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(54) **A REEL**

(71) Applicants: **Synbra Technology B.V.**, Etten-Leur (NL); **colorFabb B.V.**, Belfeld (NL)

(72) Inventors: **Jan Noordegraaf**, Etten-Leur (NL); **Dave Gijsberts**, Etten-Leur (NL); **Jos Johannes Antonius Deelen**, Belfeld (NL); **Ruud Willem Margaretha Rouleaux**, Belfeld (NL)

(73) Assignees: **Synbra Technology B.V.**, Etten-Leur (NL); **colorFabb B.V.**, Belfeld (NL)

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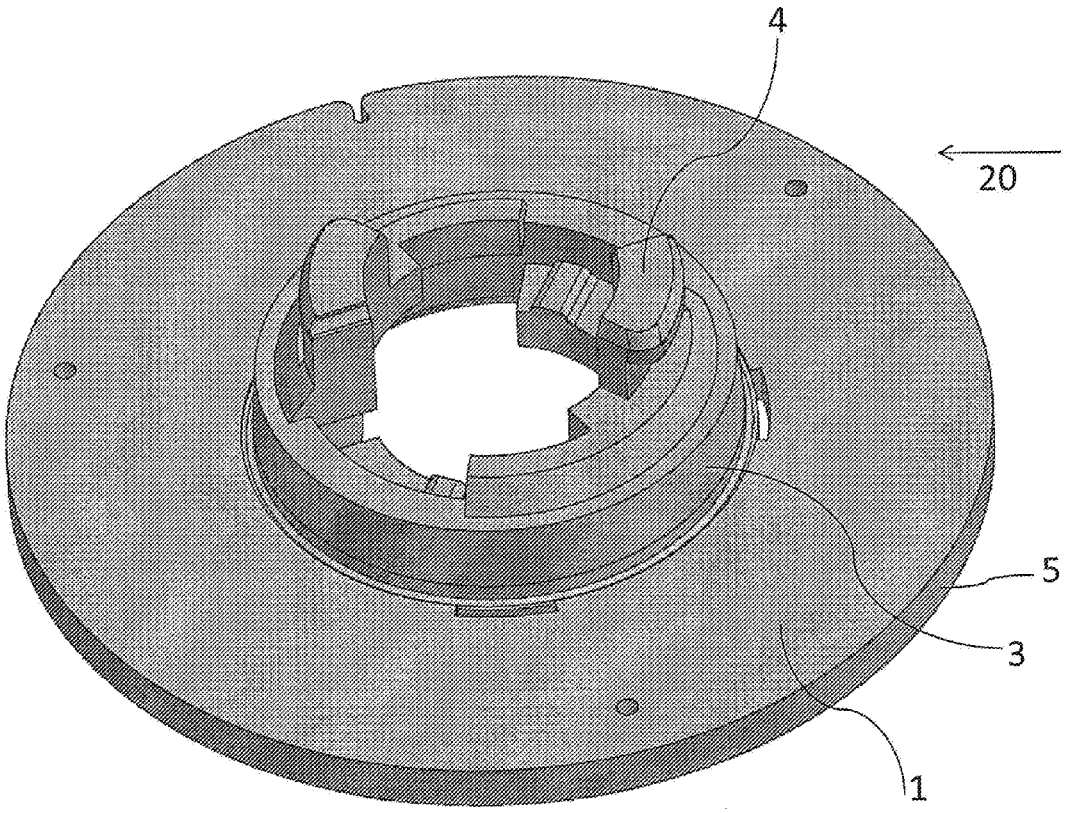
(57) **ABSTRACT**

The present invention relates to a reel (**10**) for winding up and unwinding filaments, comprising a circular middle element (**3**), circular flanges (**1**,**2**) positioned on either side of said middle element (**3**), wherein the diameter of said middle element (**3**) is smaller than the diameter of said flanges (**1**,**2**), which middle element (**3**) is suitable for winding up and unwinding filaments, wherein said middle element (**3**) and flanges (**1**,**2**) are manufactured from a biodegradable polymer.



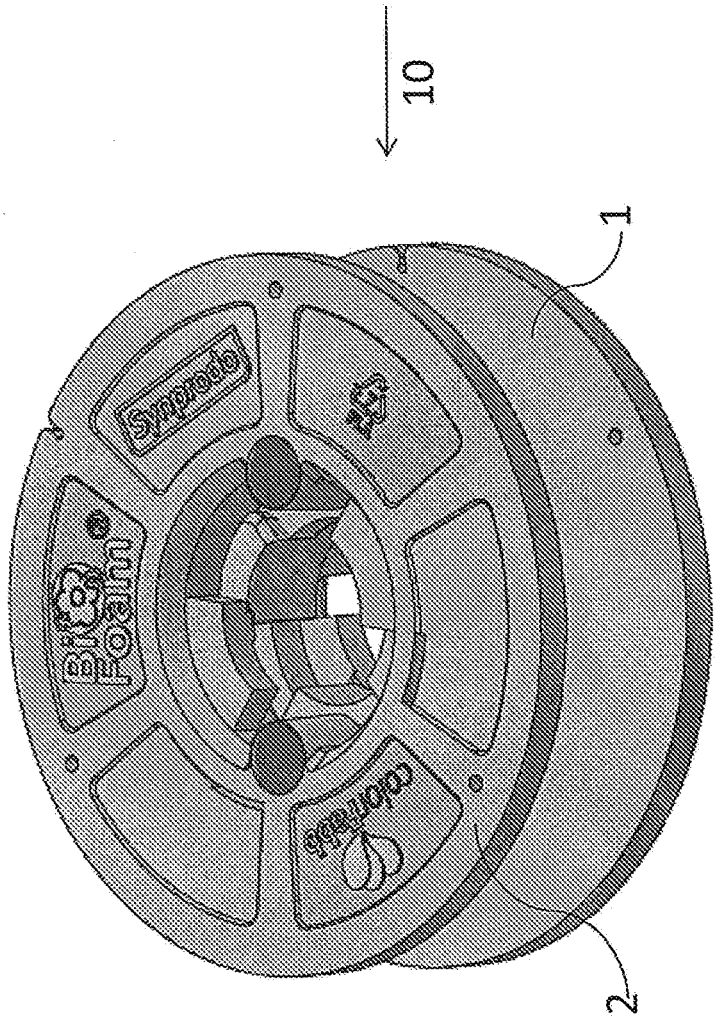


Fig. 1

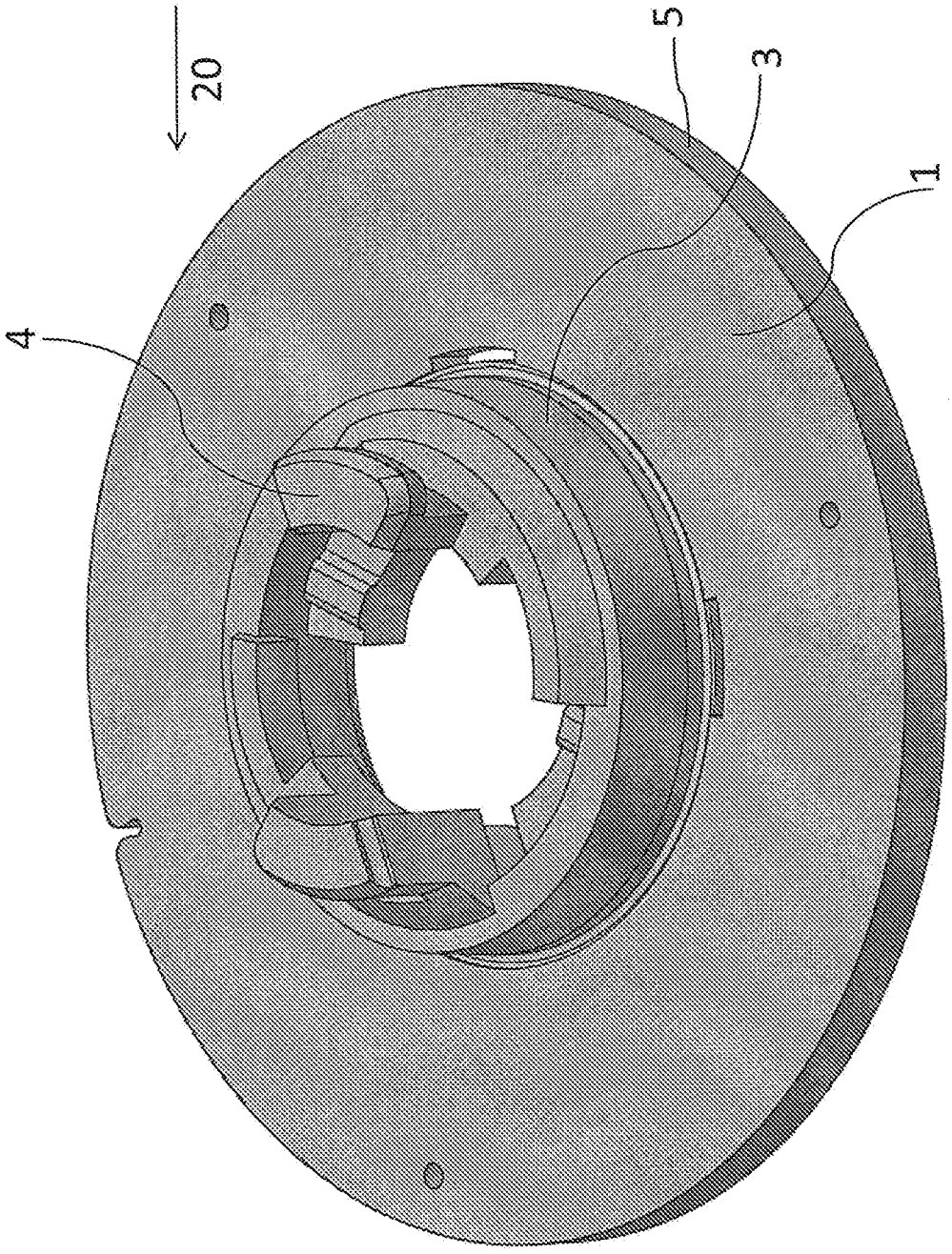


Fig. 2

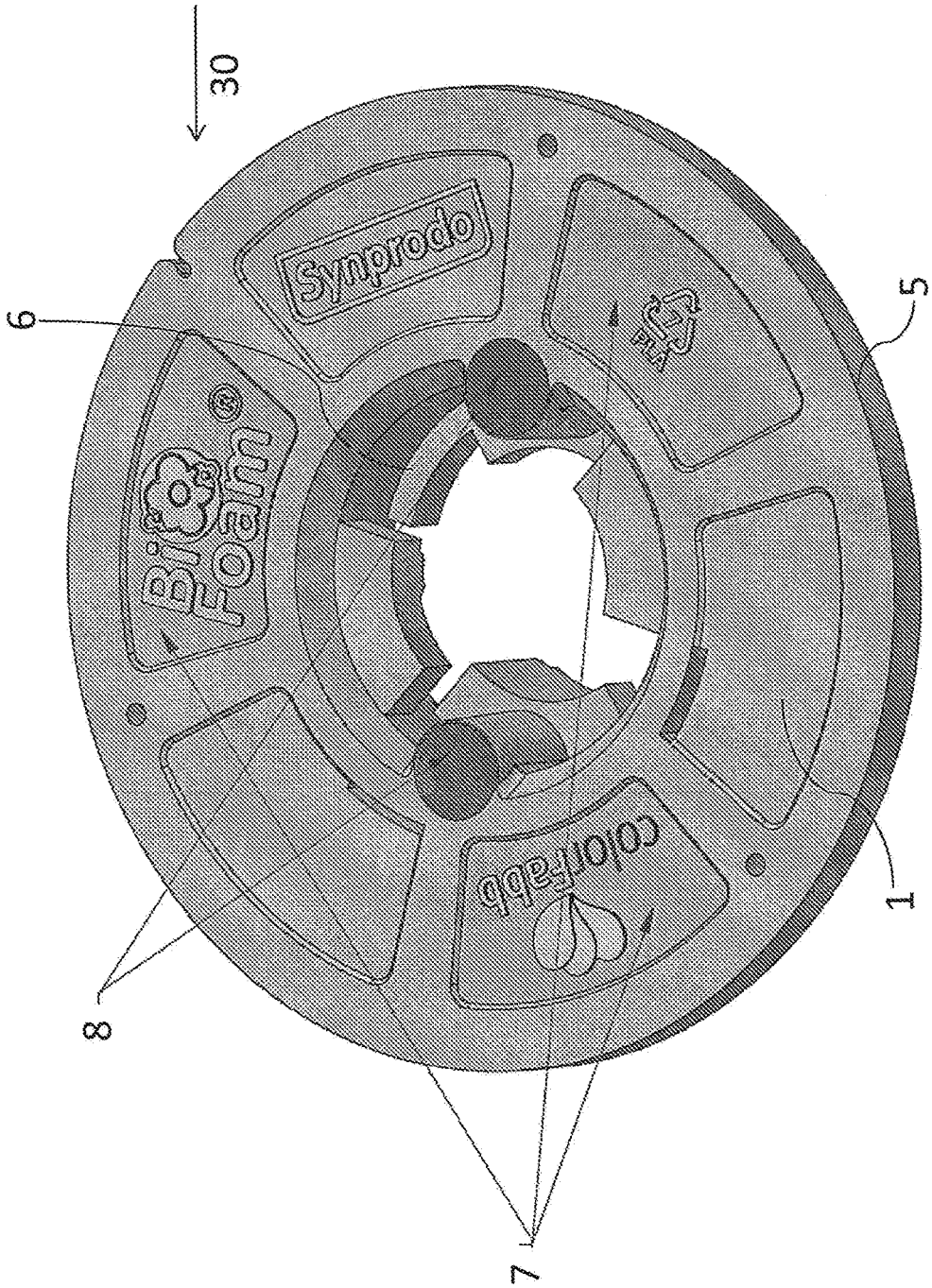


Fig. 3

A REEL

[0001] The present invention relates to a reel for winding up and unwinding filaments. Such a reel comprises a circular middle element and circular flanges positioned on either side of said middle element, wherein the diameter of said middle element is smaller than the diameter of said flanges, which middle element is suitable for winding up and unwinding filaments.

[0002] Reels are used to store filaments and to later unwind the filaments again. Every 3-D printer for instance requires a feed of material. A 3-D printer usually has a type of plastic material as feed, and this plastic material is supplied on a reel. This reel is mounted on a shaft on the 3-D printer, wherein the material is heated by the 3-D printer and a printing step then takes place. A 3-D printer makes a three-dimensional model, wherein the model is thus built up from very thin layers of material. 3-D printing can be performed in many different ways, for instance using bio-plastic, polyester and epoxy, but also photopolymer. In the fused deposition modeling (FDM) type method of 3-D printing melted plastic forms the basis of the model and is applied by means of a nozzle extruder. The starting material in this method of printing is usually a roll with yarns of plastic wound thereon, also referred to as filaments.

[0003] Reels for optical fibres for instance have been known for a long time. Known from U.S. Pat. No. 4,387,863 is a spool wherein preventing an undesired bending of the optical fibre is particularly important. The spool disclosed in this American patent is made from two halves wherein the spool is cut in the axial plane, with a double flange at both ends. The two halves are attached to each other with a tongue and groove connection. Stated as a suitable material for the spool is a semi-rigid material, for instance EPS, this providing the option of clamping connectors to the end of the yarn. The above spool is therefore intended only for yarns with a connector on the end, and the geometry of the smaller inner flange is therefore specially configured for this purpose.

[0004] Further known from U.S. Pat. No. 4,702,429 is a reel with which electrical components are shipped. The reel disclosed in this US patent consists of at least five parts: one or more cores (manufactured from expanded polystyrene (EPS)) with two flanges thereon (manufactured from card-board) and two fastener parts (manufactured from plastic). In the final configuration said reel is held together by the two fastener parts which are pressed into each other in mirrored manner, wherein use is made of a barb and grooves in the opposite part. Different shapes of core can be used to make the reel suitable for the application, in particular electrical components.

[0005] Known from Japanese publication JP2008-120572 is a reel wherein a material of a combination of PLA/PS (polylactic acid and polystyrene) is applied to manufacture the reel. For the desired conductivity a quantity of carbon powder is added, viz. 1-20% by weight, after which the intended reel is manufactured via an injection moulding process.

[0006] Japanese publication JP H05 41937 relates to a spool for fishing line, which spool is manufactured from a degradable material, in particular ethylene carbon monoxide copolymer. The spool according to this Japanese document does not provide any possibility of reducing the empty volume or improved stackability wherein less than the whole construction volume is necessary. In addition, said copolymer cannot be deemed as the biodegradable material as stated in the present application. Ethylene carbon monoxide copolymer is a high-grade technical plastic, also known as polyketones, and have high tensile and impact strength, high abrasion resistance and outstanding chemical resistance.

[0007] Japanese publication JP 2008-120572 relates to a so-called conductive reel assembled from a conductive resin composition comprising polystyrene, conductive carbon powder and polylactic acid. Such a reel is applied for winding up electronic components. Said combination of materials, which consists of 10-60% PLA, 1-20% conductive carbon powder and the for the rest of polystyrene, means that this is not a biodegradable polymer. There is moreover no mention of the density whereby it can be assumed that the PLA is of regular form with a density of >1000 g/l.

[0008] European publication EP 1 792 941 relates to a flame-retardant resin composition and articles, for instance a reel, manufactured on the basis of the said resin composition, wherein the resin composition consists of 5-95% by weight of a polylactic acid resin and of 95-5% by weight of an aromatic polycarbonate resin and at least one additive for the purpose, among others, of increasing compatibility. Further present is a flame-retardant agent, for instance a bromine or phosphorus-based compound. The addition of polycarbonate produces a material with a composition which cannot be deemed a biodegradable polymer. There is moreover no mention of the density whereby it can be assumed that the PLA is of regular form with a density of >1000 g/l.

[0009] European publication EP 1 434 088 discloses a roll support member composed of a thermoplastic resin, such as PE, PP or PS, a biodegradable resin, and a blend of paper or wood, viz. 0 to 95% by weight, preferably 1 to 51% by weight, and a thermoplastic resin. This publication refers to a blend of between ideally 51-70% paper and 49-30% plastic, if wherein PLA is one of the specified options. There is however no single example which makes mention of polylactic acid resin. There is moreover no mention made of the density whereby it can be assumed that the PLA is of regular form with a density of >1000 g/l.

[0010] Japanese publication JP H08 217338 relates to a foamed plastic part applied to cover the outer side of a paper tube. The plastic layer thus provides a top layer onto which an adhesive tape can be wound. This layer of plastic will itself impart no or little stiffness and stability to the product but serves only as covering of the paper core in order to prevent direct contact. This is a straight cylinder made up of different materials, which materials cannot be deemed a biologically degradable polymer.

[0011] Japanese publication JP 2004-043071 relates to a core in which a tape or sheet can be wound in order to protect the thin film or tape against folding or collapse during storage thereof. According to this Japanese document only the outer shell is composed of a foam-like material. No mention is moreover made of the density whereby it can be assumed that the PLA is of regular form with a density of >1000 g/l.

[0012] International application WO 2016/031861 comprises a combination of 50-80 parts by mass of a non-crystalline resin selected from styrene resins, polycarbonates, polyarylates, polyphenylene oxides and polysulfones, with 20-50 parts by mass of PLA supplemented with 10-40 parts by mass of inorganic filler. Such a composition cannot be deemed a biodegradable polymer. There is moreover no

mention made of the density whereby it can be assumed that the PLA is of regular form with a density of >1000 g/l.

[0013] International publication WO 2006/094787 relates to a spool consisting of two halves, each half of which is provided with a substantial area of contact with the other half, wherein it is stated that the connection is assembled such that the cores transpose into each other in a smooth form.

[0014] German publication DE 10 2005 010708 relates to a bayonet closure making use of a thin-walled construction with resilient tongues which serve to prevent reverse rotation of the closure, wherein the two halves are laid with closed contact surfaces against each other so that the core continues (substantially) seamlessly and there is provision for a continuous surface on the inner side of the reel.

[0015] German publication DE 197 00 185 relates to the connection of different types of spool halves wherein use is made of a corresponding contact surface located at the division between the different types of halves. Use is made on this contact surface of a relatively simple tongue and groove connection specifically designed for a thin-walled product with associated material choice. There is also provision for a continuous surface on the inner side of the spool and the winding surface is continuous.

[0016] German publication DE 40 01 250 relates to a to a reel divisible into two non-identical halves with a cylindrical press fit as connecting method, wherein there is also a provision for a continuous surface on the inner side of the reel and the winding surface is continuous.

[0017] There are a number of aspects which are an important factor in the transport of reels from manufacturer to end user. One aspect is the reuse of the reel. Particularly in the case of end users using a high volume of reels it is desirable that the weight per reel is kept as low as possible. The costs of transporting the reels can be minimized with such a manner of use. It is also desirable that the reels can be reused in effective manner after use. With recycling in mind it is preferred here that the reel comprises as few different materials as possible. It is also desirable that the reels take up as little space as possible before assembly thereof takes place. This also has a favourable effect on the costs of transporting the reels to the manufacturer which ultimately provides the reels with the desired filaments.

[0018] A drawback of for instance the reel known from the above stated U.S. Pat. No. 4,702,429 is that the fixed parts of this reel consist of various different materials, viz. cardboard and plastics, wherein only the variable core is made from an EPS foam.

[0019] Another observation relates to the spool known from the above stated U.S. Pat. No. 4,387,863 wherein because of the field of application, namely wires with connectors on the end, a specific dividing and attaching method is used in combination with a semi-rigid material, for instance EPS.

[0020] An object of the present invention is to manufacture a reel for winding up and unwinding filaments, which reel has a low weight per volume.

[0021] Another object of the present invention is to manufacture a reel for winding up and unwinding filaments, which reel is manufactured from a biodegradable material.

[0022] Yet another object of the present invention is to manufacture a reel for winding up and unwinding filaments, which reel, before arranging of filaments thereon takes place, is easily stackable whereby little volume is taken up and transport costs are limited to a minimum.

[0023] The present invention thus relates to a reel for winding up and unwinding filaments, comprising a circular middle element, circular flanges positioned on either side of said middle element, wherein the diameter of said middle element is smaller than the diameter of said flanges, which middle element is suitable for winding up and unwinding filaments, characterized in that said middle element and flanges are manufactured from a biodegradable polymer.

[0024] One or more of the stated objectives are fulfilled by applying such a reel. The application of a biodegradable polymer makes it possible for the reel to be disposed of in an environmentally-friendly manner after use. No residual product is created which is sent for instance to an incinerator or taken away to a landfill site. The application of a biodegradable polymer has the result that there is no adverse environmental impact. The material applied according to the present invention provides a distinct weight-saving and is itself responsible for the geometry and the structural integrity of the reel. This is in contrast to the above discussed prior art wherein either a regular (non-foamed) PLA, i.e. PLA in regular form with a density of >1000 g/l, is applied or a foamed plastic is used for only a part of the product where the specific properties of the foam are desired, and the foam does not therefore provide for the structural integrity.

[0025] The said biodegradable polymer is preferably selected from the group of polylactic acid, such as 99.5% pure PLLA or PDLA, copolymers of L-lactic acid with 0.5-7% D-lactic acid, starch foam and/or blends of 5-40% PLA with a remaining quantity of additional components consisting of the group of starch, PBS, PBAT, PHA, PHB, PVA and PVAc or combinations thereof and with optional addition of colouring agents, nucleants, compatibilizing agents such as Joncryl (trademark, marketed by BASF) styrene acrylate resins, in usual quantities.

[0026] Polylactic acid (PLA) is a renewable biodegradable material and is a collective term for polymers on the basis of lactic acid monomers, wherein depending on the composition the structure of polylactic acid can vary from completely amorphous to semi-crystalline or crystalline. Polylactic acid can be obtained from milk products or from for instance maize. Lactic acid is the monomer of which polylactic acid is composed and this monomer occurs in two stereoisomers, viz. L-lactic acid and D-lactic acid. Polylactic acid thus comprises a certain proportion of L-lactic acid monomers and a certain proportion of D-lactic acid monomers. The ratio of the L- and D-lactic acid monomers in polylactic acid determines the properties thereof. Reference is also made to a D value or D-content. This represents the percentage of D-lactic acid monomers in the polylactic acid. Polylactic acid commercially available at the moment has a ratio L:D of 100:0 to 75:25, in other words a D-content of 0 to 25%, or between 0 and 0.25. When polylactic acid contains more than about 12% D-lactic acid it can no longer crystallize and is therefore completely amorphous. When the D-content is a maximum of 5%, it is referred to as semi-crystalline polylactic acid. The crystallinity of the polylactic acid can be determined by means of differential scanning calorimetry (DSC). Semi-crystalline is understood to mean that the polymer can crystallize and can also melt. It can thus be stated that the lower the D-content, the higher the crystallinity of the polylactic acid. The D-content is generally determined by a known method, such as a so-called

R-lactate determination using gas-liquid chromatography (GLC) following complete hydrolysis of the polymer. Another standard method is determination via optical rotation (measured in chloroform using a Jasco DIP-140 polarimeter at a wavelength of 589 nm).

[0027] The present inventors have found that a reel manufactured from polylactic acid can be deemed a reel which is renewable and the raw material of which is not scarce, and wherein the application thereof has no adverse effects on nature and environment. A reel according to the present invention in the embodiment as foam particularly has a density of up to 100 g/l, this value being at least 10 times lighter than a reel obtained from an injection moulding process using ABS, PC or HIPS with density greater than 1000 g/l.

[0028] The term "manufactured from" applied in the present invention can be interpreted in an embodiment as "wholly manufactured from". This means that the material is composed only of biodegradable polymer. No other polymers are therefore present which can be deemed as non-biodegradable. Reference can be made in this respect to the above discussed literature references wherein for instance ethylene carbon monoxide polymer, polystyrene, polycarbonate are applied, which materials can be deemed non-biodegradable. As already stated in the present application, it is indeed possible for combinations of biodegradable polymers to be applied in the present reel. Another difference relative to the above discussed documents is that the reels referred to therein are made via injection moulding, while the present reel is essentially different because the reel is manufactured on the basis of foamed beads and there is a reduction in weight. The present reel is further distinguished in that the foamed beads are made from PLA, thereby resulting in a completely biodegradable reel. There is no question here of a blend wherein only a part of the reel is degradable. The present inventors have further established that there is in principle a good compatibility between the present reel and the yarn placed around it, since PLA is used in both cases. There is therefore the option of processing the entity of reel and yarn in the same manner at end of life (recycling, composting).

[0029] The present inventors have found that polylactic acid foam has good properties making the material suitable for processing to a reel. The polylactic acid which can be applied in such a reel according to the present invention can for instance be selected from the group consisting of semi-crystalline polylactic acid, amorphous polylactic acid and a blend thereof. It is also possible to blend the polylactic acid with other (biodegradable) polymers. Examples hereof are a copolyester of butanediol, adipic acid and terephthalic acid (trade name Ecoflex from BASF), starch paste and starch.

[0030] In an embodiment of the present invention the reel comprises polylactic acid fibres, polylactic acid foam or combinations thereof. Because of their structure such forms of polylactic acid have good properties for processing to a reel. It is further possible for the reel to comprise recycled polylactic acid. Recycling polylactic acid reduces the impact on the environment. The recycled polylactic acid can for instance come from packagings or old reels.

[0031] During forming of foamed moulded parts based on particulate expandable polylactic acid it is of great importance that the fusion between the individual particles is sufficient to obtain a product which does not disintegrate into the individual particles under a slight load. The process conditions are also very important. In view of the limited thermal stability of polylactic acid when compared to petrochemical polymers it is of great importance that proper fusion is realized even under mild process conditions.

[0032] In a specific embodiment a sufficient fusion can be achieved under mild process conditions when particulate expandable polylactic acid is provided with a coating. It should be noted here that the foamed moulded part can be obtained with two different methods. Either the particulate expandable polylactic acid is coated and then foamed in one step and formed into a foamed moulded part, or the particulate expandable polylactic acid is first pre-foamed, then coated and subsequently formed into the foamed moulded part. The coating can thus be applied directly onto the particles of polylactic acid or onto already pre-foamed particles of polylactic acid. After the coating has been applied a blowing agent has to be added to the particles in order to make them expandable (again). In the case the coating is applied to already pre-foamed particles of polylactic acid there is found to be an additional advantage, namely that the diffusion of blowing agents from the pre-foamed particles decreases so that a more reliable and more robust process is obtained. By making use of a coating foamed moulded parts can be made with improved fusion between the individual particles. This makes it possible to make moulded parts of a lower density with similar or improved strength and an excellent thermal stability, particularly in the application as reel.

[0033] As suitable coatings can be mentioned: polyvinyl acetate, polyvinyl-acetate-based polymer, polyvinyl alcohol, polycaprolactone, polyester, polyester amide, protein-based material, polysaccharide, natural wax or grease and acrylate or one or more combinations thereof. The coating can also be amorphous polylactic acid, or a combination thereof with the other coatings. Examples of a coating based on polyvinyl acetate and polyvinyl-acetate-based polymer are Vinnex and Vinnapas polymers from Wacker Chemie or Epotal from BASF. The coating on the basis of the protein-based material is preferably selected from the group consisting of gelatin, collagen, casein and soy protein and one or more combinations thereof. The polysaccharide-based coating is preferably selected from the group consisting of cellulose, cellulose derivative, starch, starch derivative, chitosan, alginate, pectin, carrageen, gum arabic and gellan gum. The coating based on natural wax or grease is preferably selected from the group consisting of beeswax, carnauba wax, candelilla wax, paraffin wax, polyethylene wax, fatty acid, monoglyceride and shellac.

[0034] The density of the said biodegradable polymer preferably lies in the range of 10 g/l and 100 g/l, in particular between 15 g/l and 60 g/l. The shake density of non-pre-foamed particles of polylactic acid according to the present invention preferably lies between 700 g/l and 1000 g/l. The present inventors have established that said density gives particularly good results in the forming of the final reel.

[0035] It is particularly desirable that said biodegradable polymer complies with the composting standard EN13432. Products specified as compostable materials are biodegradable within the norms laid down by EN13432. This European standard describes the period (three months), the conditions (industrial composting facility) and the permitted residual fractions.

[0036] From the viewpoint of storage and simplicity of manufacture, particularly in respect of the moulds applied in

the production process, it is desirable that said reel is made up of two identical halves, both of which halves are connected to each other using a bayonet closure in order to obtain the intended reel.

[0037] The intended reel thus consists of two identical halves connected to each other with a bayonet closure. The two halves, viz. the connecting bayonet closure, are safeguarded against uncoupling by a ring arranged around the core in the end flange (retaining groove). The present reel can thus be deemed a divisible reel with a continuous core and continuous surface.

[0038] The present invention thus relates to divisible reels consisting of two identical and nestable halves, wherein the coupling between the two parts is realized by means of a bayonet closure and wherein the inner side of the flanges is also provided with a groove for receiving a core sleeve therein. The said unique form of the present closure has arisen from the limitations imposed by the choice of material. The structure of the inner hole is also the result of this choice and the present inventors have nevertheless managed, despite the material rules, to create a continuously supported surface.

[0039] The present invention will be further elucidated hereinbelow on the basis of a number of examples. These examples serve only by way of elucidating the present invention.

[0040] FIG. **1** shows an embodiment of a reel for winding up and unwinding filaments according to the present invention.

[0041] FIG. **2** shows an embodiment of a sub-element of a reel for winding up and unwinding filaments according to the present invention.

[0042] FIG. **3** shows an embodiment of a sub-element of a reel for winding up and unwinding filaments according to the present invention.

[0043] FIG. **1** shows an embodiment of a reel **10** for winding up and unwinding filaments (not shown) according to the present invention. The reel **10** comprises a circular middle element wherein circular flanges **1**, **2** are positioned on either side of said middle element. The diameter of the middle element is smaller than the diameter of the circular flanges **1**, **2**, wherein the middle element is suitable for winding and unwinding of filaments. The reel **10** is wholly manufactured from a biodegradable polymer.

[0044] FIG. **2** shows schematically a sub-element **20** of a reel **10** for winding up and unwinding filaments according to the present invention. The sub-element **10** is embodied as a circle wherein flange **1** has a rim **5**. Such a rim **5** is desirable from the viewpoint of mechanical properties and also provides the option that the 3-D printing yarn or filament remains on the reel **10** after being wound up. The middle element **3** is provided with means **4** for realizing a bayonet closure. In order to assemble a reel **10** two sub-elements **20** are connected to each other using said bayonet closure. When thus assembled, a wide middle element **3** is created which serves as surface for winding 3-D printing yarn or filament thereon. During use of the reel **3** the reel is mounted on a shaft on the 3-D printer (not shown), wherein the material of the 3-D printing yarn or filament is heated by the 3-D printer and a printing step then takes place. The sub-element **20** is manufactured wholly from a biodegradable polymer.

[0045] Shown in FIG. **3** is an embodiment of a sub-element **30** of a reel **10** for winding up and unwinding filaments according to the present invention. The sub-element **30** is embodied as a circle wherein the flange **1** has a rim **5**. Located in the centre of the sub-element **30** are means **6** for realizing a bayonet closure. In order to assemble a reel **10** two sub-elements **30** are connected to each other using said bayonet closure. When thus assembled, a wide middle element is created which serves as surface for winding 3-D printing yarn or filament thereon. It is possible in a specific embodiment to combine the sub-element **20** with the sub-element **30** to form a reel. The sub-element **30** is manufactured wholly from a biodegradable polymer. In FIG. **3** profile ejectors are shown schematically with reference numeral **7** and printed/press-out fillers with reference numeral **8**.

EXAMPLE 1

[0046] A reel for winding 3-D printing yarn or filament was manufactured using EPS with a diameter of 0.7-1.0 mm and a foamed density of 60 g/l. Grains of the Styrex 710R type were pre-expanded at a temperature of 110° C. in a conventional pre-expander to 55 g/l and, after 24 hours standing, a moulding step was performed in an aluminium mould using steam at a temperature of 110° C. The final product has a moulded density of 60 g/l.

EXAMPLE 2

[0047] A reel for winding 3-D printing yarn or filament was manufactured using BioFoam with density of 60 g/l. Applied as starting material were BF710 Synterra green bio-beads, with a size of 0.7-1.0 mm, marketed by Synbra Technology. Said beads were pre-impregnated with 9% CO_2, then expanded to 55 g/l using hot air at a temperature of 90° C. as heating medium, and provided with a coating in a quantity of 5% (m/m), namely Vinnex 2510—marketed by Wacker of Burghausen (Germany)—and subsequently shaped into a 3-D reel at a shaping temperature of 90° C. in order to obtain a 60 g/l 3-D reel. Said reel was suitable for winding up a quantity of 1 kg 3 mm PLA (95%)/PHA (5%) filament.

EXAMPLE 3

[0048] A 3-D filament reel as referred to in Example 2 was manufactured using a composition of a foam of 20% PLA and 80% PBAT. Said composition was impregnated with 9% CO_2 and then expanded to 55 g/l and subsequently shaped into a 3-D reel at a shaping temperature of 90° C. in order to obtain a 60 g/l 3-D reel.

1. A reel for winding up and unwinding filaments, comprising a circular middle element, circular flanges positioned on either side of said middle element, wherein the diameter of said middle element is smaller than the diameter of said flanges, which middle element is suitable for winding up and unwinding filaments, characterized in that said middle element and flanges are manufactured from a biodegradable polymer.

2. The reel according to claim **1**, characterized in that said biodegradable polymer is selected from the group of polylactic acid, copolymers of L-lactic acid with 0.5-7% D-lactic acid, starch foam and/or blends of 5-40% PLA with a remaining quantity of additional components consisting of the group of starch, PBS, PBAT, PHA, PHB, PVA and PVAc

or combinations thereof and with optional addition of colouring agents, nucleants, compatibilizing agents in usual quantities.

3. The reel according to one or more of the preceding claims, characterized in that the density of said biodegradable polymer lies in the range of 10 g/l and 100 g/l.

4. The reel according to one or more of the preceding claims, characterized in that said biodegradable polymer complies with the composting standard EN13432.

5. The reel according to one or more of the preceding claims, characterized in that said reel is made up of two identical halves, both of which halves are connected to each other using a bayonet closure in order to obtain the intended reel.

6. The reel according to claim **5**, characterized in that said bayonet closure further comprises a retaining groove.

7. The reel according to one or more of the claims **5**-**6**, characterized in that both identical halves are nestable.

8. The reel according to one or more of the preceding claims, characterized in that said filaments are of the 3-D printing yarn type.

* * * * *