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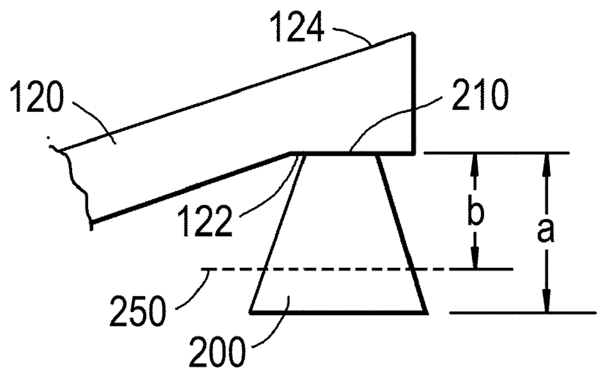
(54) **DAMPER RING FOR A ROTOR STAGE**

(57) A rotor stage (100) of a gas turbine engine (10) comprises a platform (120) from which rotor blades extend. The platform is provided with a circumferentially extending damper ring (200), the damper ring having an engagement surface (210) that engages with the platform. The damper ring has a cross-sectional shape perpendicular to the circumferential direction that has a depth (a) in the radial direction, and a neutral bending axis (250) that is spaced (b) from the engagement surface by more than half of the depth. Increasing the spacing between the engagement surface and the neutral bending axis increases the amount of slip at the interface between the damper ring and the platform, thereby increasing the amount of frictional damping.

Fig.7



EP 3 081 750 A1

Description

[0001] The present disclosure concerns a damper for a rotating part of a gas turbine engine.

[0002] A gas turbine engine comprises various stages of rotor blades which rotate in use. Typically, a gas turbine engine would have at least one compressor rotor stage, and at least one turbine rotor stage.

[0003] There are a number of ways in which the blades of a rotor stage may be attached to the engine. Generally, the blades attach to a rotating component, such as a disc, that is linked to a rotating shaft. Conventionally, blades have been inserted and locked into slots formed in such discs.

[0004] Integral bladed disc rotors, also referred to as blisks (or bliscs) have also been proposed. Such blisks may be, for example, machined from a solid component, or may be manufactured by friction welding (for example linear friction welding) of the blades to the rim of the disc rotor.

[0005] Blisks have a number of advantages when compared with more traditional bladed disc rotor assemblies. For example, blisks are generally lighter than equivalent bladed disc assemblies in which the blades are inserted and locked into slots in the disc because traditional blade to disc mounting features, such as dovetail rim slots, blade roots, and locking features are no longer required. Blisks are therefore increasingly used in modern gas turbine engines, for example as part of the compressor section (including the fan of a turbofan engine).

[0006] Typically blisks are designed where possible to avoid vibration responses from, for example, resonance and flutter, which may be distortion driven. However, blisks lack inherent damping when compared to conventional bladed disc assemblies and resonances and flutter cannot always be avoided.

[0007] Additionally, the outer surface or rim of the blisk disc portion typically forms the inner annulus for working fluid in the gas turbine engine, such as at the compressor inlet. Thus the requirement for the inner annulus position fixes the blisk outer rim radius from the engine centre line thereby determining the basic size/shape of the disc portion. Accordingly, it may not be possible to design a blisk that avoids all forced vibration responses within such constraints.

[0008] Accordingly, it is desirable to be able to provide efficient and/or effective damping to a rotor stage, for example to a bladed disc, or blisk.

[0009] According to an aspect, there is provided a rotor stage of a gas turbine engine comprising a plurality of blades extending from a generally circumferentially extending platform. A circumferentially extending damper ring is provided on the platform. The damper ring has an engagement surface that engages with the platform. The damper ring has a cross-sectional shape perpendicular to the circumferential direction. The cross-sectional shape has a depth in the radial direction, and a neutral bending axis that is spaced from the engagement surface by more than half of the depth.

[0010] The rotor stage may comprise a disc. The plurality of blades may be said to be mounted to the disc. Such a disc may be of any suitable form, for example it may be a solid disc or an annular ring.

[0011] The damper ring may be provided to any desired and/or suitable surface of the platform, for example a damper ring may be provided to a radially inner surface and/or a radially outer surface thereof.

[0012] In arrangements in which the damper ring is provided on the radially inner surface of the platform, the damper ring may be said to have a neutral bending axis that is closer to its radially inner extent than to its radially outer extent.

[0013] In arrangements in which the damper ring is provided on the radially outer surface of the platform, the damper ring may be said to have a neutral bending axis that is closer to its radially outer extent than to its radially inner extent.

[0014] In arrangements in which the damper ring is provided on the radially inner surface, the radially outer extent of the damper ring may be defined by the engagement surface (which may be referred to as a contact surface), which may be said to engage with (or be in contact with) the radially inner surface of the platform.

[0015] In arrangements in which the damper ring is provided on the radially outer surface, the radially inner extent of the damper ring may be defined by the engagement surface (which may be referred to as a contact surface), which may be said to engage with (or be in contact with) the radially outer surface of the platform.

[0016] The engagement surface may, for example, form a cylinder, or a frusto-conical shape.

[0017] According to an aspect, there is provided a rotor stage of a gas turbine engine a plurality of blades extending from a generally circumferentially extending platform. The platform has a radially inner surface. A circumferentially extending damper ring is provided on the radially inner surface of the platform. The damper ring has a cross-sectional shape perpendicular to the circumferential direction that has a neutral bending axis that is closer to its radially inner extent than to its radially outer extent.

[0018] According to an aspect, there is provided a method of damping vibrations in a rotor stage of a gas turbine engine, the rotor stage being as described and/or claimed herein. The vibration may comprise a travelling wave passing circumferentially around the circumferentially extending platform. Such a travelling wave may result in diametral mode excitation, for example of the platform. The damping may be frictional damping generated through slip (which may be circumferential slip) between circumferentially extending damper ring and the platform (for example the radially inner and/or radially outer surface of the platform) caused by the travelling wave.

[0019] In arrangements in which the damper ring is provided to a radially inner surface of the platform, the damper ring may be said to have a neutral bending surface that is closer to its radially inner extent than to its radially outer extent.

[0020] Providing a damper ring as described and/or claimed herein may provide improved damping. The further the neutral axis of the damper ring is from the engagement surface of the damper ring the greater the slip (which may be referred to as the relative movement) at the interface between the damper ring and the platform that results from a traveling wave passing around the rotor stage (for example around the platform). This increased slip may lead to increased frictional energy being dissipated at the interface between the damper ring and the platform. This increased energy dissipation may lead to improved damping.

[0021] Any suitable shape may be used for the damper ring, for example for the cross-sectional shape of the damping ring. For example, the cross-sectional shape of the damper ring may be a T-shape, for example with the base of the T (where the base is the horizontal part of the "T" as presented on this page) provided at an opposite side to the engagement surface (for example an inverted T-shape, with the base of the T-shape provided at a radially inner extent, for arrangements in which the damper ring is provided to a radially inner surface of the platform).

[0022] The cross-sectional shape of the damper ring may comprise a portion that widens with increasing distance from the engagement surface (for example with decreasing radial distance for arrangements in which the damper ring is provided to the radially inner platform). For example, a majority portion of the damper ring may widen with increasing distance from the engagement surface.

[0023] By way of further non-limitative example, the cross-sectional shape of the damper ring may comprise a trapezium.

[0024] The damper ring may have a generally annular shape. The damper ring may extend around all, or a majority, of the circumference of the rotor stage.

[0025] The cross-sectional shape of the damper ring may have a neutral axis that is spaced from the engagement surface by at least two thirds (for example three quarters, four fifths, five sixths or more than five sixths) of the cross-sectional depth. For arrangements in which the damper ring is provided to a radially inner surface of the platform, the cross-sectional shape of the damper ring may have a neutral axis that is at least twice as far - for example three times, four times, five times or more than five times - from its radially outer extent than from its radially inner extent.

[0026] The platform may be provided with a slot. The damper ring may be retained by such a slot. The damper ring may be said to sit in and/or be located by and/or at least partly located in such a slot. Such a slot may be said to engage with the radially outer extent (for example radially outer surface) of the damper ring, where the damper ring is provided to a radially inner surface of the platform.

[0027] The damper ring may be manufactured using any suitable material. For example, the damper ring may be manufactured using a single material and/or may be said to be homogeneous. The damper ring may comprise two (or more than two) different materials.

[0028] The damper ring may have a body portion and an engagement portion. The engagement portion may comprise the engagement surface that is in contact with the platform. Regardless of the material of the damper ring (for example whether it is manufactured using one, two, or more than two materials), the engagement surface may be the surface that slips relative to the platform during excitation (or vibration) of the platform. In arrangements in which the damper ring comprises a body portion and an engagement portion, the engagement portion may be manufactured using a first material, and the body portion may be manufactured using a second material. In such an arrangement, and purely by way of example only, the first material may be metal and/or the second material may be a composite, such as a fibre reinforced and/or polymer matrix composite, such as carbon fibre. In such an arrangement, the body portion and the engagement portion may, for example, be bonded together.

[0029] According to an aspect, there is provided a rotor stage of a gas turbine engine comprising a plurality of blades extending from a generally circumferentially extending platform from which the blades extend. The rotor stage comprises a circumferentially extending damper ring is provided on a circumferentially extending surface of the platform. According to this aspect, the damper ring has a body portion and an engagement portion. The engagement portion has an engagement surface that is in contact with the platform. The engagement portion is manufactured using a first material, and the body portion is manufactured using a second material. According to this aspect, the damper ring may have any suitable cross-sectional shape, including those described and/or claimed herein.

[0030] In any aspect and/or arrangements, the rotor stage may be a blisk. The plurality of blades may be provided integrally with a disc as a unitary part. In arrangements in which the rotor stage is a blisk, the circumferentially extending platform may be a blisk rim.

[0031] In any arrangement, a lubricant, such as a dry film lubricant, may be provided between the engagement surface of the damper and the platform. Such a lubricant may assist in providing a particularly consistent coefficient of friction at the engagement surface, for example during use and/or over time.

[0032] Any feature described and/or claimed herein, for example in relation to any one of the above features, may be applied/used singly or in combination with any other feature described and/or claimed herein, except where mutually exclusive.

[0033] Examples 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 in accordance with an example of the present disclosure;

Figure 2 is a schematic view of a part of a rotor stage of a gas turbine engine, including a damper ring, in accordance with an example of the present disclosure;

Figure 3 is a schematic view of a part of a rotor stage of a gas turbine engine, including a damper ring, in accordance with an example of the present disclosure;

Figure 4 is a schematic showing slip at an interface between a damper ring and a platform;

Figure 5 is a close-up view of a part of the Figure 4 schematic;

Figure 6 is a schematic cross-sectional view of a damper ring in accordance with an example of the present disclosure;

Figure 7 is a schematic cross-sectional view of a damper ring in accordance with an example of the present disclosure;

Figure 8 is a schematic cross-sectional view of a damper ring in accordance with an example of the present disclosure;

Figure 9 is a schematic cross-sectional view of a damper ring in accordance with an example of the present disclosure; and

Figure 10 is a schematic cross-sectional view of a damper ring in accordance with an example of the present disclosure;

[0034] With reference to Figure 1, a gas turbine engine is generally indicated at 10, having a principal and rotational axis 11. The engine 10 comprises, in axial flow series, an air intake 12, a propulsive fan 13, an intermediate pressure compressor 14, a high-pressure compressor 15, combustion equipment 16, a high-pressure turbine 17, and intermediate pressure turbine 18, a low-pressure turbine 19 and an exhaust nozzle 20. A nacelle 21 generally surrounds the engine 10 and defines both the intake 12 and the exhaust nozzle 20.

[0035] The gas turbine engine 10 works in the conventional manner so that air entering the intake 12 is accelerated by the fan 13 to produce two air flows: a first air flow into the intermediate pressure compressor 14 and a second air flow which passes through a bypass duct 22 to provide propulsive thrust. The intermediate pressure compressor 14 compresses the air flow directed into it before delivering that air to the high pressure compressor 15 where further compression takes place.

[0036] 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 combusted. The resultant hot combustion products then expand through, and thereby drive the high, intermediate and low-pressure turbines 17, 18, 19 before being exhausted through the nozzle 20 to provide additional propulsive thrust. The high 17, intermediate 18 and low 19 pressure turbines drive respectively the high pressure compressor 15, intermediate pressure compressor 14 and fan 13, each by suitable interconnecting shaft.

[0037] Each of the high 17, intermediate 18 and low 19 pressure turbines and each of the fan 13, intermediate pressure compressor 14 and high pressure compressor 15 comprises at least one rotor stage having multiple blades (or aerofoils) that rotate in use. One or more rotor stage may be, for example, a disc with slots (which may be referred to as dovetail slots or fir-tree slots) for receiving the blade roots. One or more rotor stages may have the blades formed integrally with the supporting disc or ring structure, and may be referred to as blisks or blings. In such arrangements, the blades may be permanently attached to the supporting disc/ring, for example using friction welding, such as linear friction welding.

[0038] Figure 2 shows a schematic side view of a part of a rotor stage 100, including a platform 120, a disc 140, a blade 160, and a damper ring 200. The platform 120, disc 140 and blade 160 may all be integral, and may be referred to collectively as a blisk 180. The rotor stage 100 may be any one of the rotor stages of the gas turbine engine 10 shown in Figure 1, such as (by way of non-limitative example) the fan 13 and/or any one or more stages of one or more of the high 17, intermediate 18 and low 19 pressure turbines and/or the high pressure compressor 15 or intermediate pressure compressor 14.

[0039] In the Figure 2 example, the damper ring 200 is provided to the lower (or radially inner) surface 122 of the platform 120. In other arrangements the damper ring 200 may engage with another part of the platform 120 such as, by way of example, an upper (or radially outer) surface 124 of the platform 120.

[0040] The damper ring 200 has an engagement surface 210 that engages with the platform 120. The engagement surface 210 may be at a radially outer extent (and/or may be said to be and/or define the radially outer surface of the damper ring 120), as in the Figure 2 arrangement. The engagement surface 210 of any arrangement may be said to extend circumferentially and/or may be at least a part of a cylinder or frusto-cone.

[0041] The damper ring 200 is shown in cross-section normal to the circumferential direction in Figure 2. The cross-sectional shape of the damper ring 200 is such that its neutral bending axis is spaced from the engagement surface 210 by more than half of the depth of the damper ring, this depth being indicated by reference 'a' in the Figure 2 example. Any suitable shape of damper ring 200 may be used to achieve this. Purely by way of example, the cross-sectional shape of the damper ring 200 shown in Figure 2 may be described as a trapezium, or trapezoid. The narrower side of the trapezium is at the engagement surface 210 (at a radially outer extent in the Figure 2 example). The wider side of the trapezium is opposite to the engagement surface 210 (at a radially inner extent in the Figure 2 example).

[0042] The example shown in Figure 3 is similar to that shown in, and described in relation to, Figure 2. Like features in Figures 2 and 3 are indicated with like reference numerals. Unlike the Figure 2 arrangement, the Figure 3 arrangement has a slot 130 provided in the platform 120. The damper ring 200 is provided (and/or located and/or secured) in the slot 130. The slot 130 may be said to receive the damper ring 200. The slot 130 may be said to extend circumferentially.

[0043] In the Figure 3 arrangement the slot 130 is provided to the radially inner surface 122 of the platform 120, although in other arrangements the slot 130 may be provided to the radially outer surface 124 of the platform 120. The cross-sectional shape (perpendicular to the circumferential direction) of the slot 130 corresponds to the cross-sectional shape of a portion of the damper ring 200 that is adjacent the engagement surface 210. In the Figure 3 arrangement this corresponds to a radially outer portion of the damper ring 200.

[0044] Any of the damper rings 200 described and/or claimed herein may function through frictional damping. Such frictional damping occurs as a result of relative movement at the interface between the damper ring 200 and the surface with which it is engaged. For example, the relative movement may be between the engagement surface 210 of the damper ring 200 and the surface of the platform 120 (for example the radially inner 122 or radially outer 124 surface) with which it is engaged. This relative movement and frictional damping mechanism is described in greater detail in relation to Figures 4 and 5.

[0045] Figure 4 shows a schematic of part of a platform 120 and damper ring 200 in a deformed state, for example due to vibration. The engagement surface 210 is shown in the deformed state in Figure 4, and the line 300 in Figure 4 represents the original, undeformed, interface between the platform 120 and the damper ring 200.

[0046] The Figure 4 view is a purely schematic representation perpendicular to the rotational axis 11 of the rotor stage 100. The view may be described as being in the radial-circumferential plane. Thus, although the undeformed interface (or engagement surface) 300 is shown as a straight line in Figure 4 for ease of representation and explanation, it will be appreciated that the actual undeformed interface would be at least a segment of a circle. Accordingly, the deflection y represents the deflection from the original circular shape, and the dimension x represents the distance around the circumference of the interface.

[0047] Figure 5 shows a close up version of the region labelled "P" in Figure 4. This region P is the region of maximum slip at the interface between the platform 120 and the damper ring 200, i.e. maximum slip at the engagement surface 210.

[0048] The neutral bending axis of the damper ring 200 is shown in Figures 4 and 5 by dashed line 250, and the neutral bending axis of the platform 120 is shown by dashed line 150. The neutral bending axis 150, 250 shown in the figures may be part of a neutral bending surface for the respective component. The neutral bending axis/surface 150, 250 of a component 120, 200 may be defined as the axis/surface that does not experience any stress and/or strain (for example in the circumferential direction) as the component deforms, for example due to vibration. The shear stress/strain may be said to be at maximum on the neutral axis/surface. The position of these neutral bending axes is shown purely schematically in Figures 4 and 5, for the purpose of explaining the frictional damping mechanism.

[0049] The thickness, or depth, of the damper ring 200 is shown by reference a. The distance of the neutral bending axis 250 of the damper ring 200 from the engagement surface 210 is labelled b in Figures 4 and 5. The distance of the neutral bending axis 150 of the platform 120 from the engagement surface 210 is labelled c in Figures 4 and 5.

[0050] Frictional damping may occur due to relative movement between the damper ring 200 and the platform 120 at the engagement surface 210. In other words, as the platform 120 and the damper ring 200 vibrate, the deflection y at a given position x around the circumference changes, and may be said to oscillate about the centreline, or undeformed line, 300. This oscillation leads to varying relative sip at the interface 210, and thus the generation of frictional energy that acts to damp the vibration.

[0051] Figure 4 represents half of a wavelength of a sinusoidal vibration. If the radius of the undeformed interface 300 is given by R, and the total number of waves (or "nodal diameters") around the circumference is given by N, then it follows that the deflection of the engagement surface 210 at a given location x around the circumference is given by:

$$y = Y\cos\left(N\frac{x}{R}\right)$$

where Y is the maximum deflection.

[0052] Differentiating this to find the slope gives:

$$\frac{dy}{dx} = -\frac{NY}{R}\sin\left(\frac{Nx}{R}\right) = \tan(\alpha)$$

where α is the angle from the undeformed shape.

[0053] This has a maximum magnitude at (for example) $x = \pi R/2N$ of:

$$\tan(\alpha) = \frac{NY}{R}$$

[0054] This value is in the region P shown in detail in Figure 5, from which it is clear that:

$$\tan(\alpha) = \frac{s}{d} \quad => \quad \frac{s}{d} = \frac{NY}{R} \quad => \quad \boxed{s = \frac{NYd}{R}}$$

where s is the maximum slip, and d is the separation between the neutral axes 150, 250 of the platform 120 and damper ring 200.

[0055] Accordingly, it is clear that the maximum slip value is a function of (in this model proportional to) the separation d between the neutral axes 150, 250 of the platform 120 and the damper ring 200. Because it is the slip s that generates the friction to dissipate the energy that in turn provides the damping, it is advantageous to maximise (or increase) this value. This may be achieved by increasing the value of d, i.e. increasing the separation between the neutral axes 150, 250 of the platform 120 and the damper ring 200.

[0056] More effective damping may be realized by increasing the distance b of the neutral axis 250 of the damper ring 200 from the engagement surface 210. Accordingly, this may be achieved by setting the distance b to be at least half of the depth a of the damper ring. This may be achieved through the use of a great many different cross-sectional shapes (perpendicular to the circumferential direction) for the damper ring 200.

[0057] Examples of different cross-sectional shapes of the damper ring 200 are shown in Figures 6 and 7. It will be understood that these shapes are merely examples of many different shapes that could be used to achieve improved damping.

[0058] Figure 6 shows a T-shaped damper ring 200. The damper ring 200 may be described as having an inverted T-shape. The T-shape is the cross-sectional shape as viewed perpendicular to the circumferential direction. This T-shape results in a neutral bending axis 250 that is closer to the radially inner extent 260 of the damper ring 200 than to the radially outer extent 210. The radially outer extent 210 of the damper ring 200 shown in Figure 6 corresponds to the engagement surface 210. The distance b of the neutral bending axis 250 from the engagement surface 210 is more than half of the depth a of the damper ring 200.

[0059] Whilst the damper ring 200 in Figure 6 is shown as being provided to the radially inner surface 122 of the platform 120, a T-shaped damper ring 200 may instead be provided to the radially outer surface 124 of the platform 120. In that case, the "T" shape would be inverted from that shown in Figure 6, such that the distance b of the neutral bending axis 250 from the engagement surface 210 remains more than half of the depth a of the damper ring 200, with the engagement surface 210 engaging with the upper surface 124.

[0060] Figure 7 shows an alternative arrangement of damper ring 200, in which the cross-sectional shape is a trapezium. Such a damper ring 200 may be similar to that shown in Figure 2 and/or 3. As with the damper ring shown in Figure 6, the damper ring 200 shown in Figure 7 has a neutral bending axis 250 that is spaced b from the engagement surface 210 by more than half of the depth a of the damper ring 200. Again, the damper ring 200 may be provided to either the radially inner surface 122 (as shown) or to the radially outer surface 124 of the platform 120 (in which case it would be inverted relative to the Figure 7 arrangement).

[0061] Figures 8 and 9 show further exemplary arrangements of rotor stages 100, each comprising a damper ring 200 and platform 120. Both arrangements include a slot 130 in the lower (or radially inner) surface 122 of the platform 120.

The damper ring 200 is retained by the slot 130. The shape of the slot 130 (for example the cross-sectional shape of the slot 130) may be said to correspond to an engagement portion (which in the illustrated examples corresponds to a radially outer portion) of the damper ring 200. In the examples of both Figure 8 and 9, the neutral bending axis 250 is further than 50% of the depth a of the damper ring away from the engagement surface (or radially outer surface, in the illustrated examples) 210 of the damper ring 200.

[0062] The damper ring 200 of the Figure 8 example comprises a body portion 202 and an engagement portion 204. The body portion 202 and the engagement portion 204 are manufactured using different materials in the Figure 8 example. For example, the body portion 202 may be manufactured using a composite material, such as a polymer matrix composite and/or a fibre-reinforced composite, such as carbon fibre. The engagement portion 204 may be manufactured using a material that is more wear-resistant than that of the body portion 202 such as, for example, a metal, for example titanium.

[0063] The Figure 9 example is broadly similar to the Figure 6 example, other than in that that platform 120 of the Figure 9 example is provided with the slot 130.

[0064] For arrangements in which the damper ring 200 is retained in a slot 130, the slot 130 may be said to have a base surface 132 and side surfaces 134. The base surface 132 may extend generally perpendicularly to (for example have a major component perpendicular to) the radial direction. The side surfaces 134 may extend generally perpendicularly to (for example may have a major component perpendicular to) the axial (or rotational) direction. The damper ring 200 may, optionally, engage with both the base surface 132 and the side surfaces 134. In that case, the engagement surface 210 of the damper ring may be defined as being that surface 210 which engages with the base surface 132 (or at least is closest to the base surface 132 of the slot 130).

[0065] Figure 10 shows a further exemplary arrangement of rotor stage 100 comprising a platform 120 and a damper ring 200. The damper ring 200 of Figure 10 sits inside a slot 130. The damper ring 200 of Figure 10 has a body portion 202 and an engagement portion 204. The body portion 202 and the engagement portion 204 are manufactured using different materials in the Figure 10 example. For example, the body portion 202 may be manufactured using a composite material, such as a polymer matrix composite and/or a fibre-reinforced composite, such as carbon fibre. The engagement portion 204 may be manufactured using a material that is more wear-resistant than that of the body portion 202 such as, for example, a metal, for example titanium. In the Figure 10 example, the damper ring 200 is provided in a slot 130 on the underside (radially inner) surface 122 of the platform 120. However, in other arrangements, platform may not be provided with a slot 130 and/or the damper ring 200 may be provided to the radially outer surface 124 of the platform 120.

[0066] It will be understood that the invention is not limited to the arrangements and/or examples above-described and various modifications and improvements can be made without departing from the concepts described and/or claimed herein. Except where mutually exclusive, any of the features may be employed separately or in combination with any other features and the disclosure extends to and includes all combinations and sub-combinations of one or more features described and/or claimed herein.

Claims

1. A rotor stage (100) of a gas turbine engine (10) comprising a plurality of blades (160) extending from a generally circumferentially extending platform (120), wherein:

a circumferentially extending damper ring (200) is provided on the platform, the damper ring having an engagement surface (210) that engages with the platform; and
the damper ring has a cross-sectional shape perpendicular to the circumferential direction that has a depth (a) in the radial direction, and a neutral bending axis (250) that is spaced (b) from the engagement surface by more than half of the depth.

2. A rotor stage of a gas turbine engine according to claim 1, wherein:

the platform has a radially inner surface (122);
the damper ring is provided on the radially inner surface of the platform;
and
the damper ring has a neutral bending axis that is closer to its radially inner extent than to its radially outer extent.

3. A rotor stage of a gas turbine engine according to claim 1 or claim 2, wherein the cross-sectional shape of the damper ring is a T-shape.

4. A rotor stage of a gas turbine engine according to any one of the preceding claims, wherein the cross-sectional shape of the damper ring comprises a portion that widens with increasing distance from the engagement surface.

5. A rotor stage of a gas turbine engine according to any one of the preceding claims, wherein the damper ring has a generally annular shape.

6. A rotor stage of a gas turbine engine according to any one of the preceding claims, wherein the neutral axis of the cross-sectional shape of the damper ring is spaced from the engagement surface by at least two thirds of the cross-sectional depth.

7. A rotor stage of a gas turbine engine according to any one of the preceding claims, wherein the radially outer extent of the damper ring is defined by the engagement surface that is in contact with the radially inner surface of the platform.

8. A rotor stage of a gas turbine engine according to any one of the preceding claims, wherein the platform is provided with a slot (130), and the damper ring is retained by the slot.

9. A rotor stage of a gas turbine engine according to any one of the preceding claims, wherein the rotor stage is a blisk, with the plurality of blades provided integrally with a disc as a unitary part to form the blisk.

10. A rotor stage of a gas turbine engine according to claim 9, wherein the circumferentially extending platform is a blisk rim.

11. A rotor stage of a gas turbine engine according to any one of the preceding claims, wherein the damper ring comprises two different materials.

12. A rotor stage of a gas turbine engine according to claim 11, wherein the damper ring has a body portion (202) and an engagement portion (204), the engagement portion comprising the engagement surface; and the engagement portion is manufactured using a first material, and the body portion is manufactured using a second material.

13. A rotor stage of (100) a gas turbine engine (10) comprising a plurality of blades (160) extending from a generally circumferentially extending platform (120), wherein:

a circumferentially extending damper ring (200) is provided on the platform, the damper ring having a body portion (202) and an engagement portion (204), the engagement portion having an engagement surface that (210) is in contact with the platform; and
the engagement portion is manufactured using a first material, and the body portion is manufactured using a second material.

14. A rotor stage according to claim 12 or claim 13, wherein:

the first material is metal; and/or
the second material is a composite material.

15. A method of damping vibrations in a rotor stage (100) of a gas turbine engine (10), wherein:

the rotor stage is a rotor stage according to any one of the preceding claims;
the vibration comprises a travelling wave passing circumferentially around the circumferentially extending platform; and
the damping is frictional damping generated through slip (s) between the engagement surface of the circumferentially extending damper ring and the platform caused by the travelling wave.

Fig.1

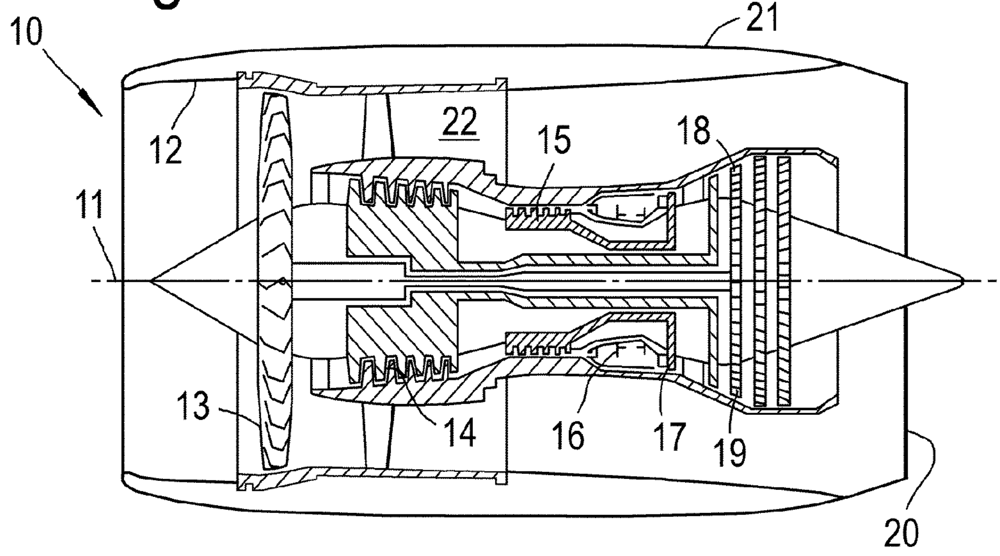
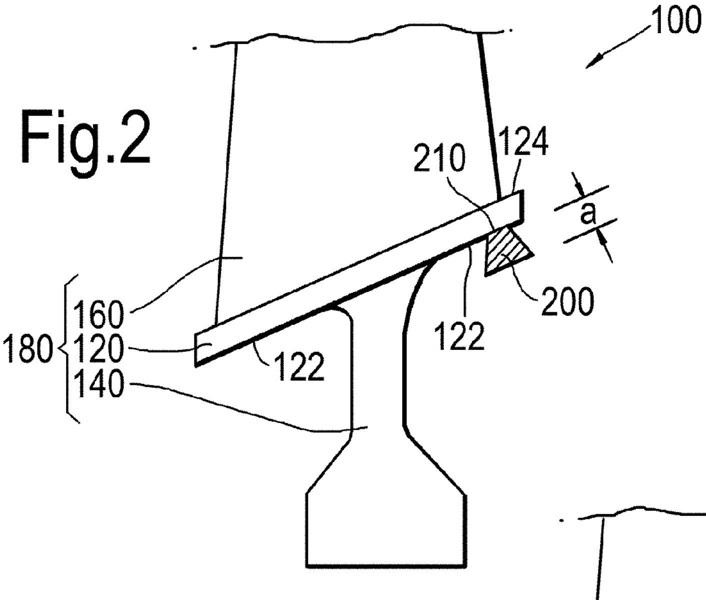


Fig.2



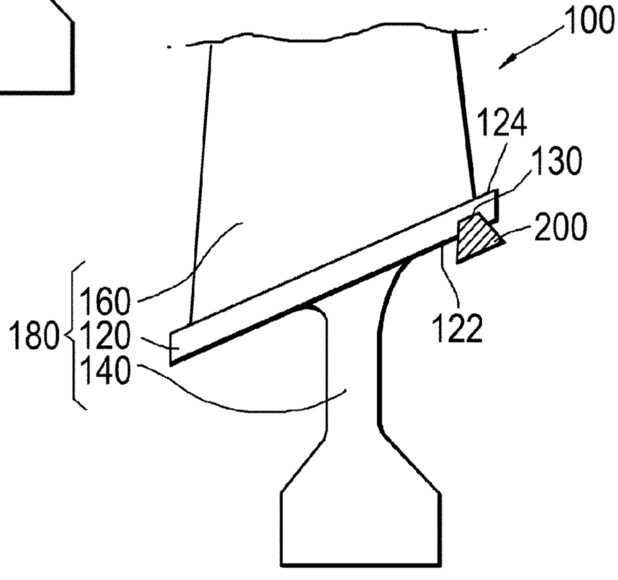


Fig.3

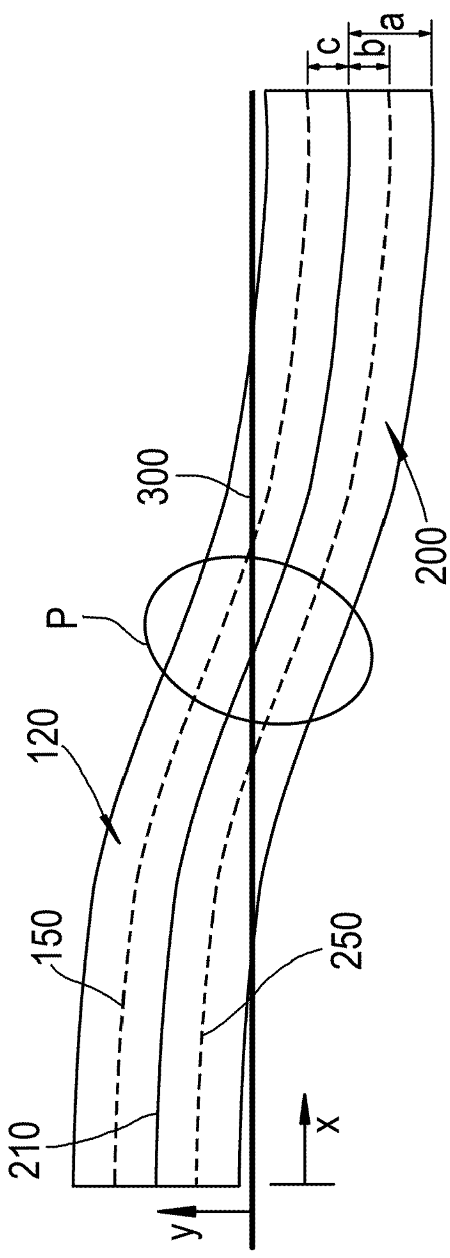


Fig.4

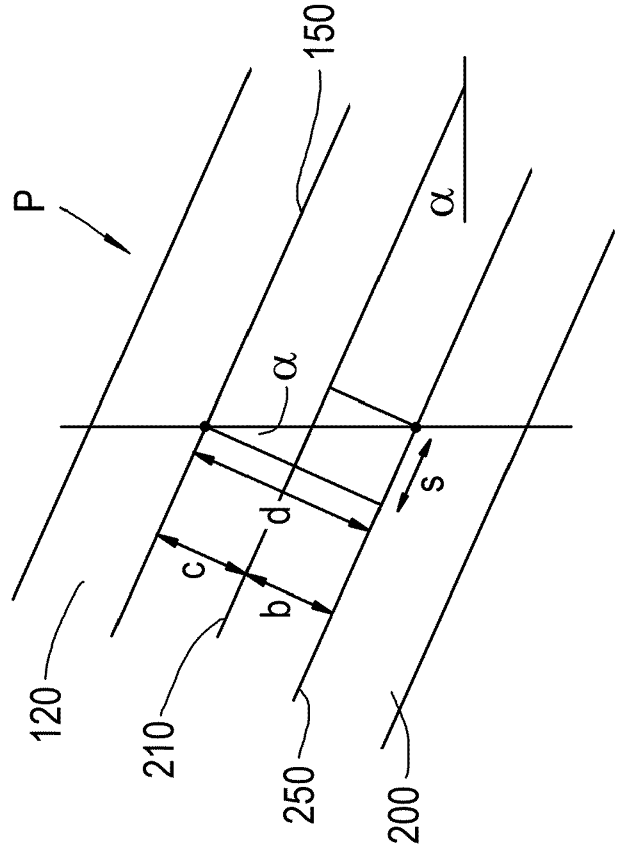


Fig.5

Fig.6

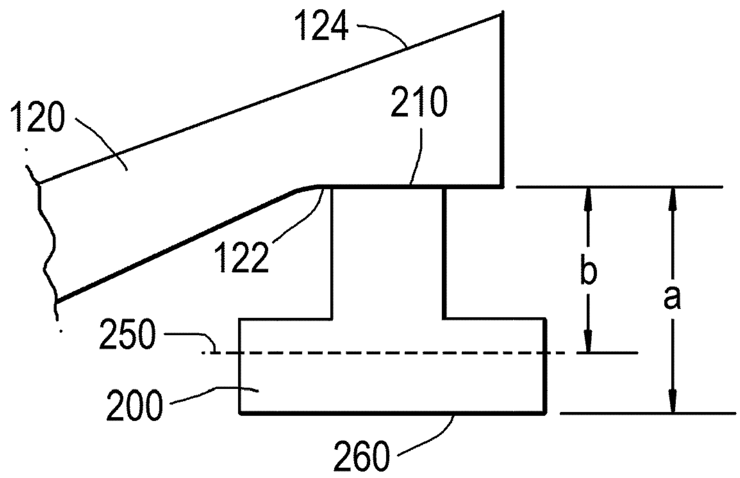


Fig.7

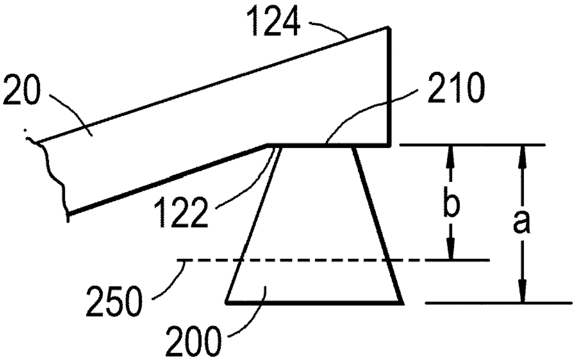


Fig.8

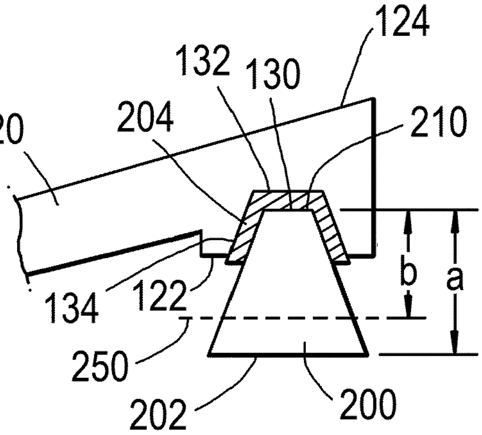


Fig.9

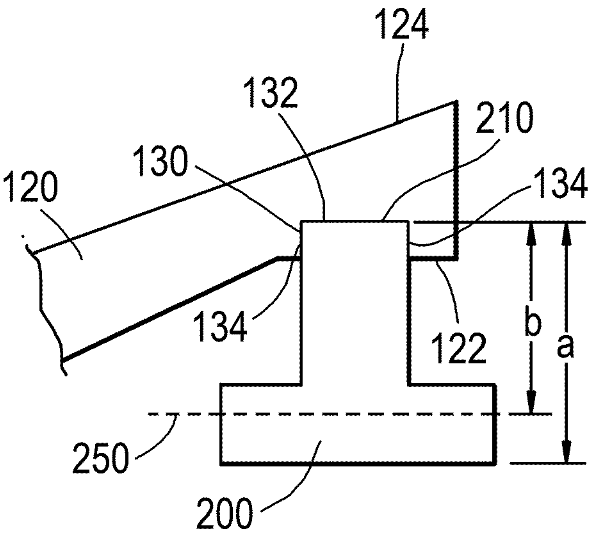

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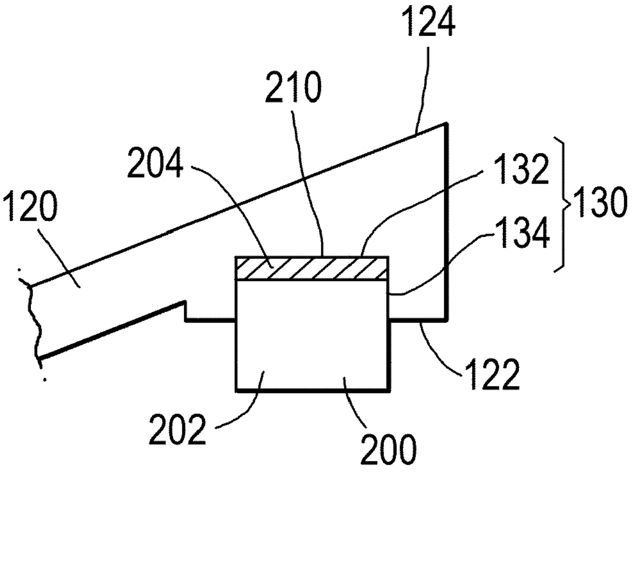
Fig.10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EUROPEAN SEARCH REPORT

Application Number
EP 16 16 0340

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The present search report has been drawn up for all claims

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Place of search	Date of completion of the search	Examiner
Munich	29 August 2016	Koch, Rafael

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