if the polymer shows poor chemical compatibility with other thermoplastic materials. This polymer should then be chosen so that it can preliminarily bind the CTMP fibre in the expanded dried web, without decreasing the porosity of the web. The polymer may then preferably have a glass transitional temperature (Tg) of -10 °C to 80 °C, more preferably +10 °C to 60 °C. The final choice depends on the required rigidity of the final product. A polymer with Tg below ambient temperature will typically contribute to a less rigid but more tough fibre-based product. A polymer with Tg above the ambient temperature will typically contribute to a rigid but more brittle product. If the target is a rigid product with temperature stability up to a certain temperature, Tg of the polymer should be chosen above that upper application temperature. Tg of the polymer should in any case be below 100°C in order to activate bonding when drying off the water. Since the sheet needs to be thermally bonded without any constricting load, the polymer must bind spontaneously. Extra heating of the dry impregnated sheet to temperatures in the range 100-150°C might be necessary to induce bonding for highly viscoelastic polymers. Thereby, a bonding of the CTMP web can be obtained by subjecting the web to a temperature above Tg, during or subsequent to drying. A self-cross linking vinylacetate-ethylene is suitable for impregnation, as it gives a tough binder matrix, which combined with moisturizing of the web before thermoforming gives the required bonding of compacted CTMP. Polyvinyl acetate, styrene-acrylate co-polymers and styrene-butadiene co-polymers are other suitable polymers when using a single thermoplastic binder.

Preferably, the thermoplastic material may be comprised of at least two different thermoplastic polymers in order to fulfil the two functions stated. In this case a combination of a first polymer with low softening temperature and a second polymer with high softening temperature is preferred. This has the advantage that each function may be fulfilled by a better adapted polymer, and that toughness and stiffness of the final composite can be optimized, since one polymer can be chosen for its ability to form the preliminary bonding of the expanded CTMP web, and another polymer can be chosen for its ability to provide toughness and stiffness in the final product. When the thermoplastic material comprises a first polymer with low softening temperature and a second polymer with high softening temperature, the first polymer is preferably comprised in an amount of 5-20 wt-% based on the total weight of the composite web.

By low softening temperature is meant in the context of the present invention that the polymer is soft enough to bind the sheet in room temperature or at moderate drying temperatures of e.g. 25-40°C, or at higher drying temperatures, of e.g. 40-80°C. When combining polymers as indicated above, the first thermoplastic polymer having low softening temperature preferably has a Tg of -60 - +80 °C. Polymers having Tg of -30 - +50 °C are preferred since they can bind the CTMP fibres with the use of less heating, and polymers having Tg -10 - +25 °C are more preferred, since they can form the preliminary bonding of the sheet at room temperature or ambient temperature. The second thermoplastic polymer in the combined polymer is thus used to bind the web further in the final thermoforming step, and also contributes to give the final product a better thermal resistance. The second polymer is not activated until the sheet is fully heated to thermoforming temperature, and has consequently a higher softening temperature, which is preferably Tg of 45-130 °C, more preferably 60-100 °C.

By applying heat during drying the impregnated sheet can be pre-bonded at the same time as the liquid carrier, typically water, is removed.

Polymers such as acrylic, styrene-acrylic, styrene, and styrene butadiene can be synthesized over a wide range of softening temperatures, including temperatures below 45°C, and are suitable for use as the first polymer. Further examples of polymers with low softening temperatures below 45°C are polyvinyl acetate (PVA, Tg +30 to +40°C), vinyl acetate-ethylene copolymer (VAE, Tg -20°C to +15°C), and ethylene-vinyl chloride co-polymer (Tg 0°C to +30°C). Polyvinyl acetate develops a strong bonding of the thermoformed article, especially when the CTMP web is moisturized before thermoforming.

Another suitable polymer type is PE- and PP-based co-polymers from the family of polyolefin latexes (e.g. Hypod and Primacor products from Dow). This type of polymers has low glass transition temperature (-63°C to -26°C) and low melting point (+85°C to +122°C). Polyolefin latex polymers have sufficient stiffness at room temperature to be used in the CTMP web. These polymers also show good performance in thermoforming in their molten state, probably because the polyolefin-base polymers have a relatively low tackiness in molten stage.

By high softening temperature is meant in the context of the present invention that the polymer is glassy in room temperature, which contributes to the stiffness of the composite at ambient temperatures. The target softening temperature is in the range between 45°C and 130°C, where the upper limit matches the softening temperature CTMP fibres. Polymers such as acrylic, styrene-acrylic, styrene, styrene-butadiene, and polyesters can be synthesized over a wide range of softening temperatures including temperatures above 45°C, and are suitable as the second polymer in the present invention. Further examples of polymers with high softening temperature are polyvinyl chloride, polyethylene terephthalate, thermoplastic starch, polylactic acid, polyhydroxy alkanoates.

In addition to the first and second thermoplastic polymer described above, a cross-linking polymer could be added as an additive for either further stiffening of the shaped three dimensional products or for increasing water-resistance and/or decrease moisture-induced swelling of the CTMP fibres.

As stated above, the thermoplastic polymer is comprised in the binder liquid in the form of a dispersion, an emulsion, or a solution of polymers. Polymer dispersions, or latexes, refer to colloidal polymer particles and droplets dispersed in a liquid phase, most dominantly water. Aqueous latex suspensions typically have particle sizes of 0.05 – 2 µm. Dispersed particles are often stabilized in water with surfactants. Inclusion of ionic groups in the synthesized polymer, such as carboxylic and sulphate groups, can also be used to stabilize dispersed plastics by means of electrostatic repulsion. Polymer emulsions are commonly defined as polymers synthesized from monomers in emulsion.

Common compositions of polymer dispersions suitable for use in the present invention are: acrylic, methacrylic, styrene-acrylic co polymers, styrene, styrene-butadiene co-polymers, vinylacetate, acrylonitrile-butadiene, vinylacetate-ethylene copolymers, ethylene-acrylic, vinylacrylates, and polyvinylchloride, polylactic acid and polyhydroxybutanoate, oleofin-rich polymers like the co-polymers from polypropylene and polyethylene. The polymer might be reactive and self-crosslinking to improve the stiffness of the binder in the final composite product.

Polymer solutions are efficient for impregnation. Water-based systems are for example biopolymers like cooked starch and proteins, or synthetic polymers like polyvinyl alcohol. Starch is not a true thermoplastic by nature, as dry starch decomposes thermally before the softening temperature is reached. Still, starch can show thermoplastic behaviour when it is combined with plasticizers like glycerol and urea, often in presence of hygroscopic moisture. It is preferred to use an aqueous polymer solution for impregnation of the CTMP web, even though some hydrophobic plastics, for example polylactic acid, can be dissolved in organic solvents and used as impregnation liquid.

During impregnation, the total amount of dispersion, emulsion or solution may be 0.1 to 10 grams per gram of dry-laid CTMP web (g/g). Preferably 1-3 g/g dispersion, emulsion or solution is added, whereby it is ensured that the CTMP web is sufficiently wetted so as to obtain the desired swelling, and at the same time the amount of water added to the web is not unnecessarily high, which means that less time and energy need to be spent on drying the expanded CTMP web. It has also been found that keeping the amount of impregnation liquid at maximum 3 g/g increases the wet strength of the expanded dry-laid CTMP web.

The solid content of polymer particles in aqueous dispersion can be between 1 % and 60 %. The upper range depends on the viscosity of the dispersion, which must be low enough to achieve efficient uptake and redistribution in the CTMP web. Many commercial types of latexes are supplied at about 50% solid content and show viscosities in the range 300-500 mPa·s, which the CTMP web can absorb as is. The dispersion may still require dilution in order to match the targeted uptake of both polymer and water by the CTMP web. The polymer uptake should match the targeted dry content polymer for the intermediate sheet, 5-50 wt-% while the water uptake should be sufficient for expansion of the calendared web, e.g. 1-2 g/g. The solid content of the dispersion is preferably between 2.5-50 wt-%, more preferably between 5 % and 25 %, in order to assure an efficient uptake, web expansion and distribution of the thermoplastic material in the dry-laid CTMP web.

The intermediate dry-laid composite web product may also contain additives to give extra functions in the material. Extra functions are for example achieved by additional dyes, extra strength agents, flame retardancy agents, barrier additives, antimicrobial additives, absorbent particles, softeners for enhanced perception and others. The additives can be added during the airlaying process of the CTMP web or preferably during impregnation.

Subsequent to impregnation of the dry-laid web comprising CTMP with the thermoplastic material a drying operation is performed to obtain the intermediate dry-laid composite web product. The drying can be performed at ambient temperature, but is preferably performed at an elevated temperature, for example in a hot air oven, in which the temperature is high enough to cause a preliminary bonding of the web by a portion of the thermoplastic material contained therein, so that the web can be handled without severe dusting, or in worst case completely falling apart. However, it is essential that the fibres of the preliminary bonded web can still move in relation to each other. The surrounding drying temperature may be set in the interval of 50 °C to 250 °C, and is preferably set in the interval of 80 °C to 150 °C. The temperature of the wet impregnated web will however be lower. When a combination of a first polymer with low softening temperature and a second polymer with high softening temperature is used, the temperature in the wet web during drying should preferably be above Tg for the first polymer and below Tg for the second polymer. In the case the CTMP is impregnated with one polymer type only, the temperature in the wet web should be above Tg of the single polymer in order to establish bonding during drying. In case the polymer has a high Tg above 100°C the drying sequence can also be terminated with an extra high-temperature peak in order to establish bonding of the sheet. The impregnation, removal of water and pre-heating before thermoforming may be integrated in one step. The surrounding temperature should then be between 130-250°C during drying and pre-heating, and the final temperature of the web after pre-heating should be over 130°C.

It is preferred that no physical constraints are applied to the web during drying until reaches ambient humidity, in order to preserve the full expanded thickness, and thereby to enhance the ductility and extensibility of the web during thermoforming.

The obtained dry-laid composite web intermediate product is reeled up to form rolls, or cut into sheets, which are then preferably stacked into bundles, to enable convenient transfer to a thermoforming tool.

If desired, the composite web can be calendared subsequent to drying, obtaining a web density of 400-1000 kg/m^3. This may be interesting when certain surface properties, e.g. improved printability, are desired. Further, a calendared web would be easier to handle and transport, due to its more robust and compact character. However, if the composite web is calendared after impregnation and drying, it must be re-swelled before thermoforming, so that the fibres can again move in relation to each other.

When the web has been impregnated and dried as described above, a dry-laid composite web is obtained, which is an intermediate product having a low density of 50-250 kg/m^3. In comparison, the density of tissue papers is in the range of 250-500 kg/ m^3, newsprint 500-600 kg/m^3, and bleached Kraft paper is around 800 kg/m^3. The low density means an increased bulk, larger separation between CTMP fibres, and a low degree of bonding between them. These properties improve the extensibility, i.e. stretchability, and three-dimensional forming capability of the dry-laid composite web. In the dry-laid composite web of the invention, the loosely bonded fibres are able to move relative each other in the sparse fibre network facilitating redistribution according to the shape of the mould. By heating the composite web to an elevated temperature in connection with the thermoforming step, the thermoplastic material provides only soft bonds between CTMP fibres and makes the sheet cohesive enough to allow sufficient stretch in the material, so that the composite web can adapt to the shape of the thermoforming mould.

A polymer film is preferably added to one or both sides of the dry-laid composite web after drying thereof. The polymer film contributes to the three-dimensional formability and/or functions as a barrier layer for various substances that may come in contact with the final thermoformed product, such as fat, liquid water, vapour or oxygen. The polymer film may have a thickness of 5-200 µm. Polymer films which are commonly used as outer layers on cellulose-fibre based packages may be used, e.g. polyethylene (PE), polypropylene (PP), and polyethylene terephtalate (PET). However, the polymeric film preferred in the present invention is made of polylactide (i.e. polylactic acid or PLA) film, since it is a sustainable material. The adhesive and highly viscous properties of plasticized PLA are utilized to improve the extensibility in thermoforming. The PLA film adheres well to the fibre web and follows the extension of the fibre web in the mould. This has surprisingly led to an improved extensibility of the fibre web in three-dimensional thermoforming. PLA remains in a plasticized and adhesive state over a wide temperature interval from the glass transition temperature (55°C) to the melting point (170°C). The PLA film therefore aids the extension of the fibre web over a wide range of thermoforming temperatures. This is especially useful if the substrate is not fully heated when it enters the thermoforming mould, as the PLA film reduces the risk of brittle fracture during the initial contact between the sample and the closing hot mould. Preferred thickness of the PLA film may be 40-60 µm.

Thermoforming

The intermediate composite web product described above is intended to be used in a thermoforming step utilizing a thermoforming tool, such as a thermo mould or vacuum-forming equipment, to obtain a desired shape. During re-shaping of the substantially flat intermediate web to a three-dimensional object, the low density intermediate web is transformed from a relatively thick low density web to a relatively thin object with considerably higher material density in the walls of the three-dimensional product. The final bonding of the composite web develops characteristically at high densities in the range 500-1000 kg/m^3. If desired the web may be cut into blanks before being introduced into the thermoforming tool.

During thermoforming, the intermediate composite web needs to be heated in order to soften the thermoplastic material, typically to about 145-200 °C. The heating can be achieved by pre-heating in an oven or over a hot surface, either batch-wise or continuously. Advantageously, the thermoforming tool is also heated.

The CTMP fibres soften when heated to about 130 °C, and it has also been found to be advantageous to the thermoforming properties of the intermediate web if it is moisturized just before thermoforming. The moisture makes the CTMP fibres softer so that they can easier assume the shape of the thermoforming mould. The web is treated with water, preferably by spraying hot water or flowing steam over the sheet, the temperature preferably being 90-100 °C. A moisture content 10-30 wt% in the web is suitable as the form-shaping tool is closing, and more preferably 15-25 wt %. The moisture content is calculated as the relative content of water in a moist web and can be analysed gravimetrically using a drying procedure. The lower limit depends on the required softening effect of water, while the upper limit is set to avoid excess moisture, which leads to steam explosion and damage to the web when the pressure is released.

The heated and preferably moistened web is pressed in the thermoforming tool by a predetermined force, so as to reach its destined three-dimensional shape. A suitable pressure may be in the range 1-200 MPa. The final degree of bonding in the CTMP fibre web depends strongly on the achieved density after compression, and thus the applied pressure during thermoforming. The required pressure also depends on the grammage of the substrate. In a preferred application the pressure exceeds 10 MPa, more preferably 20 MPa in order to compress the composite fibre web and reach densities above 800 kg/m^3, so that efficient bonding of the sheet is obtained. The upper pressure limit is set by glazing effects of the web and eventually fibre damage. The lower pressure ranges are useful if a low density material is preferred.

A thermoforming tool for use in the thermoforming according to the invention may typically include a mould cavity (female part) and a pressing tool (male part). The pressing tool forces the intermediate web into the mould cavity, so that it attains the shape of the mould cavity. The direction of movement of the pressing tool is referred to as the press direction of the thermoforming tool.

The pressure is maintained until the desired shape has been fixated, and the final three-dimensional object is then released from the forming tool.

The released object is preferably subjected to a cooling step that occurs in the tool or immediately or shortly after release from the tool, and is preferably cooled to ambient temperature. A fast cooling is especially beneficial because it restores the mechanical properties, and avoids undesired setting of the object.

The thermoforming operation may be performed in various thermoforming equipments, including compression or vacuum moulding of a pre-heated web or sheet material.

In thermoforming by compressing moulding, generally two mould parts are closed after the intermediate web has been introduced there between and a pressure is applied for a time long enough for stress-relaxation to occur in the material. For compression moulding of the dry-laid intermediate composite web of the invention, a press with heated mould parts having the desired form and capable of applying loads ranged between 1-200 MPa is preferred.

The suitable thermoforming temperature will depend on the specific polymer material comprised in the intermediate web, in addition to the softening temperature of CTMP (130 °C). In general the temperature should exceed the Tg of the polymer material, and if the polymer material comprises two or more different polymers the temperature should exceed Tg of all polymers and the softening temperature of CTMP fibres. For certain tacky polymers it can be advantageous to not exceed the melting point of the polymer having the highest Tg, in order to avoid that the object sticks to the walls of the mould and is difficult to release. A suitable temperature is in the interval 130-200 °C, more preferably 150-180 °C. At higher temperatures than 200 °C, the CTMP fibres may be damaged, and at lower temperatures than 130 °C the CTMP fibres are not soft enough to give a ductile web. The pressing time should be as short as possible, and should typically be in the range of 1-30 seconds at production conditions. Lab-scale pressing may due to the manual setup require longer times, 30-200 seconds.

In vacuum moulding, a web heated to a forming temperature is stretched onto or into a single-surface mould, and held against the mould by applying a vacuum between the mould surface and the sheet, and optionally applying pressurized air from the other side. The method is rather simple in terms of equipment needed in comparison to the compression moulding technique, but does not offer the same wide range of possible three-dimensional geometries.

In order to successfully obtain thermoformed three dimensional objects from the intermediate composite web, it is important that the intermediate web has maintained (or regained) its expanded state to as large an extent as possible, in order to obtain the best possible extensibility.

Three-dimensional objects of various shape and dimension may be obtained by thermoforming an intermediate composite web as described above. For example a thermoformed three-dimensionally shaped object may have areas in which the material has been extended (i.e., stretched) over 20 % in at least one direction. The one-dimensional extensibility is herein derived from the actual length across the object in one direction divided by the corresponding projected diameter. Thus, a formed object may have a circumference in the plane of the planar web before pressing and a maximum depth in a plane perpendicular thereto, wherein the relation of the circumference to the depth is less than 10 and the extensibility of the composite web during thermoforming is exceeding 20 %, preferably 30 %, in at least one direction.

The object may also have at least one draft angle that is less than 15°, preferably even less than 5°. In engineering, draft is the amount of taper for moulded parts perpendicular to a parting line. By tapering the sides of a mould by an appropriate so-called draft angle, the mould will be easier to remove once the plastic has hardened in the mould.

Assessing extensibility

The extensibility is evaluated from the outer area of the formed three-dimensional object, which matches the shape of the female press tool. The extension in one direction is the relation between the contour length along the profile of the cross section of the shaped object, and the distance across the opening of the object in that cross section. The largest extension will be found at the deepest moulding depth, and the distance across the opening is then the shortest distance over the opening passing over the deepest moulding depth.

Fig. 1 illustrates a cup having an elongated shape, which has a bottom and side walls. The bottom has a surface plane that is perpendicular to the press direction of the thermoforming tool, and the side walls are inclined in relation to a line perpendicular to the surface plane of the bottom, by an angle α, which is referred to as the draft angle. The thermoformed three-dimensionally shaped object has an opening in a plane perpendicular to the press direction of the thermoforming tool, at least one side wall, and a bottom, and a maximum depth area, with a maximum depth between the opening and the bottom in a plane perpendicular therebetween. The shaped object has a first extensibility in at least one first direction of at least 22 %, preferably at least 26%, even more preferably 30%, said first direction coinciding with a plane perpendicular to the plane of the opening at a point of maximum depth, and is calculated as $\varepsilon_{A-A'} = (L_{A-A'}/D_{A-A'})-1) \times 100$ %. In case the opening has been cut subsequent to thermoforming, the plane of the first direction is an imaginary plane corresponding to the opening before cutting. $L_{A-A'}$ is the contour length, which follows the profile of the shaped object along a cross section in said first direction, and $D_{A-A'}$ is the shortest distance over the opening passing over said cross section in said first direction.

The contour length $L_{A-A'}$ follows the profile of the shaped object along the cross section, while the distance $D_{A-A'}$ is the distance between the points A, A' on the periphery of the opening, which distance is the shortest distance over the opening passing over the deepest moulding depth h (maximum depth). The moulding depth is parallel to the press direction of the thermoforming tool.

The contour length $L_{A-A'}$ should preferably be measured with a measuring tape or a thread following the cross sectional plane over the outside of the object, at the deepest portion of the shaped object. The measuring device must be in contact with the sample but must not deform the sample (a support of similar shape may be used if necessary). If the opening area has a symmetrical shape, the cross sections are chosen to pass through the centre of the object.

Draft angles should be measured with a stiff measuring device, like a ruler, fitted to a tangent to the outside of the side wall over a length of 10 mm at the steepest part of the side wall. The draft angle is the angle between the tangent to the side wall and a vertical line perpendicular to the surface plane of the bottom of the cup, or a tangential plane perpendicular to the press direction of the thermoforming tool, in cases where the bottom of the shaped object is uneven. In case of a convex side wall, the object should not be deformed but instead be determined by estimating an average inclination of the side wall over a distance of 10 mm at the steepest part of the side wall.

A two-dimensional measure on extensibility is given by evaluating the extensibility in two directions that are perpendicular to each other and both lies in the plane defining the opening over the cavity. The first direction is defined as above for extensibility in one direction, matching the shortest distance over the opening that also passes over the deepest moulding depth. The second direction describes a distance over the opening that passes over the deepest moulding depth, which is perpendicular to the first direction. Evaluation of the extensibility in both these directions results in two measures on extensibility, ε_{A-A} over the first direction and ε_{B-B} over the second direction. Evaluation of ε_{B-B} is performed in the same manner as ε_{A-A}, i.e. using the same formula as above, but with the dimensions in a direction perpendicular to the first direction It is preferred that the intermediate composite web of the invention have extensibilities ε_{A-A} and ε_{B-B} that each is at least 18%, more preferably at least 22%, and even more preferably at least 26%.

EXAMPLES

A number of intermediate composite web samples were prepared and the extensibility thereof during thermoforming was evaluated by thermoforming test cups in a test mould, and evaluating the resulting three-dimensional cups obtained. Figures 2-3 shows an illustration of the test mould, where the mould is open in Fig. 2, and the mould parts are closed in Fig. 3.

The test mould comprises a female moulding cavity part 1 and a male pressing part 2. The female moulding part includes an upper flat surface 3 encircling the moulding cavity 4, having a circular upper opening with a diameter (D) and a circular bottom section. The upper opening of the moulding cavity corresponds substantially to the diameter of the thermoformed object. The interior moulding cavity 4 of the female part has the shape of a cylindrical cup having the shape of a truncated cone with a height h, and draft angle α defining the slope of the side of the cone. The truncated cone is rounded off at the edge between the side and bottom section.

The round-off consists of a sharp curvature with radius 2 mm (R_2) connecting the side wall of the cone to a plane tilted β=5.7° above the bottom plane. A second curvature with radius 192 mm (R_1) and bow length 19.1 mm connects the two last mentioned planes. The male pressing part 2 has a shape that corresponds to the female moulding cavity, but is slightly smaller so that a gap 5 is formed between the moulding cavity and the pressing part. The gap (A) in the side wall and top section is somewhat smaller than the gap (B) in the bottom section, see Table 1. A set of moulds is used to cover different draft angles, α, press depth h, and gap widths (A, B).

The extensibility in one or more directions is defined as described above by the following equation: ε = ((L/D)-1) x 100 (%), where ε is the extensibility, L is the length of a profile defined by the contour length of a test mould from a first point 6 on the periphery of the upper opening of the moulding cavity of the female part, along the cavity 4 and to a second point 7 on the periphery of the upper opening of the moulding cavity on the other side of the mould, and D is the diameter of the opening of moulding cavity. The extensibility is thus a measure of the stretching of the material in one dimension. A two-dimensional measure on extensibility is given by evaluating the extension in two directions that are perpendicular to each other and both lies in the plane defining the opening over the cavity. Mould geometries used for evaluation of extensibility of the composite intermediate web during thermoforming are shown in Table 1.

The examples below show that the intermediate webs of the present invention have an extensibility of at least 30%, or even 40% that is valid in at least two directions, including two perpendicular cross sections of the thermoformed object. The draft angles of the object are at least 15°, more preferably at least 5° on at least one side. These results are unique compared to wet-formed paper webs, which typically do not show such high extensibility in two perpendicular directions. Most continuous paper webs do not reach such high extensibility in either machine or cross direction. Continuous paper webs produced by wet-forming and micro-creping can normally reach 12%, at most 20% extensibility in one optimal direction, but typically show lower extensibility in a second perpendicular direction, normally about 9%, at most about 15%. Such anisotropy in extensibility limits the effective extensibility achieved in thermoforming, especially when producing symmetric shapes like the conical 3D shaped objects, which require equal extensibility in at least two directions. The moulded object then needs to be dimensioned after the lower extensibility value in order to avoid failures and cracks during thermoforming.

Table 1. Mould geometries for evaluation thermoforming of CTMP intermediate web

Draft angle	Diameter D of mould cavity opening (mm)	Height h (mm)	Gap width A for the bottom section (mm)	Gap width B for the side wall and top section (mm)	Extensibility as defined by Equation 1
5°	70.7	20	1.0	1.2	47%
15°	69.9	20	0.60	0.75	39%

Each thermoformed object is evaluated to see if the moulding was successful. The evaluation criteria are to check if the sheet has been completely stretched over the mould geometry to produce an intact three-dimensional cup. An unsuccessful moulding may either contain open cracks in the sample, or a severe thinning zone where the grammage has been reduced to less than half compared to the surrounding areas. A thinning zone is the first stage of failure due to insufficient extensibility, eventually leading to an open crack if more strain would be applied. It has been found that addition of moisture during thermoforming and PLA film can increase the extensibility so that severe thinning and cracks are avoided for a given sheet composition and mould geometry. This is illustrated in the examples.

Given that a thermoforming experiment was successful, a measure on the extensibility of the sheet in one dimension can be calculated according to Equation 1 above, and due to rotation symmetry this extensibility is valid in at least two directions (i.e. a first and a second direction), which includes two perpendicular cross sections of the thermoformed object.

In the following examples sheets of dry-laid calendared web of HT-CTMP fibres (Luna®) were used as starting materials for producing intermediate webs by impregnation with binder liquid and drying. Table 2 lists the different latex samples that were used. Thermoformed objects were produced from intermediate sheets and the result was evaluated.

Table 2 List of tested latex samples and their abbreviations.

Abbreviation	Chemical composition	Supplier	Product name	Glass transition temperature (°C)
PS	Polystyrene	Styron	DPP3740	ca. +100°C
SB_{9272}	Styrene-butadiene	EKA Polymer Latex	Litex PX9272	+24°C
SB_{S21C}	Styrene-butadiene	Synthomer	Litex S 21 C	+48°C
PVA	Vinyl acetate hydrofob	Celanese	Vinnamul 9300	+30°C
VAE	Vinylacetate - ethylene	Celanese	Mowilith PE 292 S	+5°C
x-VAE	Self-crosslinking vinylacetate-ethylene	Celanese	Elite Ultra	+5°C
PP_{4501}	Propylene co-polymer	Dow	Hypod 4501	-26°C

Example 1 – Preparation of a composite intermediate sheet by spray impregnation

A sheet of dry-laid calendared web of HT-CTMP fibres having a grammage of 400 g/m^2 was placed on a support grid. The sheet had a weight of 97 g. Impregnation was performed by applying latex with a spraying gun driven by pressurized air. The spray application was calibrated by applying latex at a transfer rate of about 1-2 ml/s, the exact rate was verified by weight measurements. After this calibration, spraying was operated against time to control the applied amount. The spray gun was filled with a water dispersion containing 5.3 wt% styrene-butadiene (SB) latex (EKA PL Litex PX9272) and 16.1 wt% polystyrene (PS) latex (Styron DPP 3740), based on the weight of the total dispersion. The sheet was impregnated with latex dispersion using a spray gun for a time of 100 s. The spray gun was continuously traversed over the sheet to get an even distribution of latex. After 50 s, the sheet was turned to treat both sides with latex. The total uptake of latex dispersion was 196 g, corresponding to 2.0 g/g. The impregnated sheet was transferred to a table and was dried at ambient conditions to produce a porous sheet, having a total grammage of 570 g/m^2 and a density of 124 kg/m^3. The polymer content of the intermediate sheet obtained was 7.5 wt% styrene-butadiene and 22.5 wt% polystyrene latex based on weight of the dry intermediate web.

Example 2- Preparation of a composite intermediate sheet by impregnation bath

A sheet of dry-laid calendared web of HT-CTMP fibres having a grammage of 400 g/m^2, weighing 40 g was placed in a tray. 200 ml of a dispersion containing 30 wt% styrene-butadiene latex (EKA PL PX9272) was poured over the sheet, carefully distributing the dispersion evenly. All dispersion was absorbed by the sheet, which expanded spontaneously. A porous composite sheet was obtained after drying at ambient conditions.

Example 3 - Thermoforming test, sheet with 22.5% PS and 7.5% SB latex.

An impregnated intermediate sheet as obtained in Example 1 was cut into a 13 x 13 cm sample piece. The sample was preheated in an oven at 170°C for 10 min. A mould according to Figure 2 and 3 with 69.9 mm opening diameter, 20 mm depth, mm gap width A=0.6, B=0.75 and 15° draft angle was mounted in a hot press and preheated to 135°C. The preheated sheet was in a fast sequence wetted by spraying with water to receive a total amount of about 2 g water and placed between the two mould halves in separated state. The mould was then closed and loaded in the hot press to a pressure of 43 MPa over the mould. This pressure was held for 30 s while the temperature in the mould increased to 145°C. After releasing the pressure the mould was cooled to 40°C before the sample was released. A cup-shaped sample was obtained. Inspection showed that the sample was intact over the stretched area and had a smooth surface with natural feel.

Example 4- Thermoforming with application of PLA film.

Another 13 x 13 cm sample piece of the impregnated intermediate material obtained in Example 1 was preheated at 170°C for 10 min, wetted by spraying with water to receive a total amount of 2 g, where after PLA film with thickness 40 µm was placed on both sides of the sheet. The same mould as in Example 3 was used and was preheated to a temperature of

150°C. The combined CTMP sheet and PLA film was placed between the open mould halves and the mould was then closed and loaded to 43 MPa. The pressure was maintained for 30 s, during which the temperature increased to 154°C. After releasing the pressure the mould was cooled to 40°C before the sample was released. Inspection showed that the sample was intact and had a laminated PLA film over the upper and lower surface.

Example 5 - Thermoforming test, mould with 5° draft angle - no PLA film

The experiment in Example 3 was repeated with a mould with smaller draft angle of 5°, opening diameter 70.7 mm, depth 20 mm, and gap width A=1.0, B=1.2 mm. The sample was wetted by spraying with water to receive a total amount of 2 g before thermoforming the sheet under same conditions as in Example 3. Inspection of the thermoformed cup showed that the sheet had been stretched over all the moulded area, but had a defect consisting of a 20 mm long thinning zone over the bottom area.

Example 6 - Thermoforming test, mould with 5° draft angle, with PLA film.

The experiment in Example 5 was repeated, but with application of a PLA film on the top side against the male mould part. The sheet was placed in the mould that was pre-heated to 140°C, loaded to 43 MPa and pressed for 30 s, reaching a temperature of 142°C. The mould was cooled to 40°C before the sample was released. Inspection showed that the sheet was stretched over all the moulded area with only a minor thinning effect in basis weight at the bottom surface.

Example 7 – Thermoforming test with 15 wt-% PS + 5 wt-% SB latex

A sheet of dry-laid calendared web of HT-CTMP fibres having a grammage of 600 g/m^2 was impregnated with 2 g/g water dispersion containing 3.1 wt% styrene-butadiene latex (EKA PL Litex PX9272) and 9.4 wt% polystyrene latex (Styron DPP 3740) based on the weight of the total dispersion, using the method described in Example 1. The porous sheet produced had a total grammage of 750 g/m^2 and the polymer content was 5 wt-% styrene-butadiene and 15 wt% polystyrene latex based on weight of the dry intermediate web. The porous sheet was thermoformed according to the method described in Example 3. Moisture was added to the substrate prior to thermoforming. The mould was pre-heated to 100°C. The pressure was maintained for 2 min while the temperature in the mould increased to 148°C. A cup-shaped sample was obtained. Inspection showed that the sample had a few minor cracks on the side wall.

Example 8 - Thermoforming test with 15 wt-% PS and 5 wt-% SB latex using PLA film

The test in Example 7 was repeated, with the modification that moisture was added before the applying PLA film on both sides of the sheet. The mould was pre-heated to 100°C. The pressure was maintained for 3 min while the temperature in the mould increased to 147°C. A cup-shaped sample was obtained. Inspection showed that the sample was intact and had a laminated PLA film over the upper and lower surface.

Example 9 - Thermoforming test with 1% debonder additive

The test in Example 7 was repeated, with the modification that a debonder for pulp (EKA Soft F639) was added in the impregnation liquor to give a concentration of 1 wt-% debonder in the dry intermediate web, the latex addition being unmodified. The mould was pre-heated to 145°C. The pressure was maintained for 2 min while the temperature in the mould increased to 150°C. A cup-shaped sample was obtained. Inspection that showed the sample was stretched over the mould shape with two small holes present.

Example 10 - Thermoforming test with 1% debonder additive using PLA film

The test in Example 8 was repeated, with the modification that a debonder for pulp (EKA Soft F639) was added in the impregnation liquor to give a concentration of 1 wt-% debonder in the dry intermediate web, the latex addition being unmodified. The mould was pre-heated to 100°C. The pressure was maintained for 3 min while the temperature in the mould increased to 147°C. A cup-shaped sample was obtained. Inspection showed that the sample was intact and had a laminated PLA film with weak adhesion over the upper and lower surface. This indicates that it may be preferred not to use debonder for such a product, since i may weaken the adherence of the PLA film.

Example 11 – Thermoforming test with 20 wt-% SB latex.

A sheet of dry-laid calendared web of HT-CTMP fibres having a grammage of 600 g/m^2 was impregnated with 2 g/g water dispersion containing 12,5 wt-% styrene-butadiene latex (EKA PL Litex PX9272), using the method described in Example 1. The porous sheet produced had a total grammage of 750 g/m^2, and the polymer content was 20 wt-% styrene-butadiene, based on the weight of the dry intermediate web. The porous sheet was thermoformed according to the method described in Example 4. Moisture and PLA film was added to the substrate prior to thermoforming. The mould was pre-heated to 80°C. The pressure was maintained for 2 min while the temperature in the mould increased to 145°C. A cup-shaped sample was obtained. Inspection showed that the sample was stretched over all the moulded area except for a minor crack on the side wall. The sample had a laminated PLA film over the upper and lower surface.

Example 12 – Thermoforming test with 30% SB latex

The test in example 11 was repeated with a higher solid content of the latex dispersion, 21.4 wt-%. The porous sheet produced had a total grammage of 850 kg/m^3 and a polymer content of 30 wt-% styrene-butadiene (EKA PL Litex PX9272) based on weight of the dry intermediate web. A cup-shaped sample was obtained. Inspection showed that the sample was intact and had a laminated PLA film over the upper and lower surface.

Example 13 - Thermoforming test with 20 wt-% SB latex

The test in example 11 was repeated by impregnating with 12,5 wt-% styrene-butadiene latex (Synthomer Litex S 21 C). The porous sheet produced had a total grammage of 750 kg/m^3 and a polymer content of 20 wt-% styrene-butadiene latex based on weight of the dry intermediate web. A cup-shaped sample was obtained. Inspection showed that the sample was intact and had a laminated PLA film over both the upper and lower surface.

Example 14 – Thermoforming test with 20 wt-% PS latex.

The test in Example 11 was repeated by impregnating with 12.5 wt-% styrene latex (Styron DPP 3740). The porous sheet produced had a total grammage of 750 kg/m^3 and a polymer content of 20 wt-% styrene-butadiene latex based on weight of the dry intermediate web. A cup-shaped sample was obtained. Inspection showed that the sample was intact with a rough surface structure, and had a laminated PLA film over both the upper and lower surface.

Example 15 – Thermoforming test with 11 wt-% PVA latex

A sheet of dry-laid calendared web of HT-CTMP fibres having grammage of 600 g/m^2 was impregnated with 2 g/g water dispersion containing 5.9 wt% polyvinylacetate (PVA) emulsion (Celanese Vinamul 9300), using the method described in Example 1. The porous sheet produced had a total grammage of 670 g/m^2 and the polymer content was 11 wt-% polyvinylacetate emulsion based on weight of the dry intermediate web. The porous sheet was thermoformed according to the method described in Example 4 with the following modifications: The porous sheet was pre-heated to 140°C and applied in dry state for thermoforming without any addition of water. PLA film was applied on both sides of the sheet. The mould was pre-heated to 120°C, pressure was maintained for 1 min while the temperature in the mould increased to 145°C. A cup-shaped sample was obtained. Inspection showed that the sample was intact and had a laminated PLA film over both the upper and lower surface.

Example 16 – Thermoforming test with 20 wt-% PVA latex

The test in Example 15 was repeated with a higher solid content of the latex dispersion, 12.5 wt-%. The porous sheet produced had a total grammage of 750 kg/m^3 and a polymer content of 20 wt-% polyvinylacetate emulsion (Celanese Vinamul 9300) based on weight of the dry intermediate web. The sheet was used without moisture addition and PLA film was added on both sides of the substrate. A cup-shaped sample was obtained. Inspection showed that the sample was intact and had a laminated PLA film over both the upper and lower surface.

Example 17 – Thermoforming test with 15 wt-% PS and 5 wt-% PVA latex

A sheet of dry-laid calendared web of HT-CTMP fibres having a grammage of 600 g/m^2 was impregnated with 2 g/g water dispersion containing 3.1 wt% polyvinylacetate dispersion (Celanese Vinamul 9300) and 9.4 wt% polystyrene latex (Styron DPP 3740) based on the weight of the total dispersion, using the method described in Example 1. The porous sheet produced had a total grammage of 750 g/m^2 and the polymer content was 5 wt-%

polyvinylacetate and 15 wt% polystyrene latex based on weight of the dry intermediate web. The porous sheet was thermoformed according to the method described in Example 4. Moisture and PLA film was added to the substrate prior to thermoforming. The mould was pre-heated to 110°C. The pressure was maintained for 3 min while the temperature in the mould increased to 147°C. A cup-shaped sample was obtained. Inspection showed that the sample was intact and had a laminated PLA film over both the upper and lower surface.

Example 18 – Thermoforming test with 10 wt-% PS and 10 wt-% VAE latex

A sheet of dry-laid calendared web of HT-CTMP fibres having a grammage of 600 g/m^2 was impregnated with 2 g/g water dispersion containing 6.3 wt% vinylacetate-ethylene copolymer emulsion (Celanese Mowilith PE 292S) and 6.3 wt% polystyrene latex (Styron DPP 3740) based on the weight of the total dispersion, using the method described in Example 1. The porous sheet produced had a total grammage of 750 g/m^2 and the polymer content was 10 wt-% vinylacetate-ethylene copolymer and 10 wt% polystyrene latex based on weight of the dry intermediate web. The porous sheet was thermoformed according to the method described in Example 4, except that no moisture was added after pre-heating. PLA film was added on both sides of the substrate prior to thermoforming. The mould was pre-heated to 110°C. The pressure was maintained for 3 min while the temperature in the mould increased to 147°C. A cup-shaped sample was obtained. Inspection showed that the sample was intact and had a laminated PLA film over both the upper and lower surface.

Example 19 – Thermoforming test with 20 wt-% self-crosslinking VAE

The test in Example 11 was repeated by impregnating with 12.5 wt-% self-crosslinking vinylacetate-ethylene latex (Celanese Elite Ultra). The porous sheet produced had a total grammage of 750 kg/m^3 and a polymer content of 20 wt-% self-crosslinking vinylacetate-ethylene polymer based on weight of the dry intermediate web. Moisture and PLA film was applied on both sides of the substrate before thermoforming. A cup-shaped sample was obtained. Inspection showed that the sample was intact and had a laminated PLA film over both the upper and lower surface.

Example 20 – Thermoforming test with 30 wt-% PP latex

A sheet of dry-laid calendared web of HT-CTMP fibres having a grammage of 400 g/m^2 was impregnated with 2 g/g water dispersion containing 21,4 wt% polypropene copolymer latex (Dow Hypod 4501), using the method described in Example 1. The porous sheet produced had a total grammage of 570 g/m^2 and the polymer content was 30 wt-% polypropylene copolymer latex based on weight of the dry intermediate web. A 13 x 13 cm sample piece of the impregnated intermediate material obtained was sprayed with water to receive a total amount of 2 g before it was preheated in an oven at 145°C for 9 min. Thereafter PLA film with thickness 40 µm was placed on both sides of the sheet. Same mould as in Example 3 was used and was preheated to a temperature of 80°C. The combined CTMP sheet and PLA film was placed between the open mould halves and the mould was then closed and loaded to 43 MPa. The pressure was maintained for 80 s, during which the temperature increased to 141°C. After releasing the pressure the mould was cooled to 40°C before the sample was released. A cup-shaped sample was obtained. Inspection showed that the sample had been smoothly stretched over the mould, except for a minor crack on the side wall, and had a laminated PLA film over the upper and lower surface.

The experimental results show that the intermediate web of the present invention can successfully be thermoformed into three-dimensional objects, and that by wetting and moisturizing the CTMP fibres in the intermediate web good test cups can be obtained by thermoforming a web, where the same dry web could not be formed to an acceptable cup in a dry state. Further, the experiments show that the addition of a PLA film on the surface of the intermediate web contributes to substantially enhanced formability, so that a cup having a draft angle as low as 5° can be formed. Intact cup-shaped samples illustrate that the intermediate sheet has been successfully stretched over both its machine- and cross direction during the thermoforming process. The extension in the mould corresponds to a high stretch of the material, at least 39 % in either direction. Furthermore, the thermoformed material has been evenly stretched to produce a smooth surface without any crinkling effect.

The thermoformed three-dimensional objects obtained according to the present invention may be used for packaging of various goods, e.g. sensitive goods, such as electronic equipment, cellular phones and other household and hardware items, that need protective packaging in order to avoid damage of the sensitive goods, due to for example mechanical shock, vibrations, compression, or extreme temperatures during transport, storage, or other handling.

The thermoformed three-dimensional objects according to the invention are also suitable as construction materials, especially in the form of panels, frames, lids, covers and similar. The three-dimensional shape provides both design and function to the item, e.g. structure, decoration, coverage, protection, fixation, support, storage etc. Compressed wood fibre composites show good tensile strength and stiffness, and the sustainability associated with the wood fibres give environmental benefits. A few typical examples of construction materials are indoor building materials, furniture applications and panels for use in the automotive industry. Indoor building materials are three-dimensionally shaped panels, frames, profiles, covers or the like, typically for permanent attachment. 3D shaped building materials are used both for decoration, protection and support. In furniture applications three-dimensionally shaped items can be used as self-supporting structures in furniture. 3D shaped details can also be used in multilayer-structures either as core materials or as a top ply. Three-dimensionally shaped items are also commonly used as panels in automotive industry, for example in dashboards and door panels.

CLAIMS

1. A dry-laid composite web being an intermediate product for thermoforming of three-dimensionally shaped objects, comprising 40-95 wt-% CTMP fibres, 5-50 wt-% thermoplastic material, and 0-10 wt-% additives, wherein the dry-laid composite web has been impregnated with a dispersion, an emulsion, or a solution containing the thermoplastic material and dried, obtaining a density of 50-250 kg/m^3, or, if compressed by calendering 400-1000 kg/m^3.

2. The web according to claim 1, wherein the thermoplastic material comprises a first polymer material having Tg of -60 - +80 °C, preferably -30 - +50 °C; more preferred -10 - +25°C, and a second polymer material having Tg of 45 - 130 °C, and wherein said composite web has been subjected to a temperature of above Tg of the first polymer, but not above Tg of the second polymer after impregnation, so that the first polymer binds to the CTMP fibres, while the CTMP fibres remain unbonded to the second polymer.

3. The web according to claim 2, wherein the thermoplastic material comprises 5-20 wt-% of the first polymer material based on the total weight of the composite web.

4. The web according to any of the claims 1 to 3, further comprising a polymer film layer positioned on at least one side of the web, preferably on both sides of the web forming a sandwich laminate, having a thickness of 1-500 µm, preferably 4-200 µm.

5. The web according to claim 4, wherein at least one of the polymer film layers comprises polylactide.

6. A process for producing a dry-laid composite intermediate web according to any of the claims 1 to 5 comprising the steps:

- Forming a dry-laid web comprising CTMP fibres, and preferably calendaring or compressing the dry-laid web;
- Adding thermoplastic material to the web by impregnation, wherein the thermoplastic material is added in the form of a dispersion, an emulsion, or a solution in an amount to reach 5-50 wt-% thermoplastic material based on the total dry weight of the web;
- Drying the web;
- Making rolls or sheets of the dried web.

7. The process according to claim 6, wherein the impregnation is a process where the composite web can expand freely.

8. The process according to claim 6 or 7, wherein the impregnation is performed by spraying.

9. The process according to any of the claims 6 to 8, wherein the thermoplastic material added comprises a first polymer material having Tg of -60 - +80 °C, preferably -30 - +50 °C; more preferred -10 - +25°C, and a second polymer material having Tg of 45 - 130 °C, the drying is performed at a temperature of above Tg of the first polymer, but not above Tg of the second polymer after impregnation, so that the first polymer binds to the CTMP fibres, while the CTMP fibres remain unbonded to the second polymer.

10. The process according to any of the claims 6 to 9, wherein the drying is performed without applying any physical constraints to the web until the web reaches ambient humidity.

11. The process according to any of the claims 6 to 10, wherein the web is calandered subsequent to drying, obtaining a web density of 400-1000 kg/m^3.

12. The process according to any of the claims 6 to 11, further comprising a step of applying a polymer film layer to at least one side of the dried web, said polymer film layer preferably being a polylactide film.

13. A process for producing a thermoformed three-dimensionally shaped object from a pre-manufactured dry-laid composite intermediate web according to any of the claims 1 to 5, said web having a density of 50-250 kg/m^3, comprising the steps:
- Optionally, in the case of the composite intermediate web being calandered, swelling of the web by means of wetting with water, followed by drying;
- Heating and introducing the web into a thermoforming tool having the desired shape;
- Forming the web in the thermoforming tool by pressing at a pressure of 1-200 MPa, preferably 1-100 MPa, or by utilizing a vacuum pressure;
- Releasing the thereby obtained three-dimensionally shaped object from the thermoforming tool.

14. The process according to claim 13, further including moistening of the heated web by treating it with water, preferably by spraying, to obtain a moisture content of the web of 10-30 %, more preferably 15-20 %, as the form-shaping tool is closing.

15. The process according to claim 13 or 14, further including cooling of the obtained object.

16. The process according to any one of claims claim 13 - 15, wherein the web is cut into blanks before being introduced into a form-shaping tool.

17. A thermoformed three-dimensionally shaped object obtained from the process according to claims 13-16, said object having an opening in a plane perpendicular to the press direction of the thermoforming tool used in the thermoforming process, at least one side wall, and a bottom, and a maximum depth area, with a maximum depth between the opening and the bottom, said shaped object having a first extensibility in

at least one first direction of at least 22 %, preferably at least 26%, even more preferably 30%, said first direction coinciding with a plane perpendicular to the plane of the opening at a point of maximum depth, said first extensibility being calculated as $\varepsilon_{A-A'} = (L_{A-A'}/D_{A-A'})-1) \times 100\ \%$, $L_{A-A'}$ is the contour length, which follows the profile of the shaped object along a cross section in said first direction, and $D_{A-A'}$ is the shortest distance over the opening passing over said cross section in said first direction.

18. A thermoformed three-dimensionally shaped object according to claim 17, characterised by the object additionally having a second extensibility in the plane of the opening in a second direction perpendicular to the first direction, the second extensibility being calculated in the same manner as the first extensibility, and both first and second extensibilities being at least 18%, preferably at least 22%, even more preferably at least 26%.

19. The object according to claim 17 or 18, wherein at least one draft angle is less than 15°, preferably less than 5°.

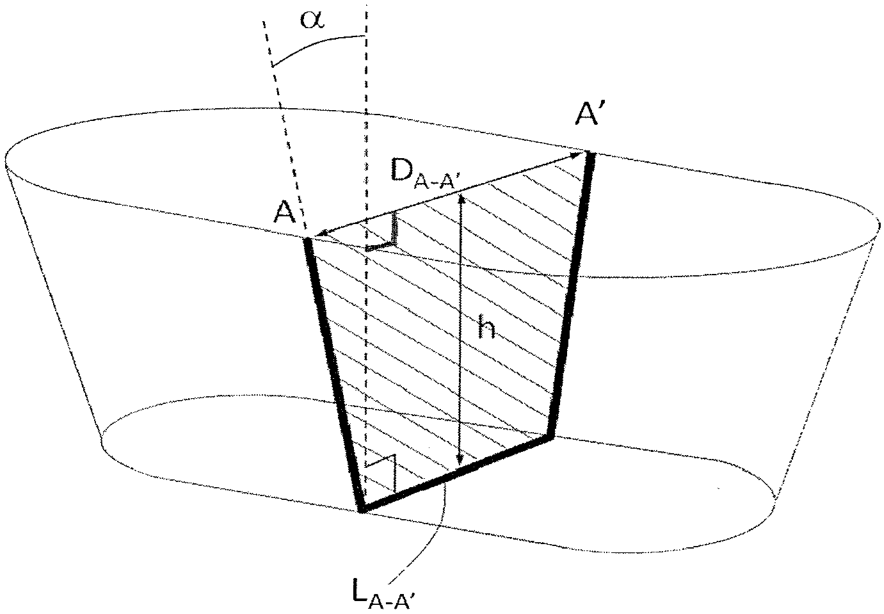

Figure 1

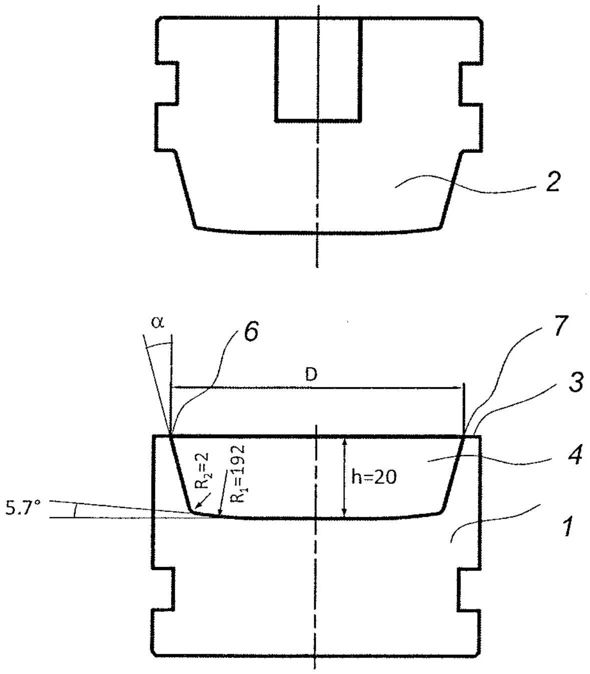

Figure 2

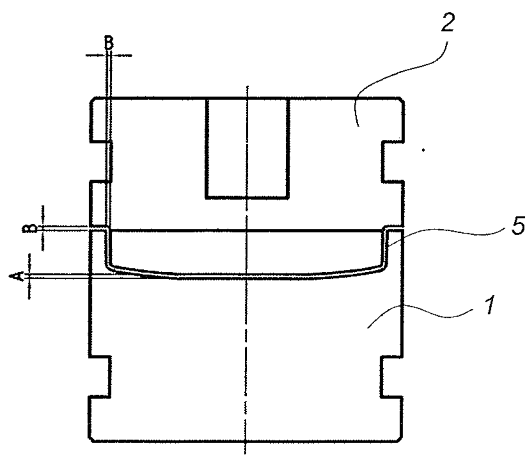

Figure 3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE2013/050217

A. CLASSIFICATION OF SUBJECT MATTER

IPC: see extra sheet

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: B27N, B29C, D04H, D21H

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

SE, DK, FI, NO classes as above

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

EPO-Internal, PAJ, WPI data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2007073218 A1 (NEW ZEALAND FOREST RES INST ET AL), 28 June 2007 (2007-06-28); page 8, line 27; page 9, line 16 - line 21; page 14, line 26 - page 14, line 28; claims --	1, 13-19
A	EP 1840043 A1 (HARTMANN AS BRDR), 3 October 2007 (2007-10-03); whole document --	1-19
A	US 3019155 A1 (SNYDER FRANCIS H), 30 January 1962 (1962-01-30); whole document --	1-19
A	US 4308187 A1 (VAN EENAM DONALD N), 29 December 1981 (1981-12-29); whole document --	1-19

☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

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

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

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
04-12-2013	05-12-2013

Name and mailing address of the ISA/SE
Patent- och registreringsverket
Box 5055
S-102 42 STOCKHOLM
Facsimile No. + 46 8 666 02 86

Authorized officer
Erika Stenroos
Telephone No. + 46 8 782 25 00

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE2013/050217

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

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

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

2. ☒ Claims Nos.: 17
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

See extra sheet

.../...

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

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

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

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

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

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

☐ No protest accompanied the payment of additional search fees.

Continuation of: Box No. II

Present claim 17 relates to a product defined (inter alia) by reference to the following parameter:

P1: $\varepsilon_{A\text{-}A'} = (L_{A\text{-}A'}/D_{A\text{-}A'})\text{-}1)$ x 100 % (extensibility)

The use of this parameter in the present context is considered to lead to a lack of clarity within the meaning of Article 6 PCT. It is impossible to compare the parameter the applicant has chosen to employ with what is set out in the prior art. The lack of clarity is such as to render a meaningful complete search impossible.

It is also questioned if a the three-dimensionally shaped object can be characterized in terms of extensibility, since the product is stiff and form stable.

Consequently, the search has been restricted to the following:
A three dimensional product produced by the material characterised in claim 2 and on page 2, line 21 – page 3, line 9.

Thence it follows that a reasoned statement under Rule 43bis.1(a)(i) with regard to novelty, inventive step or industrial applicability only is established for those parts mentioned above.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE2013/050217

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 20020127862 A1 (COOPER RICHARD D ET AL), 12 September 2002 (2002-09-12); whole document -- --------	1-19

Continuation of: second sheet

International Patent Classification (IPC)

B27N 3/04 (2006.01)
B27N 1/02 (2006.01)
B27N 5/00 (2006.01)
B29C 51/00 (2006.01)
D04H 1/26 (2012.01)
D21H 27/42 (2006.01)

WO	2007073218	A1	28/06/2007	AU	2006328021	A1	28/06/2007
				CA	2637677	A1	28/06/2007
				EP	1968775	A4	14/11/2012
				JP	2009521341	A	04/06/2009
				JP	5279125	B2	04/09/2013
				NZ	544493	A	31/07/2008
				US	8012389	B2	06/09/2011
				US	20090264560	A1	22/10/2009
EP	1840043	A1	03/10/2007	AT	443003	T	15/10/2009
				DE	602006009218	D1	29/10/2009
				ES	2334695	T3	15/03/2010
				US	20100190020	A1	29/07/2010
				WO	2007113750	A3	21/12/2007
US	3019155	A1	30/01/1962	NONE			
US	4308187	A1	29/12/1981	AU	540501	B2	22/11/1984
				AU	6729081	A	20/08/1981
				CA	1155990	A1	25/10/1983
				DE	3171643	D1	12/09/1985
				EP	0034893	A2	02/09/1981
				JP	56127662	A	06/10/1981
US	20020127862	A1	12/09/2002	US	20050085169	A1	21/04/2005
				US	6863774	B2	08/03/2005