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(54) METHOD OF MANUFACTURING A COMPOSITE FAN BLADE.

HERSTELLUNGSVERFAHREN EINER ZUSAMMENGESETZTEN VENTILATORSCHAUFEL.

PROCÉDÉ DE FABRICATION D’UNE PALE DE VENTILATEUR COMPOSITE.

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(73) Proprietor: **Rolls-Royce plc**
London N1 9FX (GB)

(72) Inventor: **Gill, Vincent**
Derby, Derbyshire DE24 8BJ (GB)

(74) Representative: **Rolls-Royce plc**
Intellectual Property Dept SinA-48
PO Box 31
Derby DE24 8BJ (GB)

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Description

Field of the invention

[0001] The present invention relates to a method of manufacturing a composite fan blade.

Background

[0002] A fan blade may be manufactured for gas turbine engines. A gas turbine engine generally comprises, in axial flow series, an air intake, a fan, one or more compressors, a combustor, one or more turbines, and an exhaust nozzle. Air entering the air intake is accelerated by the fan to produce two air flows: a first air flow (core engine flow) into compressor and a second air flow (bypass flow) which passes through a bypass duct to provide propulsive thrust. Air entering the compressor is compressed, mixed with fuel and then fed into the combustor, where combustion of the air/fuel mixture occurs. The high temperature and high energy exhaust fluids are then fed to the turbine, where the energy of the fluids is converted to mechanical energy to drive the compressor in rotation by suitable interconnecting shaft. Downstream of the turbine, the core engine flow passes through a tail bearing housing provided with vanes.

[0003] The fan comprises a rotor hub and an array of fan blades radially extending therefrom. The fan blades generally comprises an aerofoil portion having a leading edge, a trailing edge, a pressure surface wall extending from the leading edge to the trailing edge and a suction surface wall extending from the leading edge to the trailing edge. The fan blades have a root via which the blade can be connected to the rotor hub and, at an opposing end to the root, a tip. The fan blades may be metallic fan blades or composite fan blades. Composite fan blades generally include a composite body made from a fibre reinforced resin matrix, e.g. carbon fibres in a resin matrix. The leading edge and the trailing edge of the fan blade may be shielded and/or reinforced, for example a metallic member may be provided on the trailing and/or leading edge of the composite body.

[0004] Composite fan blades are generally lighter than metallic fan blades with comparable mechanical properties, so, although more expensive to manufacture, composite fan blades are increasingly used in the aerospace industry and for gas turbine engines in particular.

[0005] The composite body of the fan blade is generally a laminate having a plurality of plies laid up into a stack. The laminate can be formed using a number of different methods, for example lay-up by hand or automated fibre placement (AFP). In known methods, the plies are laid-up manually or automatically on a preform tool shaped to the finished blade suction surface to produce a fan blade preform. Once all of the plies have been laid up, the preform is transferred into a tool and cured in an autoclave to the final shape.

[0006] Briefly, in AFP, the fibre reinforcement material is applied in form of a single "tow", or multiple "tows". A "tow" may be a narrow width of tape slit from a wider tape. A lay-up head is typically used to dispense, apply and cut tows of fibre reinforcement material on the preform tool. Generally, as the lay-up head stops each time a tow (or tape) is cut, the more plies are cut, or, in other words, the shorter the applied tows, the more time is required to complete the lay-up process. Short plies are particularly ineffective at being deposited using AFP since there is less time spent placing material and more time spent in secondary operations such as cutting, positioning, accelerating and decelerating. As the lay-up head may be required to supply tows (or tapes) with different mutual orientation and therefore different length, the lay-up process may be quite time consuming.

[0007] Reducing the number of plies may speed up the process, but, as the lay-up head cannot apply tows (or tapes) longer than a longitudinal dimension of the preform tool, which substantially corresponds to the length of the fan blade along a spanwise direction, there is a minimum number of cuts required to build up the preform and therefore a minimum lay-up time.

[0008] The same considerations apply to a manual lay-up process, namely the higher the number of plies, the slower the process.

[0009] United Kingdom patent GB 1302857 A discloses an article composed of stacked laminations some or all of which have reinforcing fibres. The reinforcing fibres are oriented in different directions in different laminations. The laminations embody a settable resin that enables the article to be completed by setting the resin in all of the laminations. At least one of the laminations is folded over an edge of the article to give protection against exfoliation of laminations at the edge. The patent also discloses the manufacture of such articles by stacking the laminations for a core of the article on a part only of one or more other laminations, the reinforcing laminations being oriented in different directions in different laminations, then folding the other laminations over an edge of the stacked core, and then shaping the article and causing or allowing the resin to set.

[0010] It is desirable to overcome the above mentioned problems and reduce the lay-up time of a composite fan blade manufacturing method.

Summary

[0011] According to a first aspect, there is provided a method of manufacturing a composite fan blade as set out in claims 1 to 11.

Brief description of the drawings

[0012] Embodiments will now be described by way of example only, with reference to the Figures, in which:

> **Figure 1** is a sectional side view of a gas turbine engine;

Figure 2 is a schematic of a fan blade of the gas turbine engine of Figure 1;

Figure 3 is a schematic partial transversal sectional side view of the fan blade of figure 2;

Figure 4 is a flow diagram of a method of manufacturing the composite fan blade of figure 1;

Figure 5 is a sectional side view of an unfolded preform; and

Figure 6 is a sectional side view of a folded preform.

Detailed description

[0013] Figure 1 illustrates a gas turbine engine 10 having a principal rotational axis 11. The engine 10 comprises an air intake 12 and a propulsive fan 13 with a plurality of fan blades 40. The gas turbine engine 10 further comprises, in axial flow, an intermediate pressure compressor 14, a high-pressure compressor 15, combustion equipment 16, a high-pressure turbine 17, an intermediate pressure turbine 18, a low pressure turbine 19 and a core exhaust nozzle 23. A nacelle 21 surrounds the gas turbine engine 10 and defines a bypass duct 22 and a bypass exhaust nozzle 20. The fan 13 is coupled to and driven by the low pressure turbine 19 via shaft 26. In not illustrated embodiment, the gas turbine engine 10 may comprise a power gearbox and the fan 13 may be connected to the intermediate pressure compressor 14 through the power gearbox, which may be a reduction gearbox.

[0014] The gas turbine engine 10 works in a conventional manner with air being accelerated and compressed by the intermediate pressure compressor 14 and directed into the high pressure compressor 15 where further compression takes place. The compressed air exhausted from the high pressure compressor 15 is directed into the combustion equipment 16 where it is mixed with fuel and the mixture is combusted. The resultant hot combustion products then expand through, and thereby drive the high pressure, intermediate pressure and low pressure turbines 17, 18, 19 before being exhausted through the nozzle 23 to provide some propulsive thrust. The high pressure turbine 17 drives the high pressure compressor 15 by a suitable interconnecting shaft. The fan 13 generally provides the majority of the propulsive thrust. Additionally or alternatively such engines may have an alternative number of compressors and/or turbines and/or an alternative number of interconnecting shafts.

[0015] Figures 2 and 3 illustrates the composite fan blade 40. The fan blades 40 each comprises an aerofoil portion 42 having a leading edge 44, a trailing edge 46, a pressure surface wall 48 extending from the leading edge 44 to the trailing edge 46 and a suction surface wall 50 extending from the leading edge 44 to the trailing edge 46. The fan blade 40 has a root 52 via which the blade can be connected to a rotor hub of the fan 13. The fan blade has a tip 56 at an opposing end to the root 52. The composite fan blade 40 may optionally comprise a leading edge protective metal sheet 43 and a trailing edge protective metal sheet 45.

[0016] In the present application, as is conventional in the art, a chordwise direction C is a direction that extends from the leading edge 44 to the trailing edge 46 of the blade. A spanwise direction S is a direction that extends from the root 52 to the tip 56 of the blade. A thickness direction T is a direction that extends from the pressure surface wall 48 to the suction surface wall 50 of the fan blade 40.

[0017] The fan blade 40 comprises an outer part 58 and a core 60. The outer part 58 defines the pressure surface wall 48 and the suction surface wall 50. The outer part 58 is made by a plurality of continuous plies 62 extending from a pressure surface tip region 64 to a suction surface tip region 66 through a root region 68 of the composite fan blade 40. The fan blade 40 may further comprise filler plies 70, deposited on the continuous plies 62. Contrary to the continuous plies 62, the filler plies 70 do not extend continuously from the pressure surface tip region 64 to the suction surface tip region 66 through the root region 68. On the contrary, the filler plies 70 are interrupted at the root region 68.

[0018] The core 60 is arranged in the root region 68 and is surrounded by the continuous plies 62. The core 60 may also be in contact with the filler plies 70. In particular, the core 60 may be in contact with end portions 72 of the filler plies 70.

[0019] In some embodiment not illustrated, the filler plies 70 may be dispensed with and the core 60 may be therefore in contact with the continuous plies 62 only.

[0020] Referring now to figure 4, a flow diagram 100 illustrates a method of manufacturing a composite fan blade 40 according to the invention. The flow diagram will be described with reference to figures 5 and 6 showing a composite fan blade preform in a first, unfolded configuration C1 and in a second, folded configuration C2.

[0021] At block S1, the method comprises laying up a plurality of continuous plies 62 on a preform tool 82, wherein the continuous plies 62 extends along a longitudinal direction L from a first end 84 to a second end 86 to achieve a stack 81 of continuous plies 62. If dry fibres are used, a layer of resin may be deposited on an internal surface (i.e. a surface facing up in figures 5) of each continuous ply 62. For example, the layer of resin may be a binder resin film that serves to fix a relative position of adjacent plies after application of heat, or a toughening layer that strengthens the interface between plies, or a combination of both.

[0022] The stack 81 comprises a first portion 88 corresponding to the pressure surface wall 48, a second portion 90 corresponding to the suction surface wall 50, and a central portion 92 corresponding to the root region 68. The first end 84 corresponds to the pressure surface tip region 64 and the second end 86 corresponds to the suction surface tip region 66.

[0023] In substance, the stack 81 corresponds to the outer part 58 of the fan blade 40 and extends for a preform length L1 substantially equal to a longitudinal profile of the fan blade 40.

[0024] To accommodate the stack 81 of continuous plies 62 in the first, unfolded configuration C1, the preform tool 82 extends along the longitudinal direction L for at least the preform length L1.

[0025] In one embodiment, the preform tool 82 may be substantially flat, so that the stack 81 of continuous plies 62 in the first, unfolded configuration C1 may be substantially flat. In other embodiments, the preform tool 82 may be curved, so that the stack 81 of continuous plies 62 in the first, unfolded configuration C1 may be curved. For example, the preform tool 82 may be curved to resemble the shape of the composite fan blade 40, in particular the shape of the pressure surface wall 48 and the suction surface wall 50 of the composite fan blade 40.

[0026] Optionally, at block S2, the method may further comprise laying up filler plies 70 on the continuous plies 62 both at the first portion 88 and at the second portion 90. In detail, a first group of filler plies may be deposited on the first portion 88 and a second group of filler plies 70 may be deposited on the second portion 90. The first group and the second group of filler plies 70 may, or may not, be symmetrical with respect to a plane transversal to the longitudinal direction L and laying midway between the first end 84 and the second end 86 of the continuous plies 62. The first group and the second group of filler plies 70 may be arranged in two separate stacks. Each individual filler ply 70 may present different lengths. For example, the filler plies 70 closer to the continuous plies 62 may be longer than the filler plies 70 being arranged in the stack farther from the continuous plies 62.

[0027] At block S3, the method comprises placing the core 60 on the central portion 92 of the stack 81 of continuous plies 62 to achieve the composite fan blade preform in the first, unfolded configuration C1, or unfolded preform 83.

[0028] The core 60 may be placed on the stack 81 either manually or automatically, for example by means of any suitable robot or automatic fibre placement (AFP) machine. The core 60 may feature a tapered end 63 that may be oriented, in the unfolded configuration C1 towards either the first end 84 (not illustrated) or the second end 86 (as illustrated).

[0029] The core 60 may be separately manufactured and then placed on the central portion 92 of the stack 81 of continuous plies 62, either manually or by means of any suitable robot. Alternatively, the core 60 may be placed on the central portion 92 of the stack 81 of continuous plies 62 as part of a manual or automatic lay-up process, for example by means of an automatic fibre placement (AFP) machine.

[0030] At block S4, the method comprises folding the continuous plies 62 about the core 60, such that the first portion 84 is superimposed to the second portion 86, to achieve the composite fan blade preform in the second, folded configuration C2, or folded preform 85. The folding of the continuous plies 62 may be carried out either manually or by means of a robot provided with grippers to grip the continuous plies 62 at the first end 84.

[0031] During folding, the core 60 may be kept in position manually or by means of a frame 61. The frame 61 may be self-standing or attached to the preform tool 82. The frame 61 may be mounted on a movable robot or attached to an AFP machine.

[0032] All of the continuous plies 62 may be folded at one time, or the continuous ply 62 may be folded individually or in groups of two or more continuous plies 62.

[0033] During folding, to avoid wrinkles, the method may comprise applying pressure, either manually or by means of a roller, to the continuous ply being folded from the root 52 to the tip 56. Alternatively, or in addition, tension may be applied to the first end 84 and the second end 86 of the continuous ply 62 by means of the grippers.

[0034] The method may additionally comprise applying through thickness reinforcement to reinforce the core 60 to the outer part 58. Moreover, the method may comprise applying through thickness reinforcement to reinforce the core 60 to the central portion 92 and/or the first portion 88 and/or the second portion 90. The method may further comprise applying through thickness reinforcement to promote adhesion between the first portion 88 and the second portion 90.

[0035] At block S5, the method comprises applying pressure to the folded preform 85 to achieve a consolidated curved folded preform. Before applying pressure, the folded preform 85 may be transferred from the preform tool 82 to a form tool shaped to the finished shape of the fan blade 40. Once in the form tool, pressure is applied to the folded preform 85 to achieve the finished shape of the fan blade 40. Additionally, both pressure and heat may be applied to the folded preform 85. Moreover, vacuum may be applied to the folded preform 82 to promote debulking.

[0036] At block S6, the method comprises curing the consolidated curved folded preform to achieve the composite fan blade 40. The consolidated curved folded preform may be placed in a cure tool within a vacuum bag and cured in an autoclave under suitable temperature and pressure conditions.

Claims

1. A method of manufacturing a composite fan blade (40) extending spanwise from a root (52) to a tip (56), chordwise from a leading edge (44) to a trailing edge (46), the composite fan blade (40) comprising an outer part (58) and a core (60), the outer part (58) defining a pressure surface wall (48) extending from the leading edge (44) to the trailing edge (46) and a suction surface wall (50) extending from the leading edge (44) to the trailing edge (46), the method comprising:

   laying up a plurality of continuous plies (62) ex-

tending along a longitudinal direction (L) from a first end (84) to a second end (86) to achieve a stack (81) of continuous plies (62), the stack (81) comprising a first portion (88) corresponding to the pressure surface wall (48), a second portion (90) corresponding to the suction surface wall (50), and a central portion (92) corresponding to the root (52), wherein the first end (84) corresponds to a pressure surface tip region (64) of the composite fan blade (40) and the second end (86) corresponds to a suction surface tip region (66) of the composite fan blade (40);
placing the core (60) on the central portion (92) of the stack (81) of continuous plies (62) to achieve an unfolded preform (83);
folding the continuous plies (62) about the core (60), such that the central portion (92) of the stack (81) folds about the core (60) and the first portion (88) is superimposed to the second portion (90), to achieve a folded preform (85);
applying pressure to the folded preform (85) to achieve a consolidated curved folded preform; and
curing the consolidated curved folded preform to achieve the composite fan blade (40);
the method characterised in that in the folding step the central portion (92) of the stack (81) folds about the core (60) so as to form the root (52), and the first portion (88) and the second portion (90) extend in a spanwise direction (S) between the root (52) and respective tip regions (64, 66).

2. The method of claim 1, wherein the composite fan blade (40) further comprises filler plies (70), and wherein the method further comprises:
laying up the filler plies (70) on the continuous plies (62) both on the first portion (88) and on the second portion (90), the filler plies (70) not extending from the first portion (88) to the second portion (90) through the central portion (92).

3. The method of claim 1 or 2, comprising, after the folding of the continuous plies (62), applying heat and/or pressure to the folded preform (85) to promote adhesion of the core (60) to the outer part (58).

4. The method of any preceding claim, wherein the folding of the continuous plies (62) comprises folding all of the continuous plies (62) at one time, or wherein the folding of the continuous plies (62) comprises folding each continuous ply (62) individually, or wherein the folding of the continuous plies (62) comprises folding the continuous plies in groups of two or more plies.

5. The method of any preceding claim, comprising, during the folding of the continuous plies (62), applying pressure either manually or by means of a roller (100) to the continuous ply (62) being folded from the root (52) to the tip (56).

6. The method of any preceding claim, wherein the continuous plies (62) are made of dry fibres and optionally comprising, after the laying up of each continuous ply (62), depositing on an internal surface of said continuous ply (62) a layer of resin, or wherein the continuous plies (62) are made of pre-impregnated fibres.

7. The method of any preceding claim, comprising applying through thickness reinforcement to reinforce the core (60) to the outer part (58) and optionally wherein through thickness reinforcement comprises any one of tufting, stitching, felting, z-pinning, or intra-layer toughening using veils and nanoforests or thermoplastic toughening particles.

8. The method of any preceding claim, comprising, during the folding of the continuous plies (62), keeping the core (60) in position by means of a frame.

9. The method of any preceding claim, wherein the folding of the continuous plies (62) comprises rotating either the first end (84) or the second end (86) by substantially 180° about the core (60) towards the second end or the first end, respectively.

10. The method of any preceding claim, wherein the placing of the core (60) in the central portion (92) comprises depositing a plurality of chopped fibres on the central portion (92) of the continuous plies (62).

11. The method of any preceding claim, wherein the laying-up of the plurality of continuous plies (62) is carried out manually or automatically using automatic fibre placement.

Patentansprüche

1. Verfahren zum Herstellen einer Verbundgebläseschaufel (40), die sich in Spannweitenrichtung von einem Fuß (52) zu einer Spitze (56), in Sehnenrichtung von einer Vorderkante (44) zu einer Hinterkante (46) erstreckt, wobei die Verbundgebläseschaufel (40) einen äußeren Teil (58) und einen Kern (60) umfasst, wobei der äußere Teil (58) eine Druckflächenwand (48), die sich von der Vorderkante (44) zu der Hinterkante (46) erstreckt, und eine Saugflächenwand (50) definiert, die sich von der Vorderkante (44) zu der Hinterkante (46) erstreckt, wobei das Verfahren Folgendes umfasst:

Auflegen einer Vielzahl von kontinuierlichen Lagen (62), die sich entlang einer Längsrichtung (L) von einem ersten Ende (84) zu einem zweiten Ende (86) erstrecken, um einen Stapel (81) von kontinuierlichen Lagen (62) zu erhalten, wobei der Stapel (81) einen ersten Abschnitt (88), welcher der Druckflächenwand (48) entspricht, einen zweiten Abschnitt (90), welcher der Saugflächenwand (50) entspricht, und einen Mittelabschnitt (92) umfasst, der dem Fuß (52) entspricht, wobei das erste Ende (84) einem Druckflächenspitzenbereich (64) der Verbundgebläseschaufel (40) entspricht und das zweite Ende (86) einem Saugflächenspitzenbereich (66) der Verbundgebläseschaufel (40) entspricht;

Platzieren des Kerns (60) auf dem Mittelabschnitt (92) des Stapels (81) aus kontinuierlichen Lagen (62), um eine ungefaltete Vorform (83) zu erhalten;

Falten der kontinuierlichen Lagen (62) um den Kern (60), sodass der Mittelabschnitt (92) des Stapels (81) um den Kern (60) gefaltet wird und der erste Abschnitt (88) über den zweiten Abschnitt (90) gelegt wird, um eine gefaltete Vorform (85) zu erhalten;

Aufbringen von Druck auf die gefaltete Vorform (85), um eine verfestigte gekrümmte gefaltete Vorform zu erhalten; und

Aushärten der verfestigten gekrümmten gefalteten Vorform, um die Verbundgebläseschaufel (40) zu erhalten;

wobei das Verfahren dadurch gekennzeichnet ist, dass in dem Faltschritt der Mittelabschnitt (92) des Stapels (81) um den Kern (60) gefaltet wird, um den Fuß (52) zu bilden, und sich der erste Abschnitt (88) und der zweite Abschnitt (90) in einer Spannweitenrichtung (S) zwischen dem Fuß (52) und jeweiligen Spitzenbereichen (64, 66) erstrecken.

2. Verfahren nach Anspruch 1, wobei die Verbundgebläseschaufel (40) ferner Fülllagen (70) umfasst und wobei das Verfahren ferner Folgendes umfasst:
Auflegen der Fülllagen (70) auf die kontinuierlichen Lagen (62) sowohl auf dem ersten Abschnitt (88) als auch auf dem zweiten Abschnitt (90), wobei sich die Fülllagen (70) nicht von dem ersten Abschnitt (88) zu dem zweiten Abschnitt (90) durch den Mittelabschnitt (92) erstrecken.

3. Verfahren nach Anspruch 1 oder 2, umfassend, nach dem Falten der kontinuierlichen Lagen (62), das Aufbringen von Wärme und/oder Druck auf die gefaltete Vorform (85), um Haftung des Kerns (60) an dem äußeren Teil (58) zu fördern.

4. Verfahren nach einem vorhergehenden Anspruch, wobei das Falten der kontinuierlichen Lagen (62) das Falten aller kontinuierlichen Lagen (62) gleichzeitig umfasst, oder wobei das Falten der kontinuierlichen Lagen (62) das Falten jeder kontinuierlichen Lage (62) einzeln umfasst, oder wobei das Falten der kontinuierlichen Lagen (62) das Falten der kontinuierlichen Lagen in Gruppen von zwei oder mehr Lagen umfasst.

5. Verfahren nach einem vorhergehenden Anspruch, umfassend, während des Faltens der kontinuierlichen Lagen (62), das Aufbringen von Druck entweder manuell oder mittels einer Walze (100) auf die kontinuierliche Lage (62), die von dem Fuß (52) zu der Spitze (56) gefaltet wird.

6. Verfahren nach einem vorhergehenden Anspruch, wobei die kontinuierlichen Lagen (62) aus Trockenfasern hergestellt sind und optional umfassend, nach dem Auflegen jeder kontinuierlichen Lage (62), das Abscheiden einer Schicht aus Harz auf einer Innenfläche der kontinuierlichen Lage (62), oder wobei die kontinuierlichen Lagen (62) aus vorimprägnierten Fasern hergestellt sind.

7. Verfahren nach einem vorhergehenden Anspruch, umfassend das Aufbringen von durchgehender Dickenverstärkung, um den Kern (60) an dem äußeren Teil (58) zu verstärken, und wobei optional durchgehende Dickenverstärkung ein beliebiges von Tufting, Nähen, Filzen, Z-Pinning oder Intra-Layer-Vorspannen unter Verwendung von Schleiern und Nanowäldern oder thermoplastischen Vorspannpartikeln umfasst.

8. Verfahren nach einem vorhergehenden Anspruch, umfassend, während des Faltens der kontinuierlichen Lagen (62), das Halten des Kerns (60) in Position mittels eines Rahmens.

9. Verfahren nach einem vorhergehenden Anspruch, wobei das Falten der kontinuierlichen Lagen (62) das Drehen entweder des ersten Endes (84) oder des zweiten Endes (86) um im Wesentlichen 180° um den Kern (60) jeweils zu dem zweiten Ende oder dem ersten Ende umfasst.

10. Verfahren nach einem vorhergehenden Anspruch, wobei das Platzieren des Kerns (60) in dem Mittelabschnitt (92) das Abscheiden einer Vielzahl von geschnittenen Fasern auf dem Mittelabschnitt (92) der kontinuierlichen Lagen (62) umfasst.

11. Verfahren nach einem vorhergehenden Anspruch, wobei das Auflegen der Vielzahl von kontinuierlichen Lagen (62) manuell oder automatisch unter Verwendung von automatischer Faserplatzierung durchgeführt wird.

Revendications

1. Procédé de fabrication d'une pale de soufflante composite (40) s'étendant dans le sens de l'envergure à partir d'une emplanture (52) jusqu'à une pointe (56), dans le sens de la corde à partir d'un bord d'attaque (44) jusqu'à un bord de fuite (46), la pale de soufflante composite (40) comprenant une partie externe (58) et un noyau (60), la partie externe (58) définissant une paroi de surface de pression (48) s'étendant à partir du bord d'attaque (44) jusqu'au bord de fuite (46) et une paroi de surface d'aspiration (50) s'étendant à partir du bord d'attaque (44) jusqu'au bord de fuite (46), le procédé comprenant :

    l'empilement d'une pluralité de plis continus (62) s'étendant le long d'une direction longitudinale (L) à partir d'une première extrémité (84) jusqu'à une seconde extrémité (86) pour obtenir une pile (81) de plis continus (62), la pile (81) comprenant une première partie (88) correspondant à la paroi de surface de pression (48), une seconde partie (90) correspondant à la paroi de surface d'aspiration (50), et une partie centrale (92) correspondant à l'emplanture (52), ladite première extrémité (84) correspondant à une zone de pointe de surface de pression (64) de la pale de soufflante composite (40) et ladite seconde extrémité (86) correspondant à une zone de pointe de surface d'aspiration (66) de la pale de soufflante composite (40) ;
    le placement du noyau (60) sur la partie centrale (92) de la pile (81) de plis continus (62) pour obtenir une préforme dépliée (83) ;
    le pliage des plis continus (62) autour du noyau (60), de sorte que la partie centrale (92) de la pile (81) se replie autour du noyau (60) et que la première partie (88) se superpose à la seconde partie (90), pour réaliser une préforme pliée (85) ;
    l'application d'une pression sur la préforme pliée (85) pour obtenir une préforme pliée incurvée consolidée ; et
    le durcissement de la préforme pliée incurvée consolidée pour obtenir la pale de soufflante composite (40) ;
    le procédé étant caractérisé en ce que dans l'étape de pliage la partie centrale (92) de la pile (81) se replie autour du noyau (60) de façon à former l'emplanture (52), et la première partie (88) et la seconde partie (90) s'étendent dans une direction d'envergure (S) entre l'emplanture (52) et les zones de pointe respectives (64, 66).

2. Procédé selon la revendication 1, ladite pale de soufflante composite (40) comprenant en outre des plis de remplissage (70), et ledit procédé comprenant en outre :

    l'empilement des plis de remplissage (70) sur les plis continus (62) à la fois sur la première partie (88) et sur la seconde partie (90), les plis de remplissage (70) ne s'étendant pas à partir de la première partie (88) jusqu'à la seconde partie (90) à travers la partie centrale (92).

3. Procédé selon la revendication 1 ou 2, comprenant, après le pliage des plis continus (62), l'application de chaleur et/ou de pression sur la préforme pliée (85) pour favoriser l'adhésion du noyau (60) à la partie externe (58).

4. Procédé selon une quelconque revendication précédente, ledit pliage des plis continus (62) comprenant le pliage de tous les plis continus (62) en une fois, ou ledit pliage des plis continus (62) comprenant le pliage de chaque pli continu (62) individuellement, ou ledit pliage des plis continus (62) comprenant le pliage des plis continus en groupes de deux plis ou plus.

5. Procédé selon une quelconque revendication précédente, comprenant, durant le pliage des plis continus (62), l'application d'une pression soit manuellement soit au moyen d'un rouleau (100) sur le pli continu (62) en cours de pliage à partir de l'emplanture (52) jusqu'à la pointe (56).

6. Procédé selon une quelconque revendication précédente, lesdits plis continus (62) étant constitués de fibres sèches et comprenant éventuellement, après l'empilement de chaque pli continu (62), le dépôt sur une surface interne dudit pli continu (62) d'une couche de résine, ou lesdits plis continus (62) étant constitués de fibres pré-imprégnées.

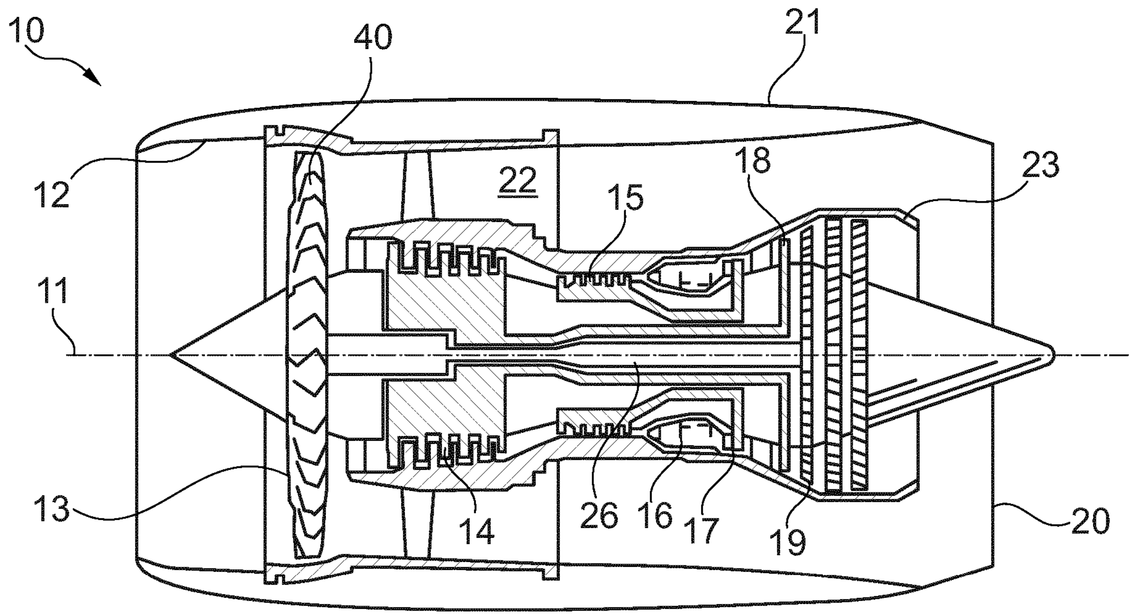
7. Procédé selon une quelconque revendication précédente, comprenant l'application d'un renforcement à travers l'épaisseur pour renforcer le noyau (60) sur la partie externe (58) et éventuellement ledit renforcement à travers l'épaisseur comprenant l'un quelconque parmi le tuftage, la couture, le feutrage, le brochage en Z ou la trempe intra-couche à l'aide de voiles et de nanoforêts ou de particules de trempe thermoplastiques.

8. Procédé selon une quelconque revendication précédente, comprenant, durant le pliage des plis continus (62), le maintien en position du noyau (60) au moyen d'un cadre.

9. Procédé selon une quelconque revendication précédente, ledit pliage de plis continus (62) comprenant la rotation soit de la première extrémité (84) soit de la seconde extrémité (86) de sensiblement 180° autour du noyau (60) vers la seconde extrémité ou la première extrémité, respectivement.

10. Procédé selon une quelconque revendication précédente, ledit placement du noyau (60) dans la partie centrale (92) comprenant le dépôt d'une pluralité de fibres coupées sur la partie centrale (92) des plis continus (62).

11. Procédé selon une quelconque revendication précédente, ledit empilement de la pluralité de plis continus (62) étant effectué manuellement ou automatiquement à l'aide du placement automatique des fibres.


10
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14
26
16
17
19
20

Fig. 1

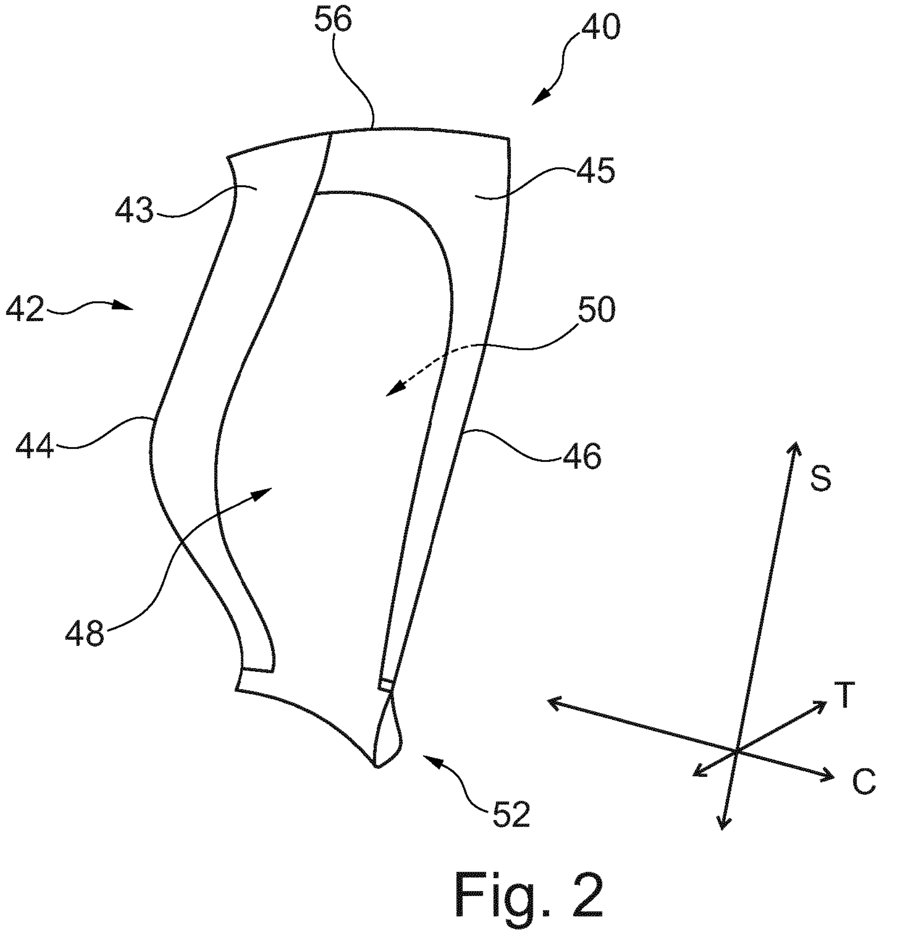
56
40
43
45
42
50
44
46
S
48
T
C
52

Fig. 2

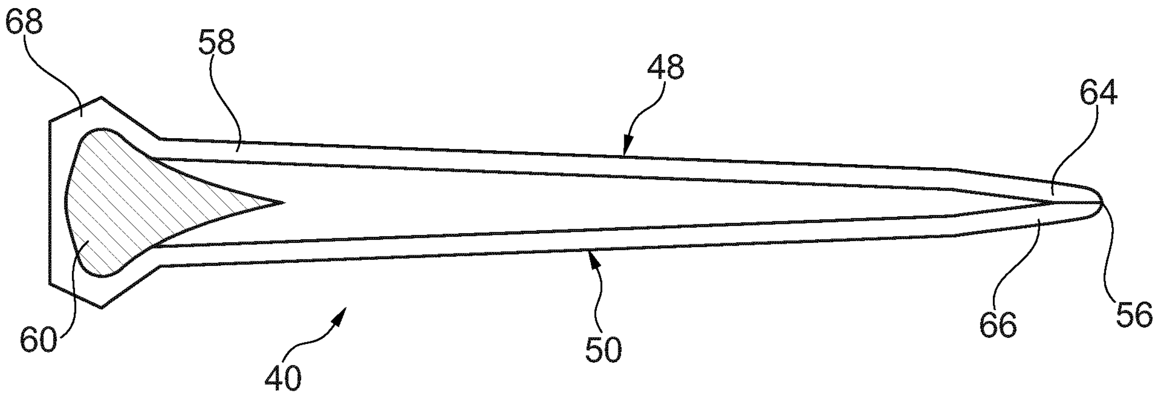
68
58
48
64
60
40
50
66
56

Fig. 3

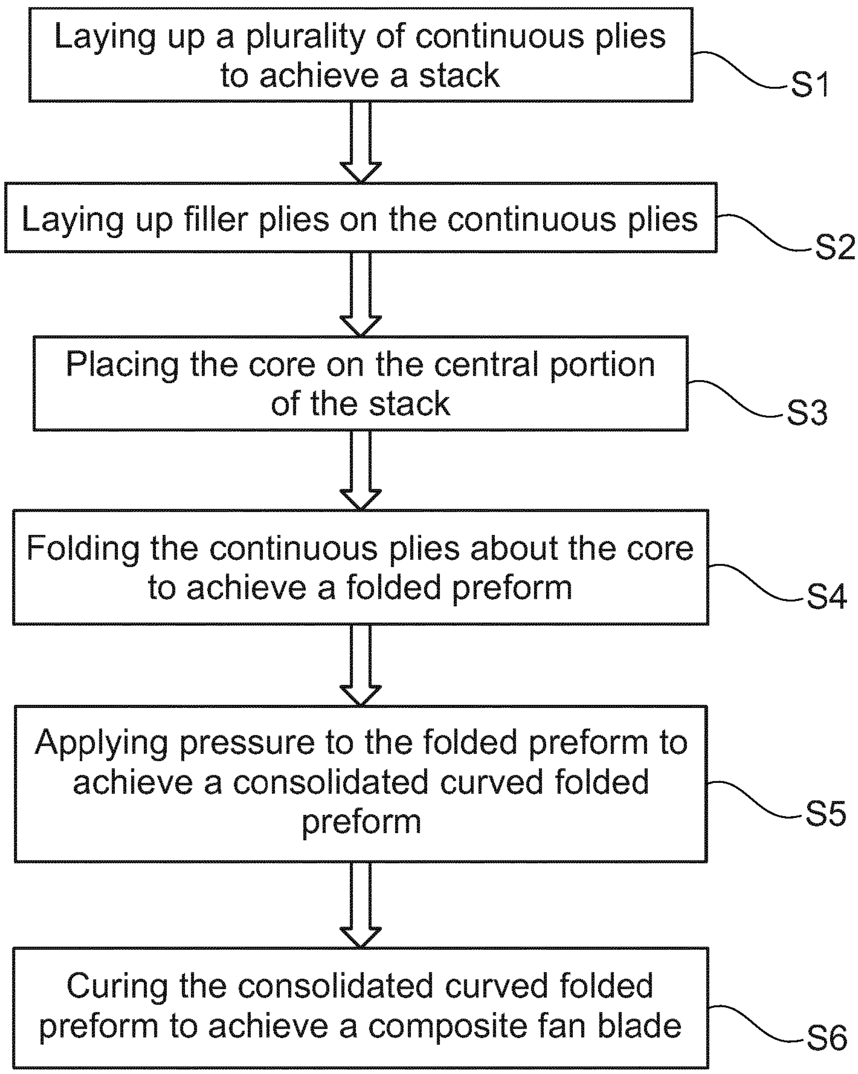
Laying up a plurality of continuous plies to achieve a stack
S1
Laying up filler plies on the continuous plies
S2
Placing the core on the central portion of the stack
S3
Folding the continuous plies about the core to achieve a folded preform
S4
Applying pressure to the folded preform to achieve a consolidated curved folded preform
S5
Curing the consolidated curved folded preform to achieve a composite fan blade
S6

Fig. 4

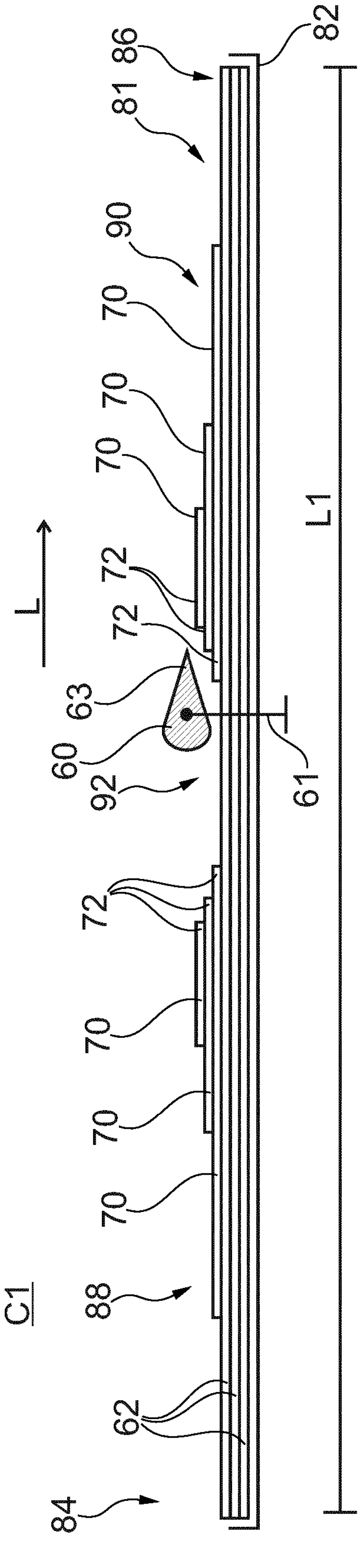
C1
L
L1
81
82
84
86
88
90
92
60
61
63
62
70
72

Fig. 5

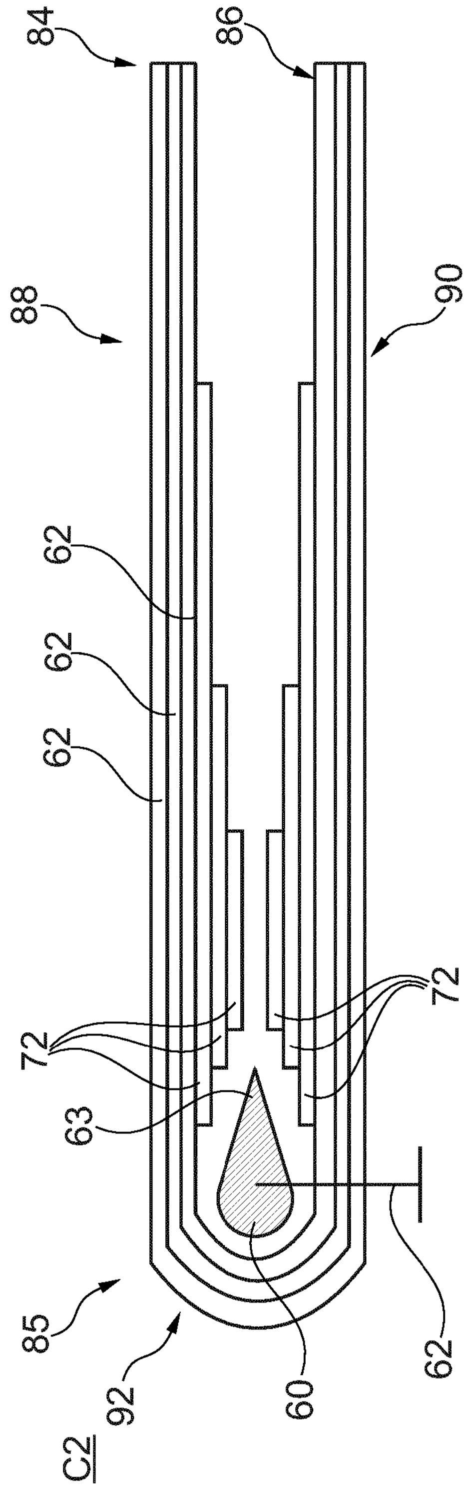
C2
84
85
86
88
90
92
60
62
63
72

Fig. 6

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- GB 1302857 A **[0009]**