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(54) **Blisk**

(57) A blisk (12) has a rotor disk part and a circumferential row of blades extending from and integral with the disk part (30). A plurality of annulus fillers (34) is provided to bridge the gaps between adjacent blades. Each annulus filler (34) has an outer lid (36) which defines an airflow surface for air being drawn through the engine in

an axial airflow direction, and an inner support structure which connects to the disk part (30) to support the lid (36) on the blisk (12). Opposite edges of the lid make respective lines of contact (38) with a suction side of one blade and a pressure side of an adjacent blade.

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Description

Field of the Invention

[0001] The present invention relates to a blisk for a gas turbine engine.

Background

[0002] A blisk is a component having a rotor disk part and integral blades. By making the blades integral with the disk part, the need to attach the blades to a rotor disk is eliminated. Improvements in efficiency can thereby be obtained. Additionally, sources of crack initiation can be eliminated.

[0003] An outer surface or rim of the disk part generally forms the inner working gas annulus of the engine.

[0004] Typically blisks are configured to avoid, where possible, forced responses from resonance and flutter. However, blisks lack inherent damping when compared to conventional bladed disk assemblies, and forced responses to resonances and flutter cannot always be avoided. Further, fixing the inner working gas annulus at the outer surface of the disk part also fixes the basic size and shape of the disk part, and thus reduces options for reconfiguring the blisk to avoid forced responses and flutter.

Summary of the Invention

[0005] An aim of the present invention is to provide an improved blisk which is, for example, less susceptible to forced responses and flutter.

[0006] In a first aspect, the present invention provides a blisk for a gas turbine engine. The blisk has a rotor disk part and a circumferential row of blades extending from and integral with the disk part. A plurality of annulus fillers is provided to bridge the gaps between adjacent blades. Each annulus filler has an outer lid which defines an airflow surface for air being drawn through the engine in an axial airflow direction, and an inner support structure which connects to the disk part to support the lid on the blisk. Opposite edges of the lid make respective lines of contact with a suction side of one blade and a pressure side of an adjacent blade.

[0007] In contrast to conventional blisks, the annulus fillers, rather than an outer surface or rim of the disk part, can thus form the inner working gas annulus of the engine. In this way, the radius of the disk part can be reduced and the length of the blades increased. These changes allow the natural frequency of the blades to be reduced. This can be advantageous if, for example, there is a need to keep the fundamental flap mode/first engine order resonance below a particular engine speed to reduce the forcing level.

[0008] Reducing the radius of the disk part can also allow the total weight of the blisk to be decreased.

[0009] Further, the annulus fillers can themselves act

as damper elements between the blades, reducing blade resonances by physical contact with the blades.

[0010] In a second aspect, the present invention provides a gas turbine engine, such as aeroengine, having the blisk of the first aspect. In particular, the blisk may be a fan blisk or a compressor section blisk.

[0011] Optional features of the invention will now be set out. These are applicable singly or in any combination with any aspect of the invention.

[0012] The suction side and pressure side aerofoil surfaces of each blade may continue radially inwardly of the respective lines of contact such that if the lids are moved radially inwardly, all the regions of suction and pressure side surfaces of the blades thereby revealed radially outwardly of the lids are aerofoil surface regions. By effectively continuing the blades as aerofoil bodies radially inwards of the lids (even though below the lids the blades are not in the working gas annulus), the increased weight of the blades due to their increased length can be reduced. An alternative of e.g. introducing a (suitably mechanically stable) step-change in the blade cross-sectional shape at the contact line would tend to add more weight to the blisk. The continuance of the blades as aerofoil bodies below the lids also allows the annulus fillers to be replaced by new fillers having lids with different aerodynamic profiles even if these different profiles lead to exposure of more blade surface above the level of the lids.

[0013] The lid of each annulus filler may have damping strips which extend along the opposite edges of the lid to contact the suction and pressure sides of the adjacent blades. Such strips can help to improve the damping properties of the fillers. The strips may be formed of elastomer. The strips can be adhesively bonded to the lid.

[0014] Additionally, or alternatively, the annulus fillers may provide frictional damping. For example, rubbing along the contact lines between the lids and the blades can provide frictional damping.

[0015] Another source of damping can be internal to the material of the support structure. For example, some or all of the support structure of each annulus filler can be formed of a laminate a portion of whose lamina are elastomeric (the other portion can be e.g. metallic).

[0016] The support structure of each annulus filler may provide beneath the lid one or more retention formations which each retains a respective hook formed at the outer surface of the disk part and thereby holds the filler in position between its adjacent blades under centrifugal loading. For example, the support structure can provide forward and rearward retention formations which respectively retain forward and rearward hooks formed at the outer surface of the disk part. Conveniently, the retention formations and hooks may be formed such that, on build, the annulus filler can be slid axially into position between its adjacent blades to mate the hooks with the retention formations. Damping pads (e.g. formed of elastomer) may be located at the interfaces between the retention formations and hooks. Such pads can help to improve

the damping properties of the filler. The pads can be adhesively bonded to the retention formations.

[0017] The retention formations can be variously shaped. For example, they can be complimentary hooks to the disk part hooks. The complimentary hooks can be at the ends of respective legs (provided by the support structure) extending radially inwardly from the underside of the lid. Another option is for the retention formations to be straps which locate under the disk part hooks. The straps can extend between side walls (provided by the support structure) extending radially inwardly from the opposite edges of the lid.

[0018] The support structure of each annulus filler may provide a front and/or rear engagement formation at the front and/or rear end of the lid, the engagement formation engaging with a respective engine component (such as an adjacent fairing) to axially hold the filler in position between its adjacent blades.

[0019] The annulus filler may be formed from aluminium alloy, titanium alloy, composite material (such as carbon fibre reinforced plastic) or a combination thereof. Advantageously, such materials are relatively lightweight, helping to reduce the weight of the blisk. In addition, in the event of accidental filler release, a lightweight filler will tend to be less damaging to the engine.

[0020] The blades may be welded (e.g. linear friction welded) to the disk part. When the annulus fillers cover the weld joints, these become aerodynamically less critical, whereby it is less important to maintain a high quality of surface finish in these regions.

Brief Description of the Drawings

[0021] Embodiments of the invention will now be described by way of example with reference to the accompanying drawings in which:

Figure 1 shows a longitudinal cross-section through a ducted fan gas turbine engine;

Figure 2 shows a close-up, longitudinal cross-section view of a blisk propulsive fan;

Figure 3 shows a close-up, longitudinal cross-section view of an annulus filler of the blisk of Figure 2;

Figure 4 shows a perspective view of the lid of an annulus filler and two adjacent blades of the blisk of Figure 2; and

Figure 5 shows a perspective view an annulus filler of the blisk of Figure 2.

Detailed Description

[0022] With reference to Figure 1, a ducted fan gas turbine engine incorporating the invention is generally indicated at 10 and has a principal and rotational axis X-

X. The engine comprises, in axial flow series, an air intake 11, a propulsive fan 12, an intermediate pressure compressor 13, a high-pressure compressor 14, combustion equipment 15, a high-pressure turbine 16, an intermediate pressure turbine 17, a low-pressure turbine 18 and a core engine exhaust nozzle 19. A nacelle 21 generally surrounds the engine 10 and defines the intake 11, a bypass duct 22 and a bypass exhaust nozzle 23.

[0023] During operation, air entering the intake 11 is accelerated by the fan 12 to produce two air flows: a first air flow A into the intermediate pressure compressor 13 and a second air flow B which passes through the bypass duct 22 to provide propulsive thrust. The intermediate pressure compressor 13 compresses the air flow A directed into it before delivering that air to the high pressure compressor 14 where further compression takes place.

[0024] The compressed air exhausted from the high-pressure compressor 14 is directed into the combustion equipment 15 where it is mixed with fuel and the mixture combusted. The resultant hot combustion products then expand through, and thereby drive the high, intermediate and low-pressure turbines 16, 17, 18 before being exhausted through the nozzle 19 to provide additional propulsive thrust. The high, intermediate and low-pressure turbines respectively drive the high and intermediate pressure compressors 14, 13 and the fan 12 by suitable interconnecting shafts.

[0025] A blisk may be used to form the propulsive fan 12 or may be part of a compressor section 13, 14 of such an engine. For example, Figure 2 shows a close-up view of a blisk propulsive fan 12. The blisk has a rotor disk part 30 and a circumferential row of fan blades 32. Annulus fillers 34, shown in more detail in Figures 3 to 5, bridge the gaps between adjacent blades.

[0026] Each annulus filler 34 has an outer lid 36 which forms the inner surface of the working gas annulus of the engine, and an inner support structure which connects to the disk part 30 to support the lid on the blisk 12. Opposite edges of the lid respectively contact the suction side aerofoil surface of one blade and the pressure side aerofoil surface of an adjacent blade along contact lines 38.

[0027] The annulus fillers 34 provide a number of advantages. They provide damping to the blades 32 by physical contact. This reduces aerofoil vibration from forced response and flutter, and thus improves the service life. The fillers also offer more flexibility in the blisk design, allowing the outer rim of the disk part 30 of the blisk to be reduced in diameter. The overall weight of the blisk 12 may thus be reduced for a given application, as the diameter of the disc part is reduced. Further, the natural frequency of the blades can be reduced due to the increase in blade length. This can be of particular benefit if there is a need to reduce the frequency of the fundamental flap mode/first engine order resonance. For example, there may be a need to keep the fundamental flap mode/first engine order resonance below a particular engine speed to reduce the forcing level.

[0028] Preferably, the aerofoil surfaces of the blade 32 continue uninterruptedly below the level of the lids 36. This allows design changes to be made to the engine whereby new annulus fillers can be installed whose lids have differently shaped air-washed surfaces.

[0029] Each annulus filler 34 is assembled between and interfaces with adjacent blades 32 on the blisk 12, thus effectively forming an annular ring out of the lids 36. The ring covers the regions where the join welds (which may be linear friction welds) between the blades 32 and the disk part 30 are typically made, thereby making weld surface finish in these regions a less critical aerodynamic issue.

[0030] Figure 3 shows front and rear hooks 40 machined integrally to the outer surface of the disk part 30. The hooks can alternatively be welded to the disk part. They can be located spatially on the disk part to suit the particular intended application, e.g. they can be located closer to the leading and trailing edges of the disk part than shown. The support structure of each filler comprises retention formations in the form of corresponding hooks 42 at the ends of respective legs 44 extending from the underside of the filler's lid. On build, the filler is slid axially into position between its adjacent blades so that the hooks 40, 42 mate with each other and provide radial retention of the fillers under centrifugal loading. The filler's support structure can provide other configurations for the retention formations, such as straps running between side walls extending from the opposite edges of the filler, the straps locating in use underneath the hooks 40.

[0031] Axial retention of the annulus fillers 34 can be achieved by fixing an engagement formation 46 at the front of each filler to the disk part 30 or to a suitable adjacent fairing such as the engine nose cone 50. Other filler configurations may adopt a single hook 42 with positive front and rear engagement of the filler.

[0032] Typically, the annulus filler is constructed of light alloy or composite material, such as aluminium, titanium, carbon fibre composite or a mixture of these materials.

[0033] Damping strips 48 can extend along the opposite edges of each lid 36 for contact with the adjacent blades 32. The strips can be formed, for example, of elastomer, which may be adhesively bonded to the lid. Preferably the strips are pre-formed to conform to the shape of the contacting aerofoil surfaces. Instead of such strips, however, frictional damping at the interfaces between the lids and the blades can be used.

[0034] Further damping can be provided by providing damping pads at the interfaces between the mating hooks 40, 42. Such pads can also be formed of elastomer and may be adhesively bonded to the filler hooks 42. Similarly, the legs of the annulus damper can be constructed in such a manner as to be flexible, e.g. as a laminate formed layers of metal and elastomer, so as to provide additional damping.

[0035] While the invention has been described in conjunction with the exemplary embodiments described

above, many equivalent modifications and variations will be apparent to those skilled in the art when given this disclosure. Accordingly, the exemplary embodiments of the invention set forth above are considered to be illustrative and not limiting. Various changes to the described embodiments may be made without departing from the spirit and scope of the invention.

10 Claims

1. A blisk (12) for a gas turbine engine, the blisk having a rotor disk part (30), a circumferential row of blades (32) extending from and integral with the disk part, and a plurality of annulus fillers (34) bridging the gaps between adjacent blades; wherein each annulus filler has an outer lid (36) which defines an airflow surface for air being drawn through the engine in an axial airflow direction, and an inner support structure which connects to the disk part to support the lid on the blisk, opposite edges of the lid making respective lines of contact (38) with a suction side aerofoil surface of one blade and a pressure side aerofoil surface of an adjacent blade.
2. A blisk according to claim 1, wherein the suction side and pressure side aerofoil surfaces of each blade continue radially inwardly of the respective lines of contact such that if the lids are moved radially inwardly, all the regions of suction and pressure side surfaces of the blades thereby revealed radially outwardly of the lids are aerofoil surface regions.
3. A blisk according to claim 1 or 2, wherein the lid of each annulus filler has damping strips (48) which extend along the opposite edges of the lid to contact the suction and pressure sides of the adjacent blades.
4. A blisk according to any one of the previous claims, wherein the support structure of each annulus filler provides beneath the lid one or more retention formations which each retains a respective hook (40) formed at the outer surface of the disk part and thereby holds the filler in position between its adjacent blades under centrifugal loading.
5. A blisk according to claim 4, wherein the retention formations and hooks are formed such that, on build, the annulus filler can be slid axially into position between its adjacent blades to mate the hooks with the retention formations.
6. A blisk according to any one of claim 4 or 5, wherein damping pads are located at the interfaces between the retention formations and hooks.
7. A blisk according to any one of the previous claims,

wherein the support structure of each annulus filler provides a front and/or rear engagement formation (46) at the front and/or rear end of the lid, the engagement formation engaging with a respective engine component (50) to axially hold the filler in position between its adjacent blades. 5

8. A blisk according to any one of the previous claims, wherein the annulus filler is formed from aluminium alloy, titanium alloy, composite material or a combination thereof. 10

9. A blisk according to any one of the previous claims, wherein the blades are welded to the disk part. 15

10. A gas turbine engine having the blisk of any one of the previous claims.

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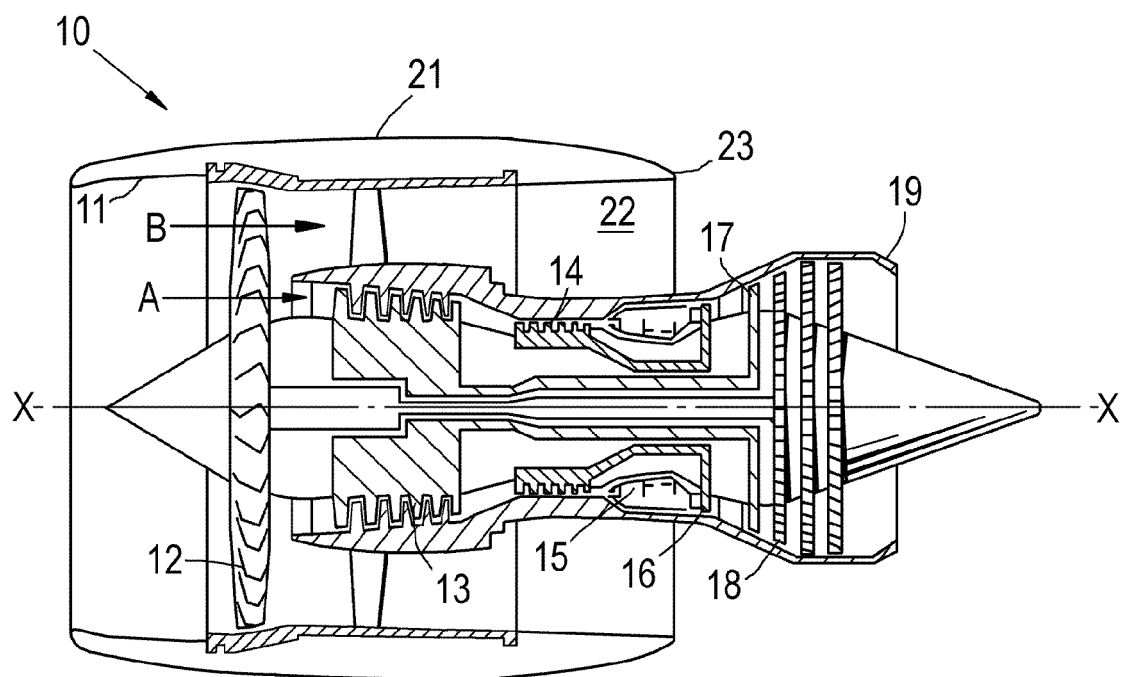
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Fig.1



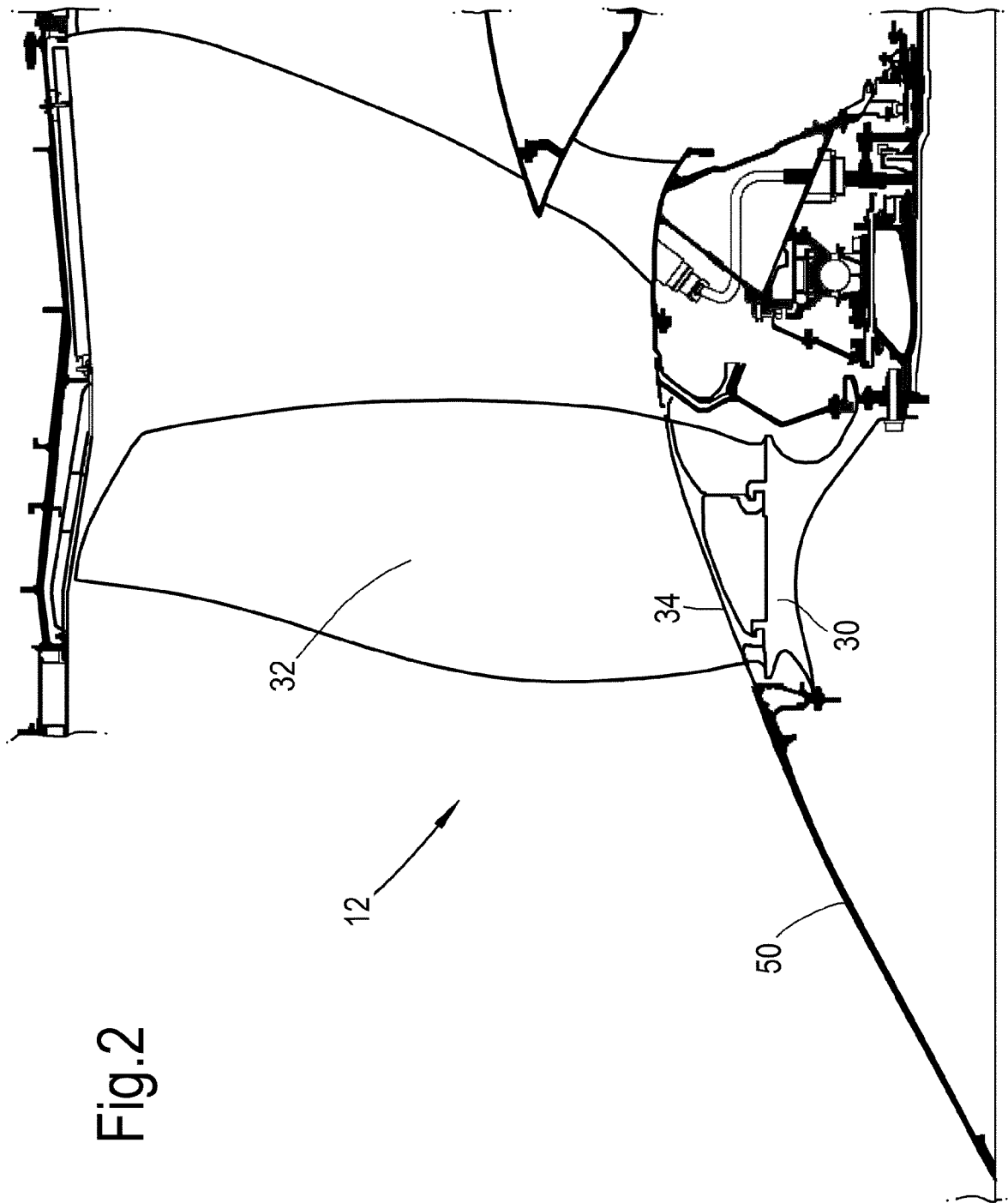


Fig.3

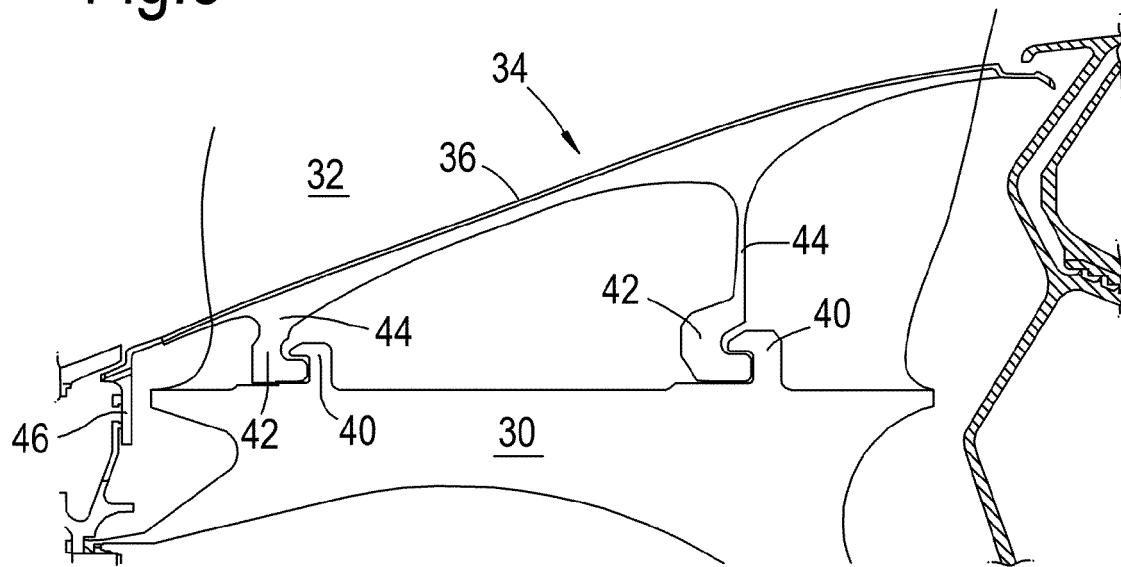


Fig.4

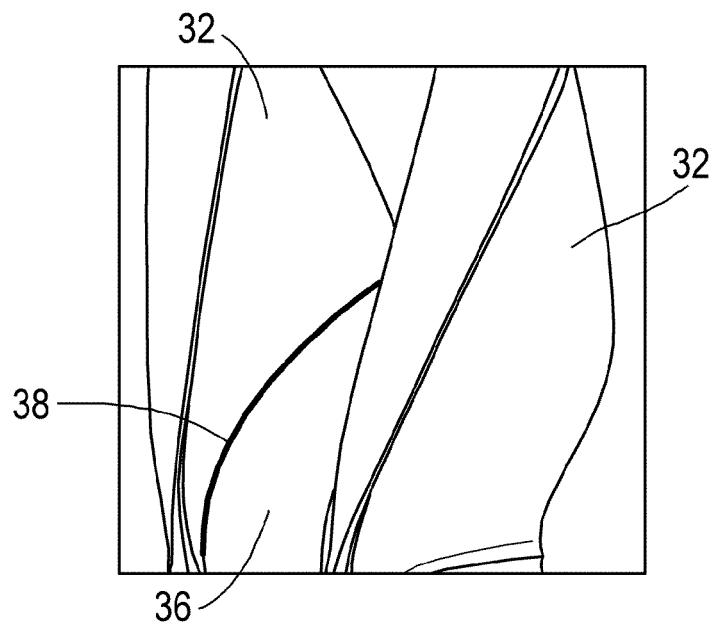
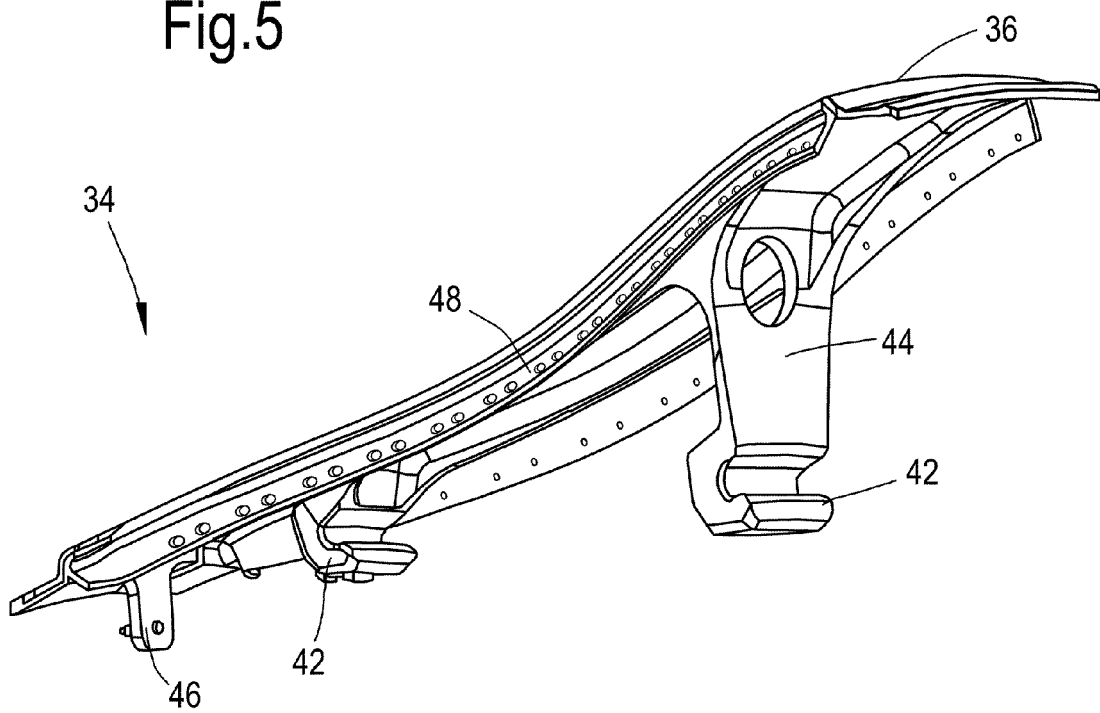


Fig.5





EUROPEAN SEARCH REPORT

Application Number
EP 15 15 0251

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			TECHNICAL FIELDS SEARCHED (IPC)
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The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 7 May 2015	Examiner Pileri, Pierluigi
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

EPO FORM 1503 03.92 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
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EP 15 15 0251

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
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