(54) Title: METHOD AND APPARATUS FOR MANUFACTURING A COMPOSITE PART

(57) Abstract: A method for manufacturing a composite part comprising a fibrous material (2) and a resin, the method comprising providing a moulding support (1), placing at least one fibrous material layer on the moulding support (1), providing an electro-activatable sheet (4) adapted change shape under the influence of electric power, placing the electro-activatable sheet (4) on the moulding support (1) so that the at least one fibrous material layer (2) is located between the moulding support (1) and the electro-activatable sheet (4), and supplying electric power to the electro-activatable sheet (4) so that the shape of the electro-activatable sheet (4) is changed so as to exert pressure onto the at least one fibrous material layer (2).

FIG. 1
METHOD AND APPARATUS FOR MANUFACTURING A COMPOSITE PART

TECHNICAL FIELD

The invention relates to a method and an apparatus for manufacturing a composite part comprising a fibrous material, as well as a composite part manufactured by the method.

BACKGROUND

In manufacturing of parts of fiber reinforces plastics, a number of different methods can be used. Usually one or more plies of fibrous material are placed on a mould, and a resin is allowed to cure while impregnating the fibers so as to stabilise them, thus forming the composite part. The fibers can be impregnated by hand, pre-impregnated, or the resin can be provided by vacuum via one or more conduits (resin infusion). Whichever method is used, before the resin is cured, usually a breather cloth and a vacuum bag, i.e. a plastic film, are placed so as to cover the fibers and resin, and are sealed around the composite part. During curing vacuum is used to withdraw air from the vacuum bag, to create a pressure in order to allow excess resin to be transported to the breather cloth so as to increase the fiber to resin ratio of the composite part, and therefore its strength to weight ratio. Also, the pressure reduces voids in the composite part.

A disadvantage of vacuum bag methods is that the pressure that can be obtained is limited to the atmospheric pressure. Also, the atmospheric pressure varies depending on the altitude and weather, so that the method presents an inconsistency.

SUMMARY

An object of the invention is to improve manufacturing of composite parts comprising fibrous materials. Another object of the invention is to increase the fiber to resin ratio in composite parts.
These objects are reached with a method for manufacturing a composite part comprising a fibrous material and a resin, the method comprising providing a moulding support, placing at least one fibrous material layer on the moulding support, providing an electro-activatable sheet adapted change shape under the influence of electric power, placing the electro-activatable sheet on the moulding support so that the at least one fibrous material layer is located between the moulding support and the electro-activatable sheet, and supplying electric power to the electro-activatable sheet so that the shape of the electro-activatable sheet is changed so as to exert pressure onto the at least one fibrous material layer.

Thus, curing of the resin takes place under the pressure exerted by the sheet. Due to the electro-activatable sheet, which can shrink and/or stretch, i.e. contract and/or expand in a direction of the extension of the electro-activatable sheet, under the influence of electric power, it is possible to effectively provide a pressure onto the composite part during curing. This pressure can be higher than atmospheric pressure, and thus the fiber to resin ratio in composite parts can be increased compared to vacuum methods.

It is understood that the electro-activatable sheet is preferably flexible so as to easily conform to the shape of the moulding support. The electro-activatable sheet can comprise a so called electroactive polymer (EAP). In particular, the electro-activatable sheet can comprise a dielectric EAP, e.g. an electrostrictive polymer or a dielectric elastomer, in which the change of shape is caused by electrostatic forces between two electrodes which, when a DC voltage is applied to the electrodes, squeeze or stretch the polymer depending on the direction of the current. Dielectric EAPs, wherein an elastomer film is sandwiched between two compliant electrodes, require no power to be kept at a given position. For the elastomer, a silicone or an acrylic elastomer can be used. The electrodes can comprise e.g. graphite powder, silicone oil / graphite mixtures, gold electrodes, etc.

Here, a composite part comprising a fibrous material refers to an article comprising a fiber reinforced plastic. The plastic, or resin, could be a thermoset resin, e.g. epoxy, or a thermoplastic. The composite part could be a separate article or a part of an article, for example a composite layer on a structure, for example also of a composite material.
The moulding support could be a mould or some other structure. For example, where the composite part produced by the inventive method is a composite layer on another composite structure, that structure could be the moulding support as understood in this presentation.

The at least one fibrous material layer can be provided on the moulding support before the electro-activatable sheet is placed on the moulding support, or the at least one fibrous material layer can be placed on the moulding support together with the electro-activatable sheet.

The method can of course include additional steps usually carried out in composite manufacturing. For example before placing the at least one fibrous material layer on the moulding support, a release agent could be placed on the moulding support. Also, a peelply, release film and/or a breather cloth can be placed between the at least one fibrous material layer and the electro-activatable sheet.

Preferably, the method comprises, e.g. while placing the electro-activatable sheet on the moulding support, fixing the electro-activatable sheet to the moulding support along at least one portion of a periphery of the electro-activatable sheet. For example, there could be two portions of the electro-activatable sheet periphery along which the electro-activatable sheet is attached to the moulding support, which portions are located opposite to each other so that the at least one fibrous material layer is located between said two portions of the periphery. In other embodiments, there could be a portion of the electro-activatable sheet periphery, which is at least partly curved so as to have two parts located opposite to each other. Thereby, the at least one fibrous material layer can be located between said two parts of the portion of the electro-activatable sheet periphery. In further embodiments, the electro-activatable sheet is fixed to the moulding support along the entire periphery of the electro-activatable sheet.

Preferably, the moulding support is convex and the change of the shape of the electro-activatable sheet is shrinkage, i.e. contraction in a direction of the extension of the electro-activatable sheet. Alternatively, the moulding support is concave and the
change of the shape of the electro-activatable sheet is stretching, i.e. expansion in a direction of the extension of the electro-activatable sheet.

In some embodiments, the resin is supplied to the at least one fibrous material layer after the electro-activatable sheet has been placed on the moulding support, as for example in a resin infusion method. In other embodiments, the at least one fibrous material layer comprises a resin when the electro-activatable sheet is placed on the moulding support. For example the fibrous material layer could be pre-impregnated with resin (prepreg), or it could be hand-impregnated with resin before the electro-activatable sheet has been provided on the moulding support.

In some embodiments, exemplified below, during the step of supplying electric power, the electric power is supplied with an alternating current so that the pressure exerted onto the at least one fibrous material is varied so as to provide a vibration to the at least one fibrous material.

The invention also relates to a composite part according to claim 8. The objects are also reached with an apparatus according to any of the claims 9-12.

DESCRIPTION OF THE FIGURES

Below, embodiments of the invention will be described with reference to the drawings, in which fig. 1 shows a cross-section of an apparatus for manufacturing composite parts according to a first embodiment of the invention, fig. 2 and fig. 3 show cross-sections of an apparatus for manufacturing composite parts according to a second embodiment, and fig. 4 and fig. 5 show diagrams of respective alternatives for electric currents supplied to an apparatus for manufacturing composite parts.

DETAILED DESCRIPTION

Fig. 1 shows a schematic cross-section of an apparatus for manufacturing a composite part comprising a fibrous material. The apparatus comprises a moulding support in the form of a convex mould 1. Placed on the mould is a laminate 2 of a plurality of fibrous material layers in the form of prepreg plies. On the laminate 2 a breather cloth
3 is placed, and on the breather cloth 3 an electro-activatable sheet 4 is placed. At a concave peripheral region 101 of the mould 1, a plurality of fixing tools 102 are provided which serve to secure the electro-activatable sheet 4 to the mould all around the laminate 2. Thus, the sheet 4 is fixed to the mould 1 along the periphery of the sheet 4. A DC electric power source 401 is connected to the electro-activatable sheet 4, and when a voltage is supplied to the sheet 4, it tends to shrink so that it is pressed to the mould 1 between the fixing tools 102. Thereby a pressure is exerted on the laminate 2 during curing thereof.

Fig. 2 shows a schematic cross-section of another embodiment of an apparatus for manufacturing a composite part comprising a fibrous material. The apparatus comprises a moulding support in the form of a concave mould 1. As in the embodiment in fig. 1, a laminate 2 is placed on the mould 1, a breather cloth 3 is placed on the laminate 2, and an electro-activatable sheet 4 is placed on the breather cloth 3. A tool 5 with a convex surface 51 facing the concave mould 1 in order to control the position of the layers 2, 3, 4 in the mould 1. A DC electric power source 401 is connected to the electro-activatable sheet 4, and when a voltage is supplied to the sheet 4, it tends to stretch so that it is pressed to the mould 1.

Reference is made to fig. 3. The tool 5 and the mould 1 are adapted to fix the layers 2, 3, 4 so as to secure that the stretching or expansion of the electro-activatable sheet 4 can be utilized for pressure on the laminate 2. More specifically, when the tool 5 and the mould 1 are in their respective relative positions for the curing of the laminate resin, a distance D1 between the tool 5 and the mould 1 at the periphery of the mould is smaller than a distance D2 between the tool 5 and the mould 1 at a located remote from the mould periphery.

Reference is made to fig. 4 and fig. 5, showing alternatives to only supplying a direct current (DC) as exemplified above. The electric power could be supplied with an alternating current (AC) so that the pressure exerted onto the at least one fibrous material is varied so as to provide a vibration to the laminate 2, in order to consolidate the fibrous material in the laminate 2. In fig. 4, the current (I) is provided in a sequence of alternating time periods of AC (dtAC) and time periods of DC (dtDC). Alternatively, an initial single time period of AC could be followed by a single time
period of DC extending until the end of the curing process. In the alternative in fig. 5, the current (I) is provided with a constant level (Is) and an overlapping varying level. In principal the frequency of the AC could be anywhere between a few Hz to several kHz, but is preferably chosen so as to be suitable for the fiber material consolidation purpose, for example within 10-500 Hz, more preferred 20-200 Hz, e.g. about 50 Hz.
CLAIMS

1. A method for manufacturing a composite part comprising a fibrous material and a resin, the method comprising providing a moulding support, placing at least one fibrous material layer on the moulding support, providing an electro-activatable sheet adapted change shape under the influence of electric power, placing the electro-activatable sheet on the moulding support so that the at least one fibrous material layer is located between the moulding support and the electro-activatable sheet, and supplying electric power to the electro-activatable sheet so that the shape of the electro-activatable sheet is changed so as to exert pressure onto the at least one fibrous material layer.

2. A method according to claim 1, comprising fixing the electro-activatable sheet to the moulding support along at least one portion of a periphery of the electro-activatable sheet.

3. A method according to any one of the claims 1-2, wherein the moulding support is convex and the change of the shape of the electro-activatable sheet is shrinkage.

4. A method according to any one of the claims 1-2, wherein the moulding support is concave and the change of the shape of the electro-activatable sheet is stretching.

5. A method according to any one of the preceding claims, wherein the resin is supplied to the at least one fibrous material layer after the electro-activatable sheet has been placed on the moulding support.

6. A method according to any one of the preceding claims, wherein the at least one fibrous material layer comprises a resin when the electro-activatable sheet is placed on the moulding support.

7. A method according to any one of the preceding claims, wherein, during the step of supplying electric power, the electric power is supplied with an
alternating current so that the pressure exerted onto the at least one fibrous material is varied so as to provide a vibration to the at least one fibrous material.

8. A composite part manufactured with a method according to any one of the claims 1-7.

9. An apparatus for manufacturing a composite part comprising a fibrous material and a resin, the apparatus comprising a moulding support, an electro-activatable sheet adapted change shape under the influence of electric power, and an electric power source connectable to the electro-activatable sheet, the apparatus being adapted for at least one fibrous material layer and the electro-activatable sheet to be placed on the moulding support, so that the at least one fibrous material layer is located between the moulding support and the electro-activatable sheet.

10. An apparatus according to claim 9, wherein the apparatus comprises at least one fixing tool for fixing the electro-activatable sheet to the moulding support along at least one portion of a periphery of the electro-activatable sheet.

11. An apparatus according to any one of the claims 9-10, wherein the moulding support is convex.

12. An apparatus according to any one of the claims 9-10, wherein the moulding support is concave.
**INTERNATIONAL SEARCH REPORT**

**International application No**

**PCT/01/005128**

**A. CLASSIFICATION OF SUBJECT MATTER**

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**ADD.**

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)

B29C B29D B01D

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

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

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**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

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