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(57) Abstract: Shaped material (1), in particular a disc for a disc brake, comprising a plurality of layers (2, 4, 6) of carbon fibres stacked in a construction direction (X), each layer (2, 4, 6) comprising a plurality of segments (8, 10) placed side by side and joined together to form said layer, the segments of a layer (2, 4, 6) comprising radial segments (8) and transverse segments (10). In each layer (2, 4, 6) of carbon fibres, the number of transverse segments (10) is greater than the number of radial segments (8). The above invention is further addresses a manufacturing method of a shaped material.

FIG. 1

Shaped material (1), in particular a disc for a disc brake, comprising a plurality of layers (2, 4, 6) of carbon fibres stacked in a construction direction (X), each layer (2, 4, 6) comprising a plurality of segments (8, 10) placed side by side and joined together to form said layer, the segments of a layer (2, 4, 6) comprising radial segments (8) and transverse segments (10). In each layer (2, 4, 6) of carbon fibres, the number of transverse segments (10) is greater than the number of radial segments (8). The above invention is further addresses a manufacturing method of a shaped material.
This invention relates to a shaped material, preferably a disc for a brake disc, and a process for the realisation of such material.

The use of discs for disc brakes made with carbon-based materials (so-called Carbon Carbon, or "C/C") has long been known.

These discs are obtained by a process that provides for the superimposition of layers of woven and/or non-woven fabric, the possible addition of resins, densification processes with carbon via liquid or gas, and suitable subsequent heat treatments.

The densification processes may for example be performed by means of CVD (Chemical Vapour Deposition), CVI (Chemical Vapour Infiltration) or LPI (Liquid Polymer Infiltration).

In some applications these materials may be used for working as friction elements at high temperatures, a circumstance that does not make them suitable for standard road applications, but rather high-range applications.

Traditionally, for the production of C/C disc-brake discs, due to the special architecture that is formed inside the related stratified structure, there are
regions of the disc that are critical to the structural level because they have a low resistance with respect to applied load.

[0007] It follows that, in correspondence of these regions, cracks or fractures could be created that are unacceptable for certain high use ranges from the point of view of performance, for the most extreme braking applications, as in the case of sports cars or even in other means of transport that travel at high speeds.

[0008] This invention relates to the preceding context, proposing to provide a shaped material and a method able to drastically reduce the possibility of fractures in a disc brake, and isotropic mechanical properties in spite of the structure of this shaped material being inherently asymmetric.

[0009] This purpose is achieved by means of a shaped material according to claim 1 and by means of a method according to claim 14. The claims dependent on these show preferred embodiments.

[0010] The object of this invention will now be described in detail, with the help of the accompanying drawings, in which:

[0011] - Figure 1 is a perspective view of a fabrication step of the shaped material of this invention, according to a possible embodiment;
[0012] - Figure 2 is a lateral schematic view of the composition and number of layers of a shaped material according to a possible variant;

[0013] - Figures 3 and 4 illustrate, respectively, a radial segment and a transverse segment employable in the shaped material of this invention.

[0014] With reference to the above-mentioned figures, reference number 1 identifies a shaped material in its entirety. Preferably, the shaped material according to this invention relates to a disc for a brake disc, advantageously a ventilated type disc.

[0015] Preferably, the shaped material 1 is characterised in that it has a residual porosity of less than 5%, for example equal to, or smaller than, 3%.

[0016] Preferably, the value of this residual porosity is considered for a shaped material 1 comprising areas of silicon carbide SiC, specifically at the end of at least one step of infiltration with silicon Si, as better described below.

[0017] The shaped material 1 comprises a plurality of layers 2, 4, 6 of carbon fibres, these layers being stacked along a construction direction X, for example vertical 'as shown in Figure 1.

[0018] Merely by way of example, at least part of the carbon fibres (preferably all such fibres) can be derived
from oxidised polyacrylonitrile fibres. For example, such fibres are produced by the company SGL Carbon SE under the tradename Panox®.

[0019] According to a preferred variant, the shaped material 1 comprises a carbonaceous matrix (i.e., composed at least 50% of carbon) in which part of the carbon fibres is at least partially englobed.

[0020] In this description, unless otherwise specified, the terms "radial", "axial", "angular" and "circumferential" will always be understood with respect to the direction construction X.

[0021] According to a variant, construction direction X is oriented parallel to a rotation axis of the shaped material 1 or of the disc for disc brake, during its use.

[0022] According to a preferred variant, the number of layers 2, 4, 6 of carbon fibres (or the number of coils of the segments 8, 10; in this regard see below) is comprised in the range 10-50, advantageously 18-40, for example 28-40 or 18-26, optionally in the range of 20-24. For example, the number of layers/coils could be about 21-23.

[0023] Merely by way of example, along the construction direction X, the shaped material may have a thickness S equal to about 40 millimetres or more, specifically between about 40-300 millimetres.
Each layer 2, 4, 6 comprises a plurality of segments 8, 10 side by side and joined together to form the aforesaid layer, the segments of a layer 2, 4, 6 comprising radial segments 8 and transverse segments 10.

The radial segments 8 are segments in which the carbon fibres are predominantly oriented in a radial direction R with respect to the construction direction x, or oriented approximately parallel to the radial direction R. On the contrary, the transverse segments 10 are segments in which the carbon fibres are predominantly oriented in a direction I incident to the preceding radial direction R. In this regard, refer to the diagrams of figures 3 and 4 that respectively show the orientations of a radial direction and a transverse direction of the respective segments 8, 10.

According to a preferred variant, the incident direction I is substantially perpendicular to the radial direction R.

Preferably, at least part of the segments 8, 10 is in the form of a circular sector or of an arc circumference, as for example shown in Figure 1. Advantageously, the circumferential width of these sectors or arches may be in the range 60-90°, advantageously 60-80°, optionally in the range of 65-72°, for example approximately 68°.
[0028] For example, all the segments could have substantially the same form.

[0029] According to a further preferred variant, each segment 8, 10 comprises mainly or exclusively unidirectional carbon fibres, arranged in the radial direction R or in the incident direction I depending on the type of segment.

[0030] According to an embodiment, the segments 8, 10 extend in a spiral around the construction direction X in a substantially continuous manner through the plurality of layers 2, 4, 6 of carbon fibres.

[0031] According to an advantageous embodiment, with respect to the construction direction X, the segments of a layer 2 are angularly offset with respect to the segments of an adjacent layer 4 (specifically: in an axial direction), so that the joining zones 12 between the segments do not overlap or do not coincide through the thickness S of the shaped material 1.

[0032] According to an embodiment (not shown), at least one segment of a layer 2 may be partially overlapped on at least one other segment that is alongside it in a circumferential direction.

[0033] In addition, in each layer 2, 4, 6 of carbon fibres, the number of transverse segments 10 is higher than the number of radial segments 8.
[0034] It follows that, innovatively, through the asymmetric or anisotropic structure discussed previously, this invention allows drastically reducing the occurrence of cracks or fractures in the shaped material. For this reason, this material is suitable for applications where - among other characteristics - also a high flexural strength is desired.

[0035] According to an advantageous variant, the number of transverse segments 10 is greater - in particular of at least one -unit, of at least two units or three or more units - with respect to the number of radial segments 8.

[0036] In other words, in the shaped material 1 according to this variant, it is preferable that there be a more pronounced prevalence of transverse segments 10 with respect to the radial segments 8.

[0037] According to a particularly preferred embodiment, inside one or more layers 2, 4, 6 of carbon fibres, five radial segments 8 could alternate with at least six or at least seven transverse segments 10.

[0038] According to a further embodiment, five transverse segments 10 could alternate with at least one, at least two or at least three radial segments 8.

[0039] Optionally, the shaped material 1 could comprise zones of silicon carbide SiC obtained by reaction of part of the carbon C of said carbon fibres, and/or of the
carbonaceous matrix of said shaped material 1, with at least part of a silicon Si infiltrated in said material 1.

[0040] According to a preferred embodiment, the silicon carbide zones could be arranged to bridge between layers 2, 4, 6 of adjacent carbon fibres.

[0041] The above objective is further solved by means of a method for the manufacture of the shaped material 1 according to any of the preceding embodiments.

[0042] Therefore, even if not explicitly stated, preferred or accessory variants of such a procedure could include any characteristic deductible even only implicitly, from a structural point of view, from the foregoing description.

[0043] The method comprises the following steps:

[0044] i) in a direction of construction X, stacking (and optionally needling) a plurality of layers 2, 4, 6 of carbon fibres or of precursors of said fibres, each of which comprises a plurality of radial segments 8 and transverse segments 10 placed side by side and joined together to form said layer, the number of transverse segments 10 of each layer 2, 4, 6 being higher than the number of radial segments 8;

[0045] ii) subjecting the product of step i) to a heat treatment or to a thermochemical treatment, so as to
densify said product and thereby obtain said shaped material 1;

[0046] iii) optionally infiltrating the product of step ii) with an infiltrating agent, such as silicon or silicon carbide.

[0047] According to a preferred variant, the step of stacking comprises a step of arranging the segments 8, 10 in a spiral around the direction of construction X, in a substantially continuous manner through the plurality of layers 2, 4, 6 of carbon fibres.

[0048] According to a further preferred variant, the infiltrating agent comprises silicon Si. According to this variant, during step iii), part of the carbon C of the carbon fibres, and/or the carbonaceous matrix of such shaped material 1, forms silicon carbide SiC by reaction with part of the infiltrated silicon Si.

[0049] According to a particularly preferred embodiment, the needling step in step i) could comprise one or more phases of transposing - for example by means of shaped needles - the carbon fibres or the precursors of these fibres through the thickness of the different layers 2, 4, 6 of the shaped material 1.

[0050] It should be clarified that, in step i), the layers 2, 4, 6 could include both carbon fibres (i.e., already carbonised fibres), or precursors of such fibres (for
example fibres of oxidised polyacrylonitrile) that turn into carbon fibres during an optional carbonisation step downstream of step i).

[0051] Innovatively, the shaped material and method of this invention allow brilliantly solving the drawbacks of the prior art.

[0052] More precisely, the previously discussed asymmetric structure allows reducing - or even eliminating - the weak points of low resistance of the known shaped materials, at the same time maintaining a good level of isotropy in the behaviour of these during use.

[0053] Advantageously, the method and the shaped material of this invention can be implemented with great simplicity in any existing production line, especially by virtue of its constructive simplicity.

[0054] Advantageously, the method and the shaped material of this invention allow achieving considerable economies of manufacture, by virtue of the fact that specific processing does not require supplementary or additional equipment respect to those normally provided.

[0055] To the embodiments of the aforesaid method and shaped material, one skilled in the art, in order to meet specific needs, may make variants or substitutions of elements with others functionally equivalent.

[0056] Even these variants are contained within the scope
of protection, as defined by the following claims.

[0057] Moreover, each of the variants described as belonging to a possible embodiment can be realised independently of the other variants described.
CLAIMS

1. Shaped material (1), for example disc for a disc brake, preferably a ventilated disc, comprising a plurality of layers (2, 4, 6) of carbon fibres stacked in a construction direction (X), each layer (2, 4, 6) comprising a plurality of segments (8, 10) placed side by side and joined together to form said layer, the segments of a layer (2, 4, 6) comprising radial segments (8) and transverse segments (10);

wherein the radial segments (8) are segments in which the carbon fibres are predominantly oriented in a radial direction (R) relative to the direction of construction (X) or oriented approximately parallel to the radial direction (R), and the transverse segments (10) are segments in which the carbon fibres are mainly directed in a direction (I) incident to said radial direction;

wherein, in each layer (2, 4, 6) of carbon fibres, the number of transverse segments (10) is higher than the number of radial segments (8).

2. Shaped material according to claim 1, wherein the number of transverse segments (10) is higher by at least one unit, by at least two units or three or more units than the number of radial segments (8).

3. Shaped material according to the preceding claims, wherein, inside one or more layers (2, 4, 6) of carbon
fibres, five radial segments (8) are alternated with at least six or at least seven transverse segments (10).

4. Shaped material according to any of the preceding claims, wherein, relative to the direction of construction (X), the segments of one layer (2) are angularly staggered with respect to the segments of an adjacent layer (4) so that the joining zones (12) between the segments do not overlap through the thickness (S) of said material (1).

5. Shaped material according to any of the preceding claims, in which the segments (8, 10) extend in a spiral around the direction of construction (X) in a substantially continuous manner through the plurality of layers (2, 4, 6) of carbon fibres.

6. Shaped material according to claim 1 or according to the previous claim, in which the number of layers (2, 4, 6) of carbon fibres or the number of coils of said segments (8, 10) is in the range 18-40, for example 28-40 or 18-26, optionally in the range of 20-24.

7. Shaped material according to any of the preceding claims, in which the incident direction (I) is substantially perpendicular to the radial direction (R).

8. Shaped material according to any of the preceding claims, wherein at least part of the segments (8, 10) are in the form of a circular sector or circumference arc, of
a circumferential width in the range 60-90°, for example of approximately 68°.

9. Shaped material according to any of the preceding claims, wherein each segment (8, 10) comprises mainly or exclusively unidirectional carbon fibres, arranged in the radial direction or in the incident direction.

10. Shaped material according to any of the preceding claims, wherein at least part of the carbon fibres, for example all, are derived from oxidised polyacrylonitrile fibres, for example Panox® fibres.

11. Shaped material according to any of the preceding claims, in which the direction of construction (X) is oriented parallel to a rotation axis of the shaped material (1) or of the disc for a disc brake, during the use thereof.

12. Shaped material according to any of the preceding claims, comprising areas of silicon carbide (SiC) obtained by reaction of part of the carbon (C) of said carbon fibres, and/or of a carbonaceous matrix of said shaped material (1), with at least part of a silicon (Si) infiltrated in said material (1), said regions of silicon carbide being arranged to bridge layers (2, 4, 6) of adjacent carbon fibres.

13. Shaped material according to any of the preceding claims, characterised in that it has a residual porosity
of less than 5%, for example smaller than or equal to 3%.

14. Method for making a shaped material (1) according to any of the preceding claims, comprising the following steps:

1) in a direction of construction (X), stacking a plurality of layers (2, 4, 6) of carbon fibres or of precursors of said fibres, each of which comprises a plurality of radial (8) and transverse segments (10) placed side by side and joined together to form said layer, the number of transverse segments (10) of each layer (2, 4, 6) being higher than the number of radial segments (8);

ii) subjecting the product of step i) to a heat treatment or to a thermochemical treatment, so as to density said product and thereby obtain said shaped material (1);

iii) optionally infiltrating the product of step ii) with an infiltrating agent, such as silicon or silicon carbide.

15. Method according to the preceding claim, wherein the step of stacking comprises a step of arranging the segments (8, 10) in a spiral around the direction of construction (X), in a substantially continuous manner through the plurality of layers (2, 4, 6) of carbon fibres.

16. Method according to claim 14 or 15, wherein the
infiltrating agent comprises silicon (Si) and wherein, during step iii), part of the carbon (C) of the carbon fibres, and/or of a carbonaceous matrix of said shaped material (1), forms silicon carbide (SiC) by reaction with part of the infiltrated silicon (Si).
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER

INV. F16D65/12

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)

F16D C04B

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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2 September 2016

Name and mailing address of the ISA:

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Date of the actual completion of the international search: 2 September 2016
Date of mailing of the international search report: 27/09/2016

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