Laminate and airplane provided with such a laminate.

Airplane comprising a fuselage with a backup structure of frames and/or stringers, wherein said backup structure supports a laminate comprising sheet metal layers and plastic layers reinforced with fiber straps of a first type that are provided between said sheet metal layers. The laminate has at least one transitional area in which at least one fiber reinforced plastic layer with fibers of the first type is interrupted, and wherein in the at least one transitional area fiber straps of a second type are comprised whereby the fiber straps of the second type exhibit a higher modulus of elasticity than the fiber straps of the first type.
Laminate and airplane provided with such a laminate

The invention relates to a laminate and to an airplane provided with such a laminate.

A laminate according to the preamble of claim 1 is known from WO 03/068494. This document discloses a laminate comprising at least one series of metal layers and fiber reinforced plastic layers which are attached to one another, whereby at least two different series are provided which series include a transition and that at the location of the transition at least one of the internal layers is discontinuous and all the other layers are continuous. The interruption of the internal layer is provided to suit the application of one or more additional layers in order to have a gradual transition between the various regions in the panel which is desirable to avoid stress concentrations. It also results in a gradual transition of the thickness of the panel which is beneficial for the avoidance of undesirable aerodynamic effects.

Generally speaking the known laminate which is used as skin material for an aircraft fuselage may for instance be composed of thin aluminium sheets with the thickness of 0.3-0.5 millimeters having in between unidirectional or cross ply pre-impregnated glass fiber/epoxy resin layers. Such a laminate with unidirectional glass fibers has a modulus of elasticity in the order of 60-70 GPa, whereas such a laminate with cross ply glass fibers may exhibit a modulus of elasticity of 50-65 GPa. A monolithic aluminium skin sheet has however a modulus of elasticity which is in the range of 70-75 GPa.

The lower stiffness of the laminate imposes on the engineer wishing to apply both laminates and monolithic aluminium sheets for the skin material of the fuselage of the airplane several design issues, which in part also relate to the design of the airplane back up structure. This has to do with the fact that a backup structure which is completely made out of aluminium exhibits a higher stiffness than laminate skin material, which therefore results in that the backup structure attracts more load than the skin. The resistance properties on fatigue crack growth of the laminate skin can therefore not be fully utilized, because the backup structure of the airplane would severely suffer from fatigue crack growth. To resolve this problem
it is known to also apply a backup structure (stringers and the like) of the same material as the laminate at the expense of higher manufacturing costs. Another proposed solution is the application of fibers with a higher stiffness, however at the expense of reduced impact performance and reduced residual strength of the laminate caused by the lower strain to failure of this type of fibers.

It is a first objective of the invention to improve the known laminate and to provide an alternative for the laminate of known construction.

It is a second objective of the invention to provide a laminate having increased damage resistance and tolerance compared to the known laminate.

It is a third objective of the invention to improve on fatigue initiation life, fatigue crack growth and residual strength.

The laminate and the airplane of the invention are to that end embodied with the features of one or more of the appended claims.

Essentially the laminate of the invention comprises sheet metal layers and plastic layers reinforced with fiber straps of a first type that are provided between said sheet metal layers, and has at least one transitional area in which at least one fiber reinforced plastic layer with fibers of the first type is interrupted such that in the at least one transitional area fiber straps of a second type are comprised whereby the fiber straps of the second type exhibit a higher modulus of elasticity then the fiber straps of the first type.

The airplane of the invention comprising a fuselage with a backup structure of frames and/or stringers, wherein said backup structure supports the said laminate is preferably construed such that the at least one transitional area in the laminate is provided at the location where the backup structure connects to and supports the laminate.

The invention is based on the insight that at the transitional area the higher modulus of elasticity of the fiber straps of the second type minimizes the stiffness difference with a backup structure of the airplane made out entirely of aluminium, thus reducing the fatigue criticality of the backup structure which can therefore be designed less costly.
Furthermore the so-called pillowing effect causes that the strains in the laminate are reduced at the location where the laminate is supported by the backup structure in comparison with the parts of the laminate that are not supported by the backup structure. This pillowing effect thus limits the strain on the fibers of the second type which exhibit a higher modulus of elasticity then the fiber straps of the first type, and which higher modulus of elasticity would normally result in reduced impact performance or residual strength.

The application of the fiber straps of the second type in the said transitional area where the laminate will be supported by the airplane's backup structure balances the load distribution between the laminate and said backup structure, improving the fatigue life of the backup structure, while at the same time the backup structure limits the strains in the fibers of the second type, which prevents premature fiber failure. At the same time the laminate exhibits the properties that are characteristic for a laminate that is provided with fibers of the first type.

Another beneficial aspect of the laminate and airplane of the invention is that the at least one transitional area and the area that immediately borders to said at least one transitional area exhibit the same thickness. This is beneficial for the avoidance of design complexity.

It is proven preferable that the fiber straps of the first type are glass fibers and the fiber straps of the second type are selected from the group comprising carbon fibers, boron fibers.

The invention will hereinafter be further elucidated with reference to a drawing of typical examples of a laminate and an airplane part construed in accordance with the principles of the invention.

In the drawing:
- figure 1A shows a first embodiment of a laminate according to the invention;
- figure 1B shows a second embodiment of a laminate according to the invention; and
- figure 2 shows a part of a fuselage of an airplane according to the invention.

Wherever in the figures the same reference numerals are
applied, these numerals refer to the same parts.

Referring first to figure 1A a laminate according to a first embodiment is shown, wherein this laminate 1 comprises sheet metal layers 2, 3 and plastic layers 4, 5 reinforced with fiber straps of a first type that are provided between said sheet metal layers 2, 3.

This laminate 1 of the invention has at least one transitional area 6 in which the fiber reinforced plastic layer or layers 4, 5 with fibers of the first type is/are interrupted, and wherein in this transitional area 6 fiber straps of a second type are comprised whereby the fiber straps of the second type exhibit a higher modulus of elasticity then the fiber straps of the first type.

In the first embodiment of the laminate 1 of the invention the fiber straps of the second type are all arranged in the same direction. The second embodiment of the laminate 1 of the invention as shown in figure 1B differentiates from the first embodiment in that the fiber straps of the second type are arranged in a first direction of the transitional area 6' as well as in a second direction of the transitional area 6'' which is orthogonal to the first direction of the transitional area 6'.

Both figure 1A and figure 1B show that the at least one transitional area 6', 6'' and the area that immediately borders to said at least one transitional area exhibit the same thickness.

It is preferred that the fiber straps of the first type are glass fibers and that the fiber straps of the second type are carbon fibers or boron fibers or another suitable type of fibers having a higher stiffness than glass fibers.

Turning now to figure 2 a part of an airplane is shown comprising a fuselage 7 with a backup structure of frames and/or stringers 8, wherein said backup structure supports a laminate 1 according to the first embodiment or the second embodiment. It is clearly shown that the at least one transitional area 6 in the laminate 1 is provided at the location where the backup structure, in the shown case the stringers 8, connect to and support the laminate 1.
Example

Comparing the laminate of the invention with a laminate according to the prior art, such as defined by the type Glare mentioned in WO 03/068494, provides the following results, whereby the known laminate is each time referenced at 100%.

fatigue initiation life : 120 %
fatigue crack growth life : 190 %
the crack growth rate at transitional area : 24 %
residual strength : 122 %

It is specifically pointed out that the offered elucidation with reference to the drawing is merely intended to elucidate the claims and that the claims should not be considered limited to what is shown in the drawing and explained with reference thereto. Accordingly the scope of the invention and the protection afforded by the appended claims should be understood in the broadest possible sense as is warranted by the contribution of the invention in comparison with the prior art as defined by the wording of the appended claims.
CONCLUSIES

1. Laminaat (1) omvattende metaallagen (2, 3) en kunststoflagen (4, 5) versterkt met vezelbanden van een eerste type die voorzien zijn tussen genoemde metaallagen (4, 5), waarbij er ten minste één overgangsgebied (6, 6', 6'') is in welke ten minste één vezelversterkte kunststoflaag met vezels van het eerste type onderbroken zijn, met het kenmerk, dat in het ten minste ene overgangsgebied (6, 6', 6'') vezelbanden van een tweede type opgenomen zijn waarbij de vezelbanden van het tweede type een hogere elasticiteitsmodulus bezitten dan de vezelbanden van het eerste type.

2. Laminaat volgens conclusie 1, met het kenmerk, dat het ten minste ene overgangsgebied (6, 6', 6'') en het gebied dat onmiddellijk grenst aan genoemd ten minste ene overgangsgebied (6, 6', 6'') dezelfde dikte bezitten.

3. Laminaat volgens conclusie 1 of 2, met het kenmerk, dat de vezelbanden van het eerste type glasvezels zijn en de vezelbanden van het tweede type geselecteerd zijn uit de groep omvattende koolstofvezels, boronvezels.

4. Laminaat volgens één der voorgaande conclusies, met het kenmerk, dat het ten minste ene overgangsgebied (6, 6', 6'') geselecteerd is op een locatie welke beoogd is om te worden verbonden met een ondersteund door een ondersteuningsconstructie (8) van een romp (7) van een vliegtuig.

5. Vliegtuig omvattende een romp (7) met een ondersteuningsconstructie (8) van frames en/of steunbalken, waarin genoemde ondersteuningsconstructie een laminaat (1) steunt welke metaallagen (2, 3) en kunststoflagen (4, 5) versterkt met vezelbanden van een eerste type omvat, welke voorzien zijn tussen genoemde metaallagen (2, 3), waarbij er ten minste één overgangsgebied (6, 6', 6'') is in welke ten minste één vezelversterkte kunststoflaag met vezels van het eerste type onderbroken is, met het kenmerk, dat het ten minste ene overgangsgebied (6, 6', 6'') vezelbanden van een tweede type omvat waarbij de vezelbanden van het tweede type een hogere elasticiteitsmodulus bezitten dan de vezelbanden van het eerste type.

6. Vliegtuig volgens conclusie 5, met het kenmerk, dat het ten minste ene overgangsgebied (6, 6', 6'') en het gebied
dat onmiddellijk grenst aan genoemd ten minste ene overgangsgebied (6, 6′, 6″) dezelfde dikte bezitten.

7. Vliegtuig volgens conclusie 5 of 6, *met het kenmerk*, dat de vezelbanden van het eerste type glasvezels zijn en de vezelbanden van het tweede type geselecteerd zijn uit de groep omvattende koolstofvezels, boronvezels.

8. Vliegtuig volgens één der conclusies 5-7, *met het kenmerk*, dat het ten minste ene overgangsgebied (6, 6′, 6″) in het laminaat (1) voorzien is op een locatie waar de ondersteuningsconstructie (8) verbonden is met het laminaat (1) en dit ondersteunt.
**SAMENWERKINGSVERDRAG (PCT)**

**RAPPORT BETREFFENDE NIEUWHEIDSONDERZOEK VAN INTERNATIONAAL TYPE**

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Aanvrager (Naam)

**Technische Universiteit Delft**

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I. **CLASSIFICATIE VAN HET ONDERWERP** (bij toepassing van verschillende classificaties, alle classificatiesymbolen opgeven)

Volgens de internationale classificatie (IPC)

B29C70/08;B32B3/18;B32B5/08;B32B5/26;B32B15/14;B32B15/20;B64C1/12

II. **ONDERZOCHTE GEBIEDEN VAN DE TECHNIEK**

Onderzochte minimumdocumentatie

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Onderzochte andere documentatie dan de minimum documentatie, voor zover dergelijke documenten in de onderzochte gebieden zijn opgenomen

III. **GEEN ONDERZOEK MOGELIJK VOOR BEPAALDE CONCLUSIES**

(opmerkingen op aanvullingsblad)

IV. **GEBREK AAN EENHEID VAN UITVINDING**

(opmerkingen op aanvullingsblad)

Form PCT/ISA 201 A (11/2000)
ONDERZOEKSRAPPORT BETREFFENDE HET
RESULTAAT VAN HET ONDERZOEK NAAR DE STAND
VAN DE TECHNIEK VAN HET INTERNATIONALE TYPE

A. CLASSIFICATIE VAN HET ONDERWERP

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Volgens de Internationale Classificatie van octrooien (IPC) of zowel volgens de nationale classificatie als volgens de IPC.

B. ONDERZOEKTE GEBIEDEN VAN DE TECHNIEK

- Onderzochte minimum documentatie (classificatie gevolgd door classificatiesymbolen)
  - B29C
  - B32B
  - B64C

- Onderzochte andere documentatie dan de minimum documentatie, voor dergelijke documenten, voor zover dergelijke documenten in de onderzochte gebieden zijn opgenomen

Tijdens het onderzoek geraadpleegde elektronische gegevensbestanden (naam van de gegevensbestanden en, waar uitvoerbaar, gebruikte trefwoorden)

EPO-Internal, WPI Data

C. VAN BELANG GEACHTDE DOCUMENTEN

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X Verdere documenten worden vermeld in het vervolg van vak C.

X Leden van dezelfde octrooilfamilie zijn vermeld in een bijlage

Verzenddatum van het rapport van het onderzoek naar de stand van de techniek van internationaal type

Datum waarop het onderzoek naar de stand van de techniek van internationaal type werd voltoid

27 januari 2011

Naam en adres van de instantie

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

De bevoegde ambtenaar

Okunowski, Joachim

Formuler PCT/SA/2001 (tweede blad) (Januari 2004)
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**OCTROOICENTRUM NEDERLAND**

**WRITTEN OPINION**

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**International Patent Classification (IPC)**

INV. B29C70/08 B32B3/18 B32B5/08 B32B5/26 B32B15/14 B32B15/20 B64C1/12

**Applicant**

Technische Universiteit Delft

This opinion contains indications relating to the following items:

- ☑ Box No. I  
  Basis of the opinion
- □ Box No. II  
  Priority
- □ Box No. III  
  Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- □ Box No. IV  
  Lack of unity of invention
- ☑ Box No. V  
  Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- □ Box No. VI  
  Certain documents cited
- □ Box No. VII  
  Certain defects in the application
- □ Box No. VIII  
  Certain observations on the application

**Examiner**

Okunowski, Joachim

Form NL237A (Dekblad) (July 2006)
Box No. I  Basis of this opinion

1. This opinion has been established on the basis of the latest set of claims filed before the start of the search.

2. With regard to any nucleotide and/or amino acid sequence disclosed in the application and necessary to the claimed invention, this opinion has been established on the basis of:
   a. type of material:
      □ a sequence listing
      □ table(s) related to the sequence listing
   b. format of material:
      □ on paper
      □ in electronic form
   c. time of filing/furnishing:
      □ contained in the application as filed.
      □ filed together with the application in electronic form.
      □ furnished subsequently for the purposes of search.

3. □ In addition, in the case that more than one version or copy of a sequence listing and/or table relating thereto has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that in the application as filed or does not go beyond the application as filed, as appropriate, were furnished.

4. Additional comments:

Box No. V  Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

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2. Citations and explanations

   see separate sheet
In Figure 4C of D1 (see also paragraph [0041] of D1) an airplane fuselage section is disclosed of a laminate of titanium layers and at least one carbon fibre reinforced layer. This laminate has another structure in the keel portion than in the surrounding side wall portions. All portions have in common that the outer skin is a titanium foil, followed by a first carbon fibre hoop. Further on in the wall portions is a ply 15 of longitudinally extending carbon fibres, and Figure 4c shows that, in the keel portion, the place of this ply 15 is taken in by a layer of boron-carbon fibre plies, which, by the presence of the boron fibres, must have a higher elastic modulus than the carbon fibres alone, as is confirmed by the higher compressive strength of the keel. The fibres are applied as tape (page 14, line 47 and page 9, line 23).

The keel portion effectively interrupts the laminate of the wall portions, and forms a transition zone between the two walls. The disclosure of D1 is therefore considered to be prejudicial to the novelty of the subject-matter of claims 1 and 5.

The additional features of claims 2-4 and 6-8 are not disclosed in D1 in combination with the novelty-destroying embodiment of D1. Therefore, no objection for lack of novelty is raised against these claims. Also, no objection is raised for lack of an inventive step. It would appear that D4 is most suitable as closest prior art. No suggestion could be found in the prior art to attain laminate stiffening in the area of fastening to the support structure by locally employing, in at least one of the fibrous layers, fibres with a higher modulus of elasticity than elsewhere in the laminate.