PLANKING PANEL FOR A STRUCTURAL COMPONENT, FLOW BODY COMPRISING SUCH A PLANKING PANEL AND DEVICE FOR MONITORING MATERIAL DAMAGE ON SUCH A PLANKING PANEL

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ABSTRACT

The invention pertains to a planking panel (B) for a structural component (1) that is realized in the form of a sandwich component in its inner region (Bl) that extends in a planar fashion and features a first skin section (11), a second skin section (12) and a core section (13) that is situated between these two skin sections, wherein the core section (13) connects the first and the second skin sections (11, 12) to another in a planar fashion, with the invention being characterized in that a plurality of monitoring lines (14) is provided that extend over a planar section of the core section (13) to be monitored in order to detect damage in the core section (13) and respectively feature a first connection point (15) on a first end (14a) and a second connection point (16) on a second end (16a) in order to apply a monitoring signal (UK), wherein the monitoring lines (14) have a tear strength that lies in the range between 50% and 100% of the tear strength of the core section (13).
PLANKING PANEL FOR A STRUCTURAL COMPONENT, FLOW BODY COMPRISING SUCH A PLANKING PANEL AND DEVICE FOR MONITORING MATERIAL DAMAGE ON SUCH A PLANKING PANEL

[0001] This patent application claims the filing date of German patent applications DE 10 2010 027 696.0, DE 10 2010 027 695.2, DE 10 2010 031 688.1 and DE 10 2010 031 690.3 and of U.S. provisional patent applications 61/365,857, 61/365,882, 61/365,873 and 61/365,863, all of which were filed on Jul. 20, 2010. Due to the above reference, the disclosures of these patent applications are incorporated into the present patent application.

[0002] The invention pertains to a planking panel for a structural component that is realized in the form of a sandwich component in its inner region that extends in a planar fashion and features a first skin section, a second skin section and a core section situated between these two skin sections, wherein the core section connects the first and the second skin sections to one another in a planar fashion, as well as to a flow body with such a planking panel and a device for monitoring material damage on a planking panel.

[0003] Planking panels of this type are known from the prior art and used as covering components for the design of surfaces in various branches of industry. Due to the simple structure, these components make it possible to realize a large variety of different surface shapes such that components of this type are suitable, for example, for use as interior covering in vehicles. However, such sandwich components have the disadvantage that the relatively soft core section is susceptible to tearing under mechanical loads, particularly impact loads. Since the core section is covered by skin sections on both sides, it is difficult to determine if the component is damaged without subjecting the component to destructive testing.

[0004] Particularly in the field of manned aviation, the operability of the aircraft and therefore the structural integrity of the components installed therein play an important role. An undetectable critical damage of a safety-relevant component can lead to the failure of various technical systems and therefore have catastrophic consequences. In the aircraft industry, safety-relevant components therefore are inspected, repaired and possibly replaced if the damage can no longer be economically repaired within predefined intervals, namely in accordance with a maintenance schedule. The planking of an aircraft is continuously subjected to possible collisions with other bodies during flying operations. The aircraft is frequently hit by rocks, hailstones during thunderstorms or even birds that get into the flight path of the aircraft. The impact of such a foreign body or part thereof on a planking element realized in the form of a sandwich structure must be categorized as particularly critical because the deformation, to which the sandwich element is subjected, can cause the foam core in the interior to tear or to separate from the surrounding skin sections without such damage being visible from outside.

[0005] This is the reason why such sandwich components have so far not been used as safety-relevant components of the planking in the construction of aircraft, particularly in commercial aviation.

[0006] It is the objective of the invention to disclose a planking panel for a structural component with the lowest weight possible, a flow body with such a planking panel and a device for monitoring material damage on a planking panel that can be used for the main-load bearing region of a safety-critical component structure.

[0007] This objective is attained with the characteristics of the independent claims. Other embodiments are disclosed in the dependent claims that refer to these independent claims.

[0008] The inventive solutions allow the non-destructive testing (Non Destructive Testing) of a planking panel and, in particular, the reliable detection of all types of damages.

[0009] According to the inventive solution of a planking panel, it is proposed to form the core section of a planking panel realized in the form of a sandwich structure of foam material and to utilize this planking panel in a main-load bearing region of the aircraft structure despite its susceptibility. However, the integrity of the material of the core section (structural integrity) is checked by means of at least one monitoring line with a tear strength that in terms of its amount is lower than the fracture strength of the planar region of the core section such that damage in the core section can be detected in a non-destructive, simple and reliable fashion. In this way, the planking panel can be used as damage-tolerant planking panel such that it is suitable, in particular, for use as part of an aircraft structure.

[0010] The term main-load bearing region refers to a region of the aircraft structure, the damage of which can lead to a catastrophic event for the aircraft during the flight if the damage occurs in such a way that this region is no longer able to withstand tensions resulting from the main loads being applied to the aircraft structure.

[0011] The invention proposes a planking panel for a structural component that is realized in the form of a sandwich component in its inner region that extends in a planar fashion and features a first skin section, a second skin section and a core section that is situated between these two skin sections and connects the first and the second skin sections to one another in a planar fashion. In order to detect damages in a fictitious monitoring volume of the core section that is respectively monitored with respect to the presence of damage, at least one monitoring line is provided in this monitoring volume or a plurality of monitoring lines extending over the monitoring volume of the core section to be monitored is provided. Depending on the respective application, the monitoring line or the monitoring lines is/are arranged in the monitoring volume in such a way that damage monitoring of the monitoring volume can be realized. Each monitoring line may respectively feature a first connection point at a first end and a second connection point at a second end in order to apply a monitoring signal. Alternatively, one connection point may be coupled to several monitoring lines. In this case, the monitoring lines have a tear strength that lies, in particular, in the range between 50% and 100% of the tear strength of the core section.

[0012] Such an arrangement provides the advantage that defects in the core section of the planking panel can be detected immediately after they occur and a defective component can be very quickly identified as such in order to be subsequently replaced.

[0013] In another embodiment of the invention, the tear strength of the monitoring lines lies in the range between 80% and 100% of the tear strength of the core section, but it is particularly referred that the tear strength of the monitoring lines lies in the range between 90% and 100% or 90% and 95% of the tear strength of the core section.
Furthermore, the core section may have a tensile strength in the range between 1.5 MPa and 2.5 MPa and/or a shear strength in the range between 0.8 MPa and 1.6 MPa.

According to an embodiment of the invention, it is proposed that at least one monitoring line within the monitoring volume extends in the planking panel in a meander-shaped fashion such that bridging segments extending along the thickness direction of the planking panel and between the oppositely arranged skin sections and reversing segments that respectively connect these bridging segments and are respectively situated in one of the oppositely arranged skin sections are formed, wherein reversing segments that lie behind one another in the longitudinal direction of the monitoring line are situated in different skin sections. In this case, the connection points of the at least one monitoring line may be situated in different skin sections or in one and the same skin section.

A plurality of monitoring lines may extend in a thickness direction of the planking panel, wherein each monitoring line features two connection points, and wherein a first connection point is situated on the first skin section and a second connection point is situated on the second skin section.

Due to this arrangement, the formation of tears in the core section that extend transverse to the thickness direction can be detected in a particularly simple fashion.

According to an embodiment of the invention, each monitoring line features two connection points. According to another embodiment, at least one connection point is provided and coupled to several monitoring lines.

In another embodiment of the present invention, a plurality of monitoring lines may extend in a longitudinal direction of the planking panel, wherein each monitoring line features two connection points, both of which are situated on the first skin section or both of which are situated on the second skin section.

Due to this arrangement, the formation of tears in the core section that extend along the thickness direction and therefore transverse to the longitudinal direction of the planking panel can be detected in a particularly simple fashion.

Furthermore, the monitoring lines may consist of electrical conductors, the connection points may consist of electrical connection points and the monitoring signal may be an electric monitoring voltage signal.

This provides the advantage that the monitoring voltage can be respectively applied to one electrical conductor. If a current flow does not take place in the conductor or deviates from a predefined current value, it can be determined that the conductor and therefore also the core section is damaged.

The monitoring lines may furthermore and/or additionally consist of optical waveguides, the connection points may consist of optical connection points and the monitoring signal may be an optical monitoring signal.

The utilization of optical waveguides as monitoring lines provides the advantage that, in contrast to electrical conductors, no interference signals originating, for example, from magnetic fields are induced such that the damage detection can also be reliably carried out in magnetic fields. This is particularly advantageous when the aircraft flies through a thunderstorm, in which lightning strikes that generate magnetic fields occur.

Furthermore, the monitoring signal may be permanently applied to the monitoring lines or the monitoring signal may be applied to the monitoring lines for a predefined time period within predefined time intervals.

The first variation provides the advantage that damage can be immediately detected. If a monitoring signal is permanently applied, a line interruption leads to an immediate signal loss and therefore to an intermediate defect detection. The second alternative provides the advantage of a consistent inspection activity for maintenance personnel in terms of conduct such that the maintenance activities can be more precisely defined and optimized. Furthermore, a measurement in the dormant state is in most instances more reliable than in the operating state.

According to an inventive embodiment, the core section of the planking panel is formed of a homogenous material.

Furthermore, the core section may consist or be formed of a foam core and, in particular, an aluminum foam core, a ceramic core or a sandwich core. According to another embodiment, the core section itself features an intermediate layer and/or is realized in the form of a composite core that is composed of several sandwich cores.

Furthermore, the tear strength of the monitoring lines may correspond to a tensile strength in the range between 1.5 MPa and 2.5 MPa and a shear strength between 0.8 MPa and 1.6 MPa.

Another aspect of the present invention concerns a flow body, particularly for an aircraft, with a planking panel.

According to another exemplary embodiment, a device for monitoring material or structural damage on a planking panel is proposed, wherein the monitoring device features an activation device for transmitting a signal via the monitoring line and an evaluation device, by means of which it can be determined if the monitoring line is intact based on the signal transmitted via the monitoring line in order to detect damage in the foam section, wherein the activation device is designed in such a way that it transmits the monitoring signal via the monitoring lines permanently or within predefined time intervals.

Exemplary embodiments of the invention are described below with reference to the attached schematic figures, in which:

FIG. 1 shows a top view of a section of an aircraft tail unit with an inventive planking panel.

FIG. 2 shows a partial section through an inventive planking panel according to a first embodiment of the invention, in which the planking panel features a monitoring line extending in the longitudinal direction of the core section in order to detect damage in a monitoring volume of the core section.

FIG. 3 shows a partial section through an inventive planking panel according to another embodiment of the invention, in which the planking panel features a monitoring line that extends in the core layer in a meander-shaped fashion, wherein the connection devices coupled to the monitoring line are respectively provided on different skin sections.

FIG. 4 shows a partial section through an inventive planking panel according to another embodiment of the invention, in which the planking panel features a monitoring line that extends in the core layer in a meander-shaped fashion, wherein the connection devices coupled to this monitoring line are respectively provided on the same skin section.

FIG. 5 shows a partial section through an inventive planking panel with several variations of the arrangement of the monitoring lines,
FIG. 6 shows a partial section through an inventive planking panel according to a second embodiment, and FIG. 7 shows another partial section through an inventive planking panel.

FIG. 1 shows a structural component 1 with a plurality of inventive planking panels B that at least partially form a surface of the structural component 1. The structural component 1 may comprise a flow body 1 such as, for example, a tail unit of an aircraft, particularly an aircraft wing, an elevator, a rudder or a part of the aircraft fuselage.

A coordinate system is illustrated for orientation purposes and respectively defines a chord direction I, a wing span direction S and a thickness direction D of the aircraft wing or the structural component and therefore of the planking panel B.

This coordinate system is also illustrated in FIG. 2 that shows a collision of a foreign body F with the planking element B. FIG. 2 shows a partial section along a line of section that extends in a plane defined by the thickness direction D and the wing span direction S in FIG. 1. The planking element B features a first skin section 11 in its upper region referred to the thickness direction D and a second skin section 12 in its oppositely arranged lower region referred to the thickness direction D. The skin sections 11, 12 have a small thickness in comparison with their lateral dimensions and therefore form planar, panel-shaped bodies. A core layer 13 provided between the first skin section 11 and the second skin section 12 has a greater thickness than the skin sections 11, 12. On its upper surface, the core layer 13 is in planar contact with the first skin layer 11. The core layer 13 is furthermore in planar contact with the second skin layer 12 on its lower surface. The planar contact can be additionally intensified, for example, by providing an adhesive between the core layer and the skin layer or by producing screwed or riveted connections. According to FIG. 1, the planking panels B feature an inner region IB, in which the monitoring lines 14 extend.

In the first embodiment of the invention illustrated in FIG. 2, a monitoring line 14 extends through the core layer 13 of the planking panel B in a longitudinal direction of the planking panels B. The monitoring line 14 has a first end 14a and a second end 14b, wherein the first end 14a is connected to a first connection point 15 and the second end 16a is connected to a second connection point 16. Both connection points 15, 16 are arranged in the first skin layer 11, but could also be arranged in the second skin layer 12 in an alternative embodiment of the invention. A monitoring signal can be externally applied to the monitoring line 14 via the connection points 15, 16, wherein the monitoring signal is transmitted from the first connection point 15 to the second connection point 16 or vice versa.

The monitoring lines 14 used may consist of electrical conductors or optical waveguides such as, for example, fiber optic cables. A monitoring signal corresponding to these lines then needs to be applied in the form of an electrical or optical signal. An external diagnostic system or an internal diagnostic system arranged in the planking panel B determines if the applied signal is transmitted via the monitoring line 14. The utilization of electrical conductors makes it possible to manufacture particularly cost-efficient planking elements B, wherein the high robustness of the electrical conductors reduces the effort for the manufacturing process of the planking panels B. The utilization of optical monitoring lines provides the advantage that the planking panels B are insensitive to electromagnetic interferences.

FIG. 7 shows a first embodiment of the invention, wherein this figure shows an exemplary tear R formed as a result of the impact of the foreign body F according to FIG. 2. This impact leads to a deflection of the entire planking panel B, wherein the core section 13 in the interior of the panel is subjected to a tensile stress that acts in its longitudinal direction. The core section 13 tears if this tensile stress exceeds a maximum material value such that the tear shown is formed. The monitoring line 14 extends along the longitudinal direction of the planking panel B and has a tear strength that is essentially identical to the tear strength of the material of the core section 13. This means that tearing of the core section 13 directly leads to an interruption of the monitoring line 14. A signal transmission therefore cannot take place and the diagnostic device detects a defect. In FIG. 7, a monitoring voltage Uk is applied to the monitoring lines 14 at the connection points 15, 16 such that a monitoring signal in the form of a predefined current intensity flows through the monitoring line 14.

However, a signal transmission does not have to completely fail in order to detect damage. In an alternative embodiment of the invention, a monitoring signal may be applied in the form of an electric voltage UK that generates a current flow with a predefined current value in the monitoring line 14. If the diagnostic device measures a current flow with the predefined current value, it is determined that no damage exists. However, if a current value is detected that deviates from the predefined current value, it is determined that the planking panel B is damaged. This embodiment naturally can be combined with the embodiment, in which only the current value “zero” defines a damage scenario.

The monitoring signal may flow through the monitoring line 14 permanently or in a pulsed fashion. When the monitoring line 14 is interrupted, a signal transmission no longer takes place starting at the time of its interruption, wherein this is immediately detected by the diagnostic device that simultaneously also outputs the monitoring signal. In a pulsed signal application, the diagnostic device determines that damage exists on the planking panel B by means of the first signal that is applied to the monitoring line 14 after a damage scenario and cannot be transmitted. In this way, energy can be saved in comparison with a permanent signal transmission.

The monitoring lines 14 have a tear strength that is adapted to the material properties of the core section 13. In this respect, the tear strength lies in the range between 80% and 100%, preferably between 80% and 100%, particularly between 90% and 100%, of the tear strength of the material of the core section 13. This makes it possible to ensure that the monitoring line 14 is also destroyed when the core section 13 suffers damage in the form of a tear. In another preferred embodiment of the present invention, the tear strength of the monitoring line 14 lies in the range between 80% and 95% of the tear strength of the material of the core section 13. This embodiment provides the advantage that the monitoring line 14 is also severed in the corresponding region even if the core section 13 was not yet damaged, but rather merely subjected to a load that lies in the fringe load range of its material, wherein the diagnostic system consequently detects that the planking panel B was at least subjected to a load in the fringe range. Subsequently, the diagnostic device can output a warning message in advance such that the planking panel B can be replaced before an actual damage scenario occurs.
The tear strength of the monitoring lines preferably corresponds to a tensile strength that lies between 1.5 MPa and 2.5 MPa, but preferably amounts, in particular, to 1.9 MPa, and/or a shear strength that lies between 0.8 MPa and 1.6 MPa, but preferably amounts to 1.15 MPa.

FIG. 5 shows several variations of the arrangement of the monitoring lines, wherein the connection points to the second skin section and the core section are provided on the same skin section. The monitoring lines may extend from a first skin section to a second skin section essentially parallel to the thickness direction D. The skin sections may alternatively be arranged vertically such that the monitoring lines extend essentially parallel to the chord direction T. FIG. 5 furthermore shows an exemplary tear R that conceivably could have been formed upon the impact of a foreign body F as illustrated in FIG. 1. The tear intersects with at least one of the monitoring lines such that a signal transmission is no longer possible along these several monitoring lines.

FIG. 6 shows another embodiment of the present invention, wherein the structure of the planking panel is made of a sandwich component identical to that described with reference to FIG. 1. However, the monitoring lines extend from the first skin section to the second skin section and are provided at predefined critical points of the planking panel in this case. A tear shown extends essentially parallel to the skin sections and therefore transverse to the monitoring lines. A foreign body F that laterally impacts on the planking panel generates an impulse that is illustrated in the form of the vectors FK and leads to a compression of the planking panel. The effective force causes the skin sections to deflect, namely away from the core section, such that the tear R shown is formed. In this case, the tear R also serves the monitoring lines such that the monitoring signals can no longer be transmitted and the diagnostic device determines that the planking panel has been damaged.

The monitoring lines or arrangement of monitoring lines provided in the monitoring volume V can be regarded as an invention. The arrangement of the monitoring lines extends from the first skin section and the core section in a meander-shaped fashion, wherein the connection devices are coupled to this monitoring line and are respectively provided on different skin sections. FIG. 4 shows a variation of this embodiment, in which the planking panel B features a monitoring line that extends in the core layer or the core section 13 in a meander-shaped fashion, wherein the connection devices 15, 16 coupled to this monitoring line 14 are respectively provided on the same skin section 11 or 12.

1. A planking panel for a structural component that is realized in the form of a sandwich component in its inner region that extends in a planar fashion and features a first skin section, a second skin section, and a core section that is situated between these two skin sections and connects the first and the second skin sections to one another in a planar fashion,

2. The planking panel according to claim 1, wherein the core section has a tensile strength in the range between 1.5 MPa and 2.5 MPa and/or a shear strength in the range between 0.8 MPa and 1.6 MPa.

3. The planking panel according to claim 1, wherein at least one monitoring line extends in the planking panel in a meander-shaped fashion such that bridging segments extending along the thickness direction of the planking panel and between the oppositely arranged skin sections and reversing segments that respectively connect these bridging segments and are respectively situated in one of the oppositely arranged skin sections are formed.

4. The planking panel according to claim 3, wherein the connection points of the at least one monitoring line are situated in different skin sections.

5. The planking panel according to claim 3, wherein the connection points of the at least one monitoring line are situated in one and the same skin section of the skin sections.

6. The planking panel according to claim 1, wherein the planking panel features a plurality of monitoring lines that extend along the thickness direction of the planking panel, wherein each monitoring line features two connection points, and wherein a first connection point is respectively situated on the first skin section and a second connection point is respectively situated on the second skin section.

7. The planking panel according to claim 1, wherein the planking panel features a plurality of monitoring lines that extend along the longitudinal direction of the planking panel and each monitoring line features two connection points, both of which are situated on the first skin section or both of which are situated on the second skin section.

8. The planking panel according to claim 1, wherein the monitoring lines consist of electrical conductors, the connection points consist of electrical connection points and the monitoring signal consists of an electric monitoring voltage.

9. The planking panel according to claim 1, wherein the monitoring lines consist of optical waveguides, the connection points consist of optical connection points and the monitoring signal consists of an optical monitoring signal.

10. The planking panel according to claim 1, wherein the core section consists of a homogeneous material that preferably is specifically lighter than the two skin sections.

11. The planking panel according to claim 1, wherein the core section consists of a foam core, particularly a polymer foam core, an aluminum foam core, a ceramic core or a massive core.

12. The planking panel according claim 1, characterized in that the core section consists of a composite core that is formed of several sandwich cores.

13. The planking panel according to claim 1, characterized in that the tear strength of the monitoring lines corresponds to a tensile strength in the range between 1.5 MPa and 2.5 MPa and a shear strength between 0.8 MPa and 1.6 MPa.

14. A flow body, particularly for an aircraft, with a planking panel according to claim 1.

15. A device for monitoring material damage on a planking panel in accordance with claim 1, wherein the monitoring device features an activation device for transmitting a signal via the monitoring line and an evaluation device, by means of which it can be determined if the monitoring line is intact.
based on the signal transmitted via the monitoring line in order to detect damage in the foam section, wherein the activation device is designed in such a way that it transmits the monitoring signal via the monitoring lines permanently or within predefined time intervals.

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