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(54) METHOD OF AND MOULD FOR MANUFACTURING AN INSULATION COMPONENT FOR ELECTRIC APPLICATIONS

(57) The invention relates to the method of manufacturing of an insulation component (1) for electric applications and in particular to an insulation component made from cellulosic material. The invention is characterized in that in the step of pre-preparing the mold (2), only the non-metallic material is used to form the mold (2) and the mold (2) is manufactured in any additive manufacturing process. The mold (2) has a bulky like structure (2a) with an open-like porous structure or a lattice-like structure (2b) in any form, or structure being their combination, which structure is adapted to be non-permeable for cellulosic material in the form of wet sheet made of unbleached cellulose kraft pulp during the step of forming and drying the shell (1 a) of the raw component (1). The step of drying the shell (1 a) of the raw component (1) is performed by using an external microwave sources of heat with the wavelength range of 3÷300 mm and a frequency range of 0,3÷300 GHz that heats the shell (1a) of the raw component (1) directly up to temperature in the range of 100÷200°C.

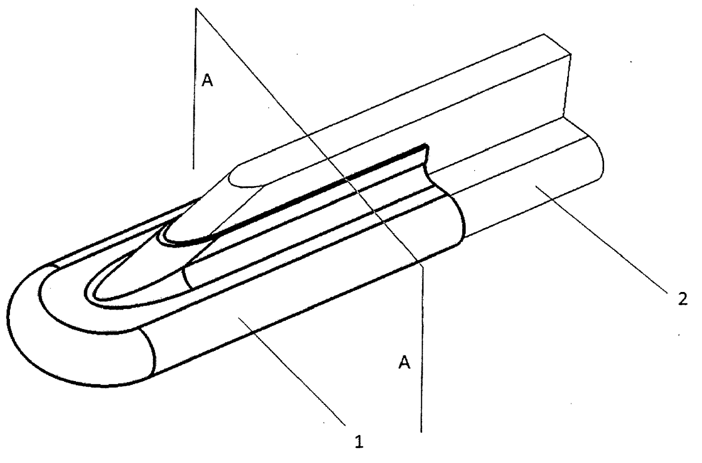

Fig. 1

EP 3 342 572 A1

Description

[0001] The invention relates to the method of manufacturing of an insulation component for electric applications and in particular to an insulation component made from cellulosic material. The insulation component in general is designed for electrical power transformer or transformer unit.

[0002] Insulation components for electric applications, especially being used in power transformers, for example snouts, yokes collars and edge collars are typically made of cellulosic material and the process of manufacturing is carried out using a metal mold. When insulation components are made of cellulosic material the manufacturing process is complex, multi-stage, long-lasting, energy-consuming and laborious. The process of manufacturing comprises the step of preparing of wet cellulose sheet, forming of the wet cellulose sheet on the metal mold, compressing of the wet cellulose sheet, drying the wet cellulose sheet in convective oven, removing the dried component from the metal mold and, finally, machining of the dried cellulose component to obtain the final shape of the component. In convection drying the material formed on the mold and compressed is placed in electric oven where hot air flow is forced with a fan to heat the mold. In this method the cellulose material is heated indirectly by means of heat conduction from the mold. The metal mold could be the potential source of metal contamination in insulation components what can worsen their insulating properties or even lead to their failure. In order to avoid a contamination of the insulation component with metallic particles the mold should be done with other non-metallic material. Therefore, there is a need to limit the drawbacks of the current manufacturing method.

[0003] There is known from GB Patent application GB 2456502 a method of shaping and of handling an articles by pulp molding with the use of a permeable shaping tool. The shaping tool is prepared for molding process and the tool has a surface member with a plurality of perforations and a supporting inner member with an evacuation channels for enabling the fluid under suction to pass from the pulp slurry into the surface member from its outer surface, through the perforations and the space between the surface and support member and out through the channels, while pulp from the slurry is retained and built up on the outer surface member forming a raw component. The component is removed from the shaping tool with a handling tool for drying. Both the surface member and the support member are suitably made of a heat fusible thermoplastic such as Nylon 12 by the additive layer manufacturing method. The drawback of this solution consists in the drying process. This process is provided as additional process and need to transfer the component from the tool to another place where the component is dried in a known way. So there is a need to improve the manufacturing process by changing the step containing the drying the component.

[0004] Each transformer unit has usually a very specific and individual design, what influences also the design of insulation components. It means in practice that for each insulation component a geometry of an individual metal mold has to be fabricated. Consequently, hundreds or even thousands of molds have to be stored in a mold shop. So there is a need to make a modular mold for manufacturing the insulating component.
All drawbacks presented above are preferably omitted in the invention according to claims 1-7.

[0005] The essence of the method of manufacturing of an insulation component for electric applications made of cellulosic material, using a mold being pre-prepared for the insulation component; which method has a step in which a wet sheet of cellulose pulp is deposited on the mold and comprises the step of modeling a shell of a raw insulation component by pressing the wet sheet of the cellulose pulp to external surface of the mold in order to map the shape of the mold into a shell of the raw insulation component, having a step of drying the shell of the raw component, step of removing the dried shell of the raw component from the mold and step of machining of the dried shell of the raw component into the final shape of the insulation component; is that in the step of pre-preparing the mold, only the non-metallic material is used to form the mold. The mold is manufactured in any additive manufacturing process and has a bulky like structure with an open-like porous structure or a lattice-like structure in any form, or structure being their combination which structure is adapted to be non-permeable for cellulosic material in the form of wet sheet made of unbleached cellulose kraft pulp during the step of forming and drying the shell of the raw component. The step of drying the shell of the raw component is performed by using an external microwave sources of heat.

[0006] Preferably microwave sources of heat have a wavelength range of 3÷300 mm and a frequency range of 0,3÷300 GHz.

[0007] Preferably the mold is made of thermoplastic like for example polycarbonate, polyamide, polyetherimide or thermoset polymer like for example acrylic or epoxy resin.

[0008] The essence of the mold for manufacturing of an insulation component for electric applications according to method presented in the claims 1-2, is that the mold has a bulky structure in cross-sections made along whole length of the mold.

[0009] Alternatively the mold for manufacturing of an insulation component for electric applications according to method presented in the claims 1-2, is characterized in that, the mold is provided with a cavity made along the length of the mold.

[0010] Preferably the mold is equipped with an internal core which is inserted to cavity inside the mold.

[0011] Preferably the internal core is protruding from the mold to form an internal inset for at least one additional module slid over the core.

[0012] Preferably the internal core is equipped with at least one internal channel placed longitudinal in the core which is connected with a system of micro channels made inside the core and made inside the mold in the structure which are adapted for transferring outside the mold an evaporated water from the cellulose kraft pulp.

[0013] The mold is pre-prepared from non-metallic material in any additive manufacturing process what allows for manufacturing sophisticated features of the mold with a structure without any metal contamination. This is vital, since metallic inclusions can lead to the failure of insulation component, and consequently of electric device, under electric field. The complex shape of the shell of the mold for example a tube-like shell with a core inserted to the shell allows modifying the shape of the mold. The modular shape of the mold solves the problem with storing hundreds or even thousands of molds in a mold shop. As the mold is made of non-metallic material, as for example from thermoplastic material it can be possible to recycle the material and reuse it for manufacturing of a new mold. The step of drying the insulation component might lead to increased effectiveness of the drying process. Convection drying is replaced by microwave heating thanks to the application of polymeric molds instead of metallic ones. In this solution the wet sheet of cellulose pulp is heated directly and the mold material does not have to be thermally conductive. Design freedom coming with additive manufacturing process allows for including sophisticated features in the mold geometry like internal channels or open-like pores for optimum moisture removal from the insulation component during drying process. Improved drying mechanism results in less time- and energy-consuming manufacturing process. The porous and lattice-like structure of the mold according to the invention results in lower weight of the mold. Additive manufacturing of molds allows to integrate parts including moving elements in a single production process resulting in simplified insulation component manufacturing without any assembly steps.

[0014] The method according to the invention is explained in the exemplary embodiment in the drawing where:

fig. 1 - shows an exemplary mold together with an insulating component in an axonometric view,

fig. 2 - shows the mold with the insulation component from fig. 1 in a cross-section, in the first embodiment of the mold,

fig. 3 - shows the mold from the fig. 1 in a cross-section, in the second embodiment of the mold,

fig.4 - shows the mold from fig. 3 with an internal core in an axonometric view,

fig.5 - shows the mold from fig. 4 with additional modules placed on the internal core in an axonometric view,

fig. 6 - shows the mold from fig. 5 having the internal core provided with longitudinal channels carried out in the core in an axonometric view,

fig. 7 - shows the mold from fig. 5 having the micro-pores carried out in the mold in an axonometric view,

fig. 8 - shows the mold with the insulation component from fig. 3 in a cross-section, having the internal core provided with longitudinal channels carried out in the core and having the micro-pores carried out in the core,

fig. 9 - presents the flow chart of the manufacturing steps.

[0015] In the exemplary embodiment the insulation component 1 is formed on a mold 2. The component has a form of a transformer foot insulation element for a power transformer. The insulation component 1 has a shape projecting the shape of the mold 2. The method of manufacturing of an insulation component 1 comprises the following steps, presented in fig. 9:

- Pre-preparing a mold 2 for the insulation component 1 according to the shape of the insulation component from non-metallic material, preferably from thermoplastic like for example polycarbonate, polyamide, polyetherimide or thermoset polymer like for example acrylic or epoxy resin and having an open-like porous structure or lattice-like structure in any form, which structure is adapted to be non-permeable for cellulosic material in the form of wet sheet made of unbleached cellulose kraft pulp,
- Depositing a cellulose material in the form of wet sheet made of unbleached cellulose kraft pulp on an external surface of the mold 2,
- Modeling an insulation component 1 by pressing the wet cellulose kraft pulp to the external surface of the mold 2 in order to map the shape of the mold 2 into a shell 1a of the insulation component 1, where the modeling is performed manually by pressing the pulp to the external surface of the mold or using a classic pressing tool, not presented in the drawing,
- Drying the shell 1a of the insulation component 1 by using external microwave sources of heat with a wavelength range of 3÷300 mm and a frequency range of 0,3÷300 GHz that heats the shell 1a of the component directly up to temperature in the range of 100÷200°C,
- Removing the shell 1 a of the component 1 from the mold matrix 2 by any known way,
- Machining of the dried shell 1a of the raw component 1 into the final shape of the insulation component 1.

Step 1. Pre-preparing a mold.

[0016] In the step of pre-preparing, a mold 2 for manufacturing of an insulation component 1 is prepared. The insulation component 1 has a shape projecting the shape of the mold 2. An exemplary transformer foot insulation element for transformer deposited on the mold 2 is presented in the drawing. The shape of the insulation component could be very complicated, so the additive manufacturing technology is used to prepare the mold 2. As the insulation component is applied as an electrical insulation component, any metallic particles or even track of metal contamination can not be present in its structure. The mold is prepared from non-metallic material, for example from thermoplastic like polycarbonate, polyamide, polyetherimide or thermoset polymer like acrylic or epoxy resin. For the transformer foot insulation element the structure of the mold is made as a bulky mold structure 2a, (fig. 2) for all cross sections of the mold or is made as a casing with a bulky structure 2a of the wall of the casing, (fig. 3) with a cavity 3 inside the mold and having a part with lattice-like structure 2b. In the cavity 3 a core 4 is inserted which is protruding outside of the mold 2 to form an internal inset for at least one additional module 5 slid over the core 4. The length of the core 4 is determined by the need of the shape of the component 1. For the transformer foot insulation element at least one additional module 5 is placed along the longitudinal axis of core 4 in such a way that each additional module 5 can change the shape of a mold and can lengthen for example the length of the mold. Such modification of the mold renders it as universal mold.

[0017] The core of the mold 1 can have a special longitudinal channels 6 made inside the core structure. The mold 2 can have a system of micro channels 7 inside that are connected with the channels 6 in the core of the mold 2. These channels could be very useful in the step of drying the component on the mold what is explained in the step 4.

Step 2. Depositing a cellulose material on the mold.

[0018] In this step a wet pulp is deposited on the external surface of the mold. For manufacturing an insulation component a wet sheet of an unbleached cellulose kraft pulp 7 is prepared. The sheet is superimposed on the mold manually layer by layers or the wet sheet can be superimposed by a special tool or tools, not presented in the drawing.

Step 3. Modeling an insulation component.

[0019] This step is realized by pressing the wet cellulose kraft pulp 7 to the external surface of the mold 2 in order to map the shape of the mold 2 into a shell 1 a of the insulation component 1, where the modeling is performed manually by pressing the pulp to the external surface of the mold or using a classic pressing tool, not presented in the drawing.

Step 4. Drying the shell of the insulation component.

[0020] The step of drying the shell 1a of the insulation component 1 is performed by using an external microwave sources of heat with a wavelength range of 3÷300 mm and a frequency range of 0,3÷300 GHz that heats the cellulose material of the insulation component 1 directly up to temperature in the range of 100÷200°C. In this method the heat is generated directly inside the material being dried by microwave heating and the evaporated water is transferred either outside the mold 2 into environment or towards the mold 2 and then is transferred through the system of micro-channels 7 inside the mold 2 and the channels 6 inside the core 4 of the mold 2. Additionally there can be a pump connected to the channels 6 in the core sucking and evacuating the moistured air from the component being dried, what is not presented in the drawing.

Step 5. Removing the shell of the component from the mold.

[0021] In this step removing the shell 1a of the component from the mold 2 is carried out manually or mechanically with tools assigned for such a work.

Step 6. Machining of the dried shell.

[0022] Machining of the dried shell 1 a of the component into the final shape of the insulation component 1 in a known way by using band saw and by deburring the component edges on a grinding machine.

Claims

1. The method of manufacturing of an insulation component (1) for electric applications made of cellulosic material using a mold (2) being pre-prepared for the insulation component (1); the method having a step in which a wet sheet of cellulose pulp is deposited on the mold (2) and comprises the step of modeling a shell (1 a) of a raw insulation component (1) by pressing the wet sheet of the cellulose pulp to external surface of the mold (2) in order to map the shape of the mold (1) into a shell (1a) of the raw insulation component (1), having a step of drying the shell (1a) of the raw component (1), step of removing the shell (1a) of the raw component (1) from the mold (1) and step of machining of the dried shell (1 a) of the raw component into the final shape of the insulation component (1); **characterized in that** in the step of pre-preparing the mold (2), only the non-metallic material is used to form the mold (2), the mold (2) is manufactured in any additive manufacturing process and has a bulky like structure (2a) with an open-like porous structure or a lattice-like structure (2b) in any form, or structure being their combination which

structure is adapted to be non-permeable for cellulosic material in the form of wet sheet made of unbleached cellulose kraft pulp during the step of forming and drying the shell (1 a) of the raw component (1), and the step of drying the shell (1 a) of the raw component (1) is performed by using an external microwave sources of heat.

2. The method according to claim 1, **characterized in that** the microwave sources of heat have a wavelength range of 3÷300 mm and a frequency range of 0,3÷300 GHz.

3. The method according to claims 1-2, **characterized in that** the mold (2) is made from thermoplastic like for example polycarbonate, polyamide, polyetherimide or thermoset polymer like for example acrylic or epoxy resin.

4. The mold for manufacturing of an insulation component (1) for electric applications according to method presented in the claims 1-3, **characterized in that** the mold (2) has a bulky structure (2a) in a cross-sections made along whole length of the mold.

5. The mold for manufacturing of an insulation component (1) for electric applications according to method presented in the claims 1-3, **characterized in that** the mold (2) is provided with a cavity (3) made along the length of the mold.

6. The mold according to claim 5, **characterized in that** the mold (2) is equipped with an internal core (4) which is inserted to cavity (3) inside the mold (1).

7. The mold according to claim 5, **characterized in that** the internal core (4) is protruding from the mold (2) to form an internal inset for at least one additional module (5) slid over the core (4).

8. The mold according to claim 5, **characterized in that** the internal core (4) is equipped with at least one internal channel (6) placed longitudinal in the core (4) which is connected with a system of micro channels (7a) made inside the core (4) and micro-channels (7) made inside the mold (2) in the structure (2a) which are adapted for transferring outside the mold (2) an evaporated water from the cellulose kraft pulp.

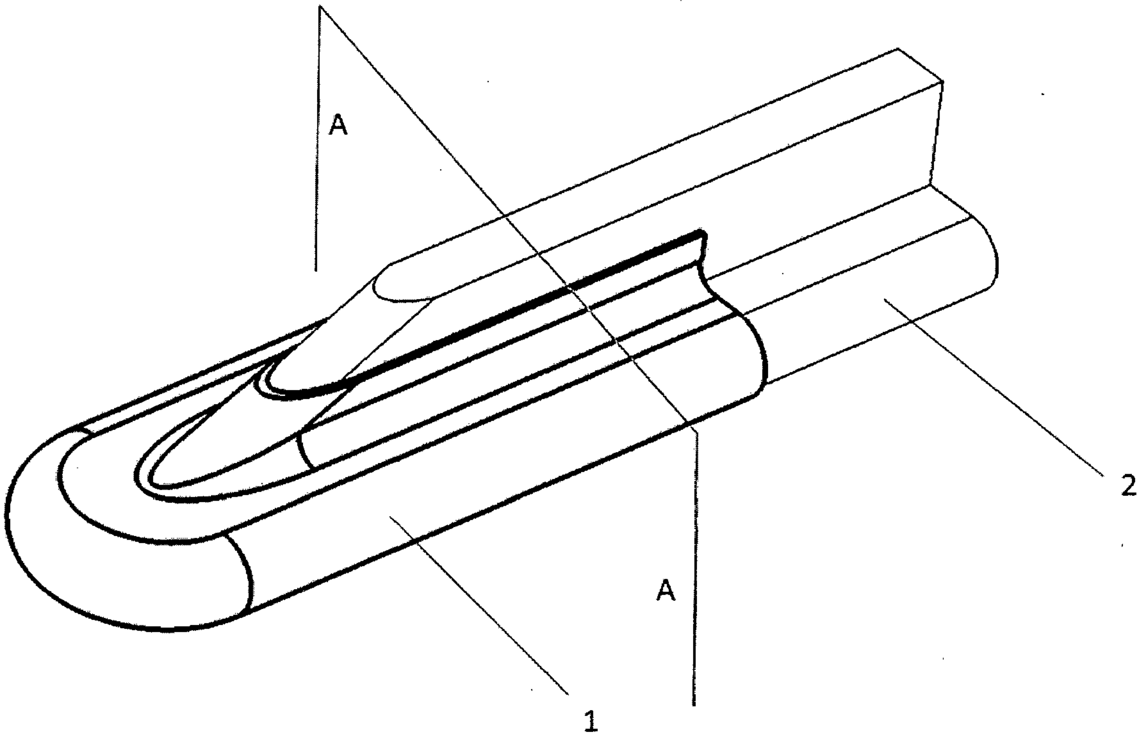

Fig. 1

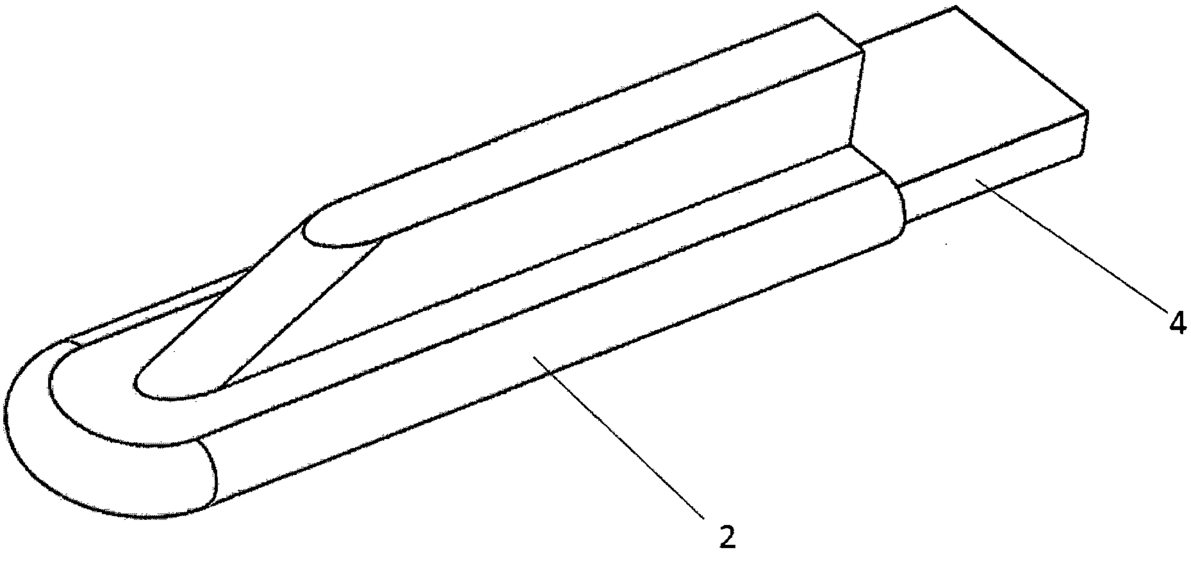

Fig. 4

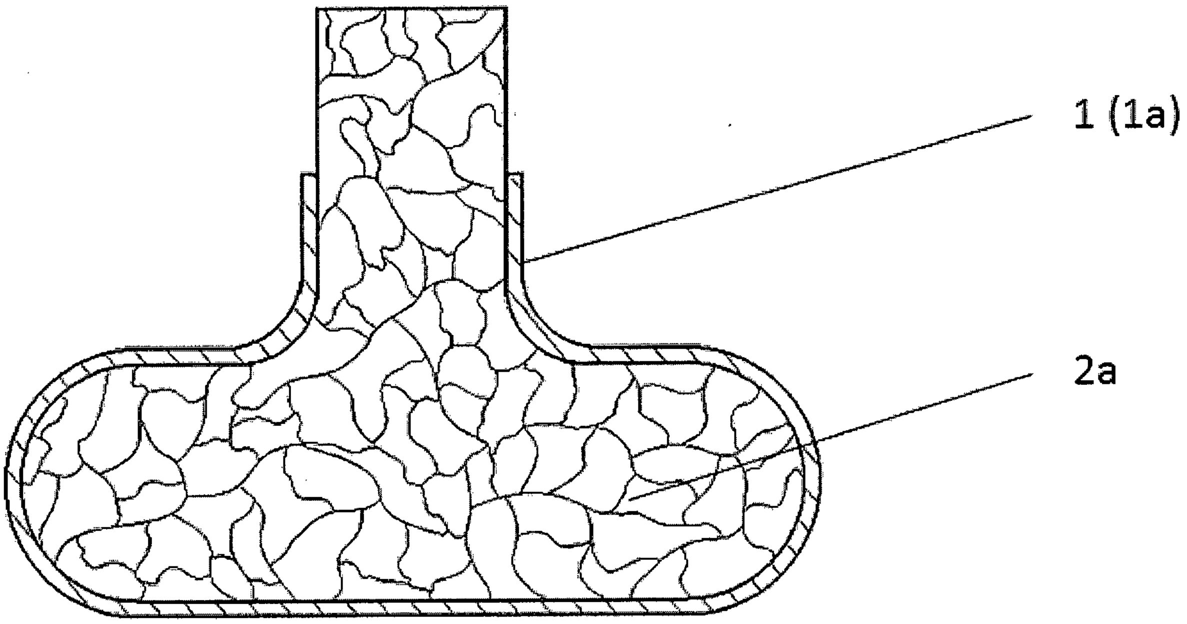

Fig. 2

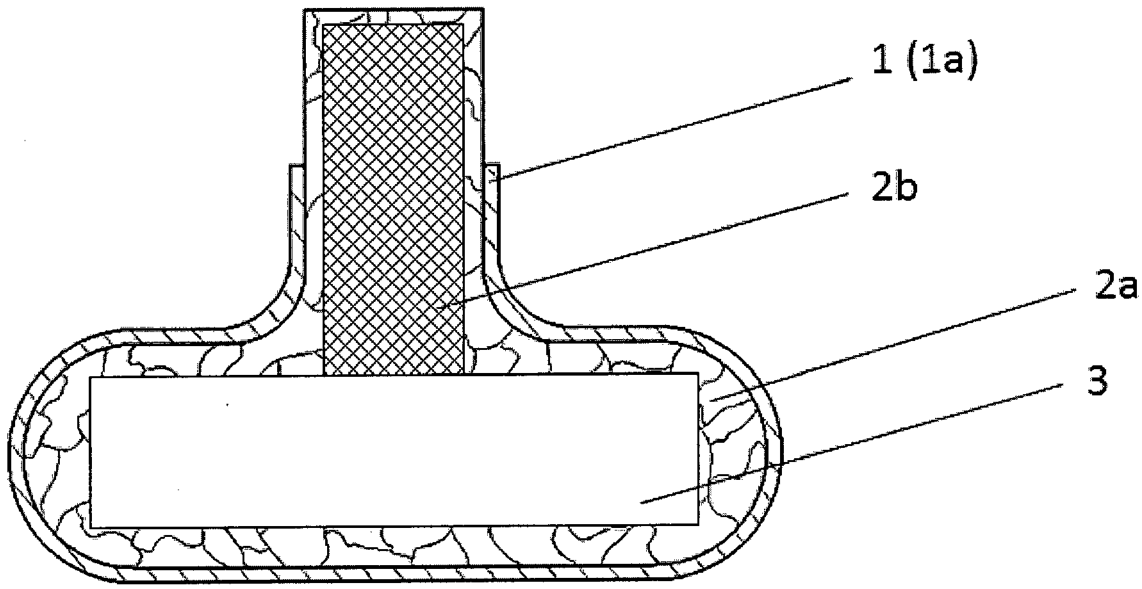

Fig. 3

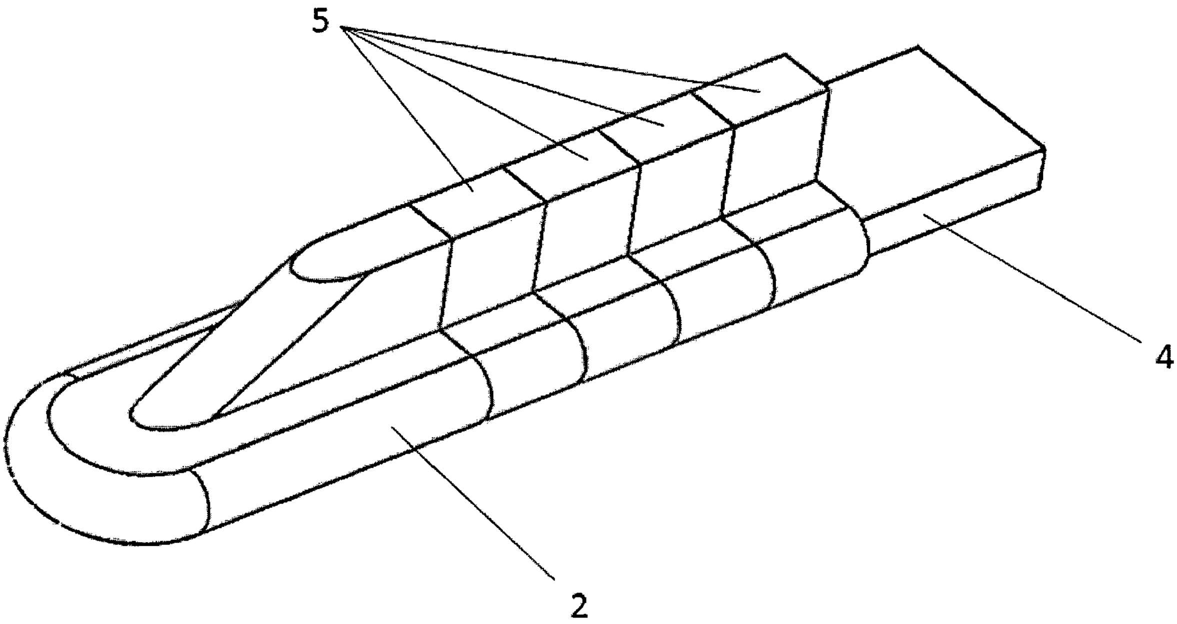

Fig. 5

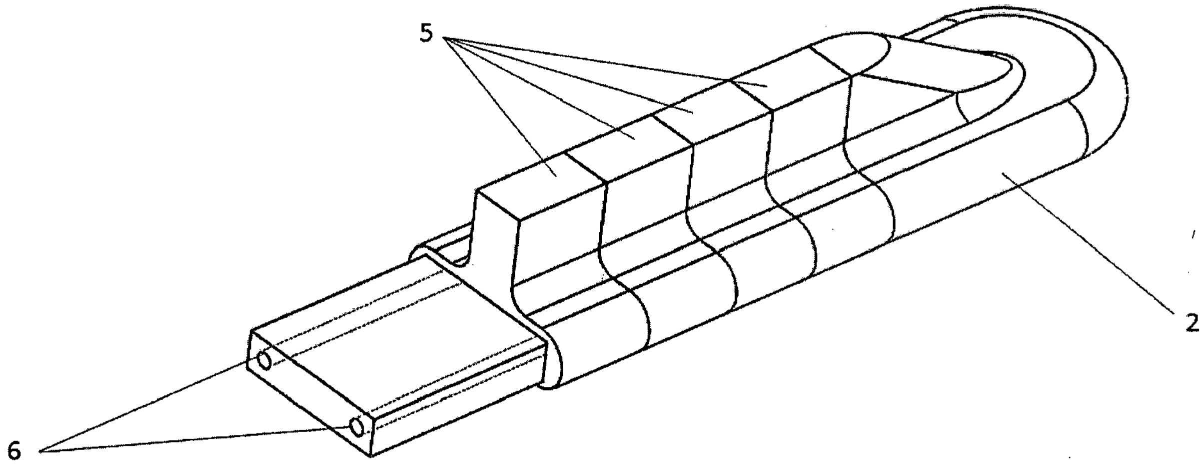

Fig. 6

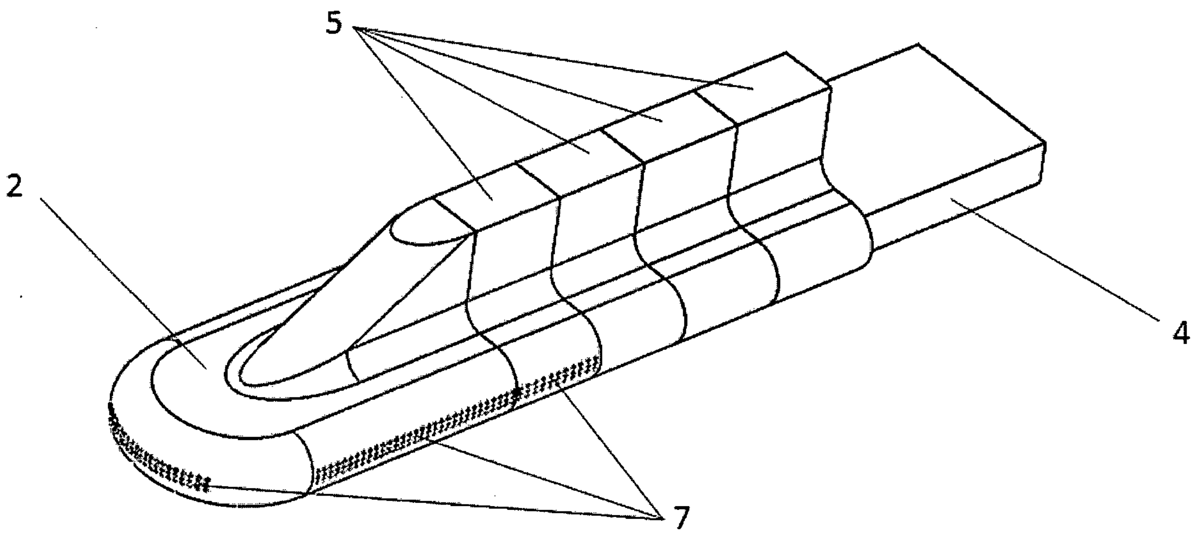

Fig. 7

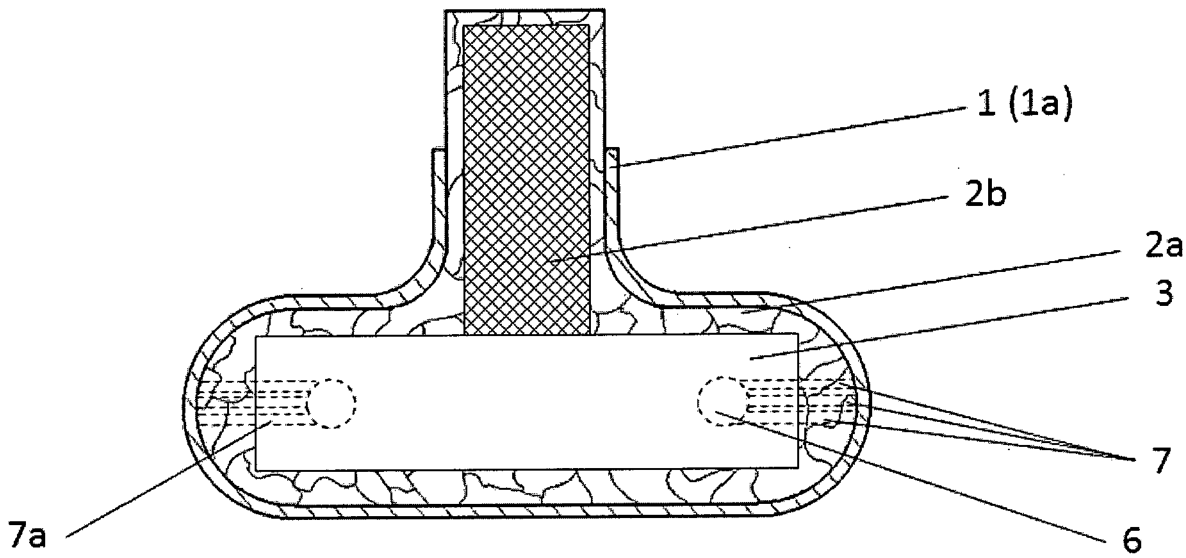

Fig. 8

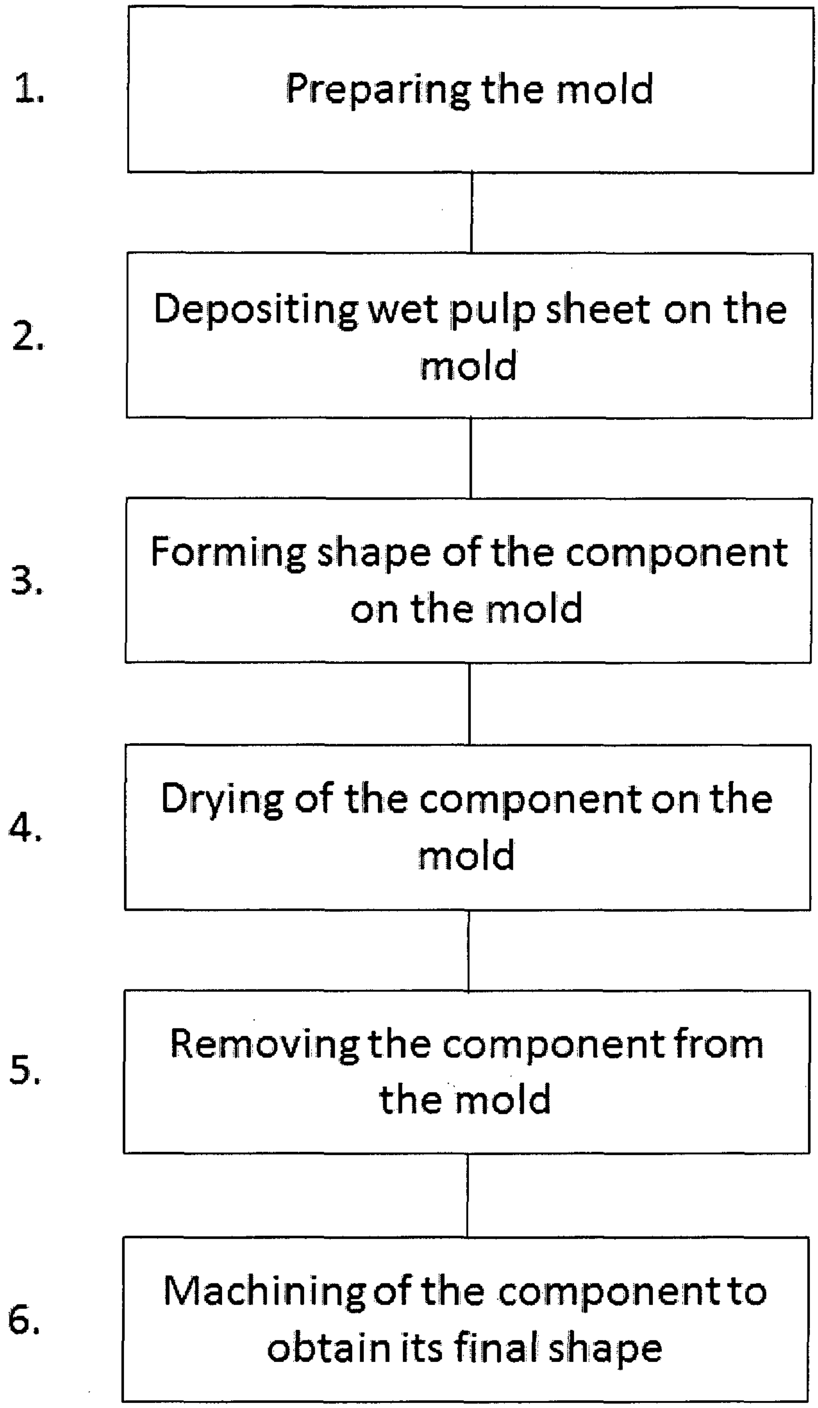
1.
Preparing the mold
2.
Depositing wet pulp sheet on the mold
3.
Forming shape of the component on the mold
4.
Drying of the component on the mold
5.
Removing the component from the mold
6.
Machining of the component to obtain its final shape

Fig. 9

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EUROPEAN SEARCH REPORT

Application Number
EP 16 46 0104

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The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	10 March 2017	Rüdiger, Patrick

CATEGORY OF CITED DOCUMENTS

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

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