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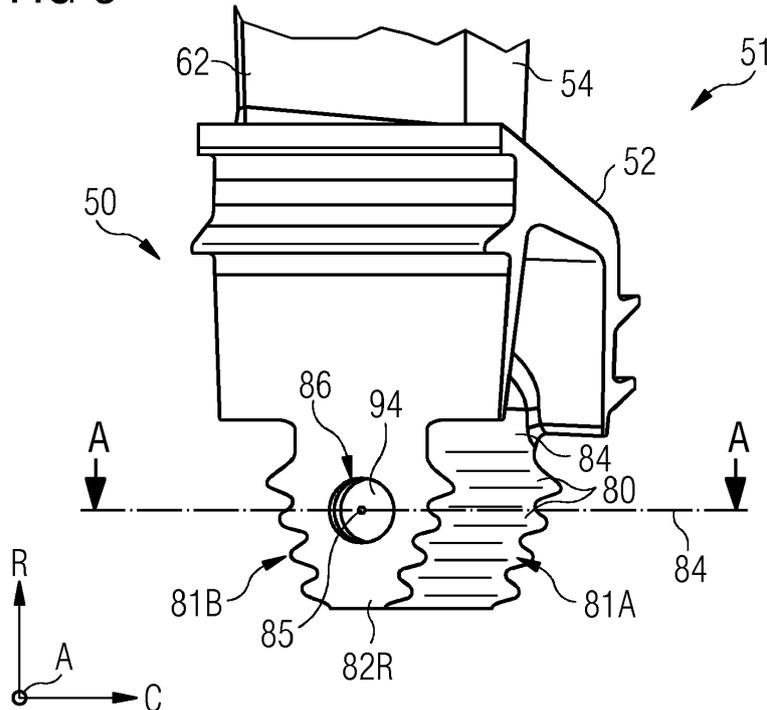
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(54) **Blade arrangement for assembly and assembly tool**

(57) A blade 51 and an assembly tool 87 for assembling a blade set to a rotor disc 35 is disclosed. The blade 51 comprises a root portion 50, an aerofoil 54 and a shroud 56, the root portion 50 has two lateral sides each defining at least one bearing surface 80 and at least one end surface 82R, 82F, the blade 51 has a centre-of-resistance line 84 which passes through the root portion

50 and is generally parallel to a plane of at least one bearing surface 80, the centre-of-resistance line 84 intersects the at least one end surface 82R, 82F at an intersection point 85, the at least one end surface 82R, 82F comprises an assembly feature 86 having a contact surface 94, 100 arranged about the intersection point 95.

FIG 3



Description

FIELD OF INVENTION

[0001] The present invention relates to a blade arrangement and an assembly tool suitable for facilitating assembly of the blade arrangement or array of blades to a rotor disc of a gas turbine for example.

BACKGROUND OF INVENTION

[0002] Turbine blades are assembled into respective slots in a retention disc to form a rotor assembly. The blades have interlocked shrouded tips and are subjected to vibrations which are damped by the use of a sliding contact between their interlock surfaces. These interlock surfaces are in contact during cold build or with minimal clearance which is insufficient to allow the insertion of a single blade into the disc whilst adjacent blades are already inserted. In either case it means the blades cannot be assembled singly but need to be assembled to the disc as a set of blades. The force between the contacting interlock surfaces of adjacent blades is related to the blade torsion characteristics and the force imparted on the blade to necessitate assembly. Depending on the level of contact at cold build between the interlock faces and the torsional stiffness of the blades, the amount of force required to assemble the blades may be considerable.

[0003] Also, it is important to control the assembly force so as not to damage the blades or the disc. The use of force on a blade and host disc during assembly may result in component damage.

[0004] This problem also applies to dismantling the blades from the disc after service, sampling or inspection reasons. Although the blades may be deemed end-of-life, it may be a requirement for the disc to be used again. In certain cases the blades may be refurbished for further use, and so it is important not to damage the blade or disc during removal.

[0005] Currently, assembly and disassembly is carried out by careful use of manual force. One method includes the use of a vibratory hammer applying force via a punch onto a blade root end face. However, damage to blades and disc are too frequent. In addition, this manual process is expensive and time consuming.

SUMMARY OF INVENTION

[0006] One objective of the present invention is to prevent damage to any one of the blades or disc during assembly or disassembly of the blades and disc. Another objective is to provide a consistent force for all blades and between blades and disc during assembly or disassembly of the blades and disc.

[0007] To meet these and other objectives there is provided a blade and assembly tool having cooperating and largely interchangeable features.

[0008] In a first aspect a blade for assembling or disassembling to a rotor disc comprises a root portion, an aerofoil and a shroud, the root portion has two lateral sides each defining at least one bearing surface and at least one end surface, the blade has a centre-of-resistance line which passes through the root portion and is generally parallel to a plane of at least one bearing surface, the centre-of-resistance line intersects the at least one end surface at an intersection point, the at least one end surface comprises an assembly feature having a contact surface arranged about the intersection point.

[0009] The centre-of-resistance line may be generally parallel to a plane of at least one bearing surface.

[0010] The assembly feature may comprise a recess into the at least one end surface.

[0011] The assembly feature may comprise a projection extending from the at least one end surface.

[0012] The assembly feature may define a generally flat contact surface that is generally perpendicular to the centre-of-resistance line.

[0013] The generally flat contact surface may be not parallel to the at least one end surface. The at least one end surface may be parallel to a radial plane of the disc. The radial plane is perpendicular to a rotational axis of the engine.

[0014] The assembly feature may define a curved contact surface that intersects the centre-of-resistance line, the curved contact surface can be any one of the group comprising convex or concave shapes.

[0015] The assembly feature may define a lip at least partly surrounding the contact surface. The lip is advantageously provided to prevent the assembly feature and contact surface from disengaging one another during assembly or disassembly of the blades and the disc.

[0016] The shroud may be an interlocking shroud or have a nominal clearance gap such that a single blade may not be inserted and a set of blades must be inserted together.

[0017] In another aspect of the present invention there is provided an assembly tool for assembling an array of blades to a rotor disc, the assembly tool comprising a slave disc having an axis, a ring mountable to the slave disc via a slidable mounting and defining an array of generally axially extending fingers for engaging an assembly feature on each blade of the array of blades, the slidable mounting is arranged to have a slide angle θ to the axis, the fingers comprise a contact surface configured for engagement with a contact surface of an assembly feature on the blades.

each finger of the annular array of fingers extending from the ring in a direction along a longitudinal axis, the longitudinal axis is arranged to have an angle θ from the axis. the contact surface is flat or curved.

the finger defines a recess in which the contact surface is located.

the contact surface has a shape of any one of the group comprising flat, curved, convex and concave.

[0018] One advantage of the present invention is to

provide a force in the direction along the centre or resistance of the blade. Another advantage of the present invention is to provide an arrangement of the blade and assembly tool which does not disengage during assembly or disassembly of the blades and disc. Another advantage of the present invention is the arrangement does not induce torque or twist to the blade via the contact between assembly feature and assembly tool. Another advantage is that the arrangement can centre the assembly feature and assembly tool so that the force is applied along a centre of resistance line of the blade root and at or very near to an intersection point the centre of resistance line makes with the blade root end surface.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] Further features, properties and advantages of the present invention will become clear from the following description of embodiments in conjunction with the accompanying drawings.

FIG. 1 shows a schematic turbine engine in a sectional view in which the present invention may be incorporated,

FIG. 2 is a view on a shroud of a blade looking in a generally circumferential direction; the blade is in accordance with the present invention,

FIG. 3 is a view looking at a downstream surface of a root of a turbine blade incorporating an exemplary embodiment of the present invention,

FIG. 4 is a section A-A, shown in FIG.3, which is through the root of the turbine blade,

FIG.5 is a view looking radially inwardly on an assembly pushing tool in accordance with the invention,

FIG.6 is an isometric view of the assembly pushing tool mounted to an angular timing feature and engaging part of an annular array of turbine blades all in accordance with the present invention,

FIGs 7A and 7B show alternative embodiments of the present invention and are part views of section A-A of the root of the turbine blade shown in FIG.3 and including a pushing or assembly tool,

FIG.8 is a further embodiments of the present invention and is a view of section A-A of the root of the turbine blade shown in FIG.3 and including a pushing or assembly tool and

FIG.9 shows an alternative embodiment of the present invention and is a part view of section A-A of the root of the turbine blade shown in FIG.3 and

including a pushing or assembly tool.

[0020] Throughout the figures the same reference numerals have been used to denote the same features.

DETAILED DESCRIPTION OF INVENTION

[0021] Figure 1 is a schematic illustration of a general arrangement of a turbine engine 10 having an inlet 12, a compressor 14, a combustor system 16, a turbine system 18, an exhaust duct 20 and a twin-shaft arrangement 22, 24. The turbine engine 10 is generally arranged about an axis 26 which for rotating components is their rotational axis. The arrangements 22, 24 may have the same or opposite directions of rotation. The combustion system 16 comprises an annular array of combustor units 36, only one of which is shown. In one example, there are six combustor units evenly spaced about the engine. The turbine system 18 includes a high-pressure turbine 28 drivingly connected to the compressor 14 by a first shaft 22 of the twin-shaft arrangement. The turbine system 18 also includes a low-pressure turbine 30 drivingly connected to a load (not shown) via a second shaft 24 of the twin-shaft arrangement.

[0022] The terms radial, circumferential and axial are with respect to the axis 26. The terms upstream and downstream are with respect to the general direction of gas flow through the engine and as seen in FIG.1 is generally from left to right.

[0023] The compressor 14 comprises an axial series of stator vanes and rotor blades mounted in a conventional manner. The stator or compressor vanes may be fixed or have variable geometry to improve the airflow onto the downstream rotor or compressor blades. Each turbine 28, 30 comprises an axial series of stator vanes 33 and rotor blades 51 mounted via rotor discs 35 arranged and operating in a conventional manner. A rotor assembly 36 comprises an annular array of rotor blades or blades 51 and the rotor disc 35.

[0024] In operation air 32 is drawn into the engine 10 through the inlet 12 and into the compressor 14 where the successive stages of vanes and blades compress the air before delivering the compressed air into the combustion system 16. In a combustion chamber 37 of the combustion system 16 the mixture of compressed air and fuel is ignited. The resultant hot working gas flow is directed into, expands and drives the high-pressure turbine 28 which in turn drives the compressor 14 via the first shaft 22. After passing through the high-pressure turbine 28, the hot working gas flow is directed into the low-pressure turbine 30 which drives the load via the second shaft 24.

[0025] The low-pressure turbine 30 can also be referred to as a power turbine and the second shaft 24 can also be referred to as a power shaft. The load is typically an electrical machine for generating electricity or a mechanical machine such as a pump or a process compressor. Other known loads may be driven via the low-pres-

sure turbine. The fuel may be in gaseous and/or liquid form.

[0026] The turbine engine 10 shown and described with reference to FIG.1 is just one example of a number of engines or turbomachinery in which this invention can be incorporated. Such engines gas turbines or steam turbine and include single, double and triple shaft engines applied in marine, industrial and aerospace sectors.

[0027] FIG. 2 is a view of a tip 49 of a blade 51 looking in a generally circumferential direction. FIG.3 is a view looking at a downstream surface 82R of a root portion 50 of the blade 51 incorporating an exemplary embodiment of the present invention. A set of reference axes are shown on each of FIG.2 and FIG.3 where the circumferential direction is shown by arrow C, the radial direction is shown by arrow R and the axial direction is shown by arrow A. Arrow A is intended to be parallel to the engine's rotational axis 26. The axes A, C and R are mutually perpendicular to one another.

[0028] The blade 51 is one of the annular array of blades mounted on one or both the rotors 35. Each blade 51 comprises the root portion 50, an inner platform 52, an aerofoil 54 and a shroud 56 at the tip 49. The aerofoil 54 has a suction surface 62 and a pressure surface 64 which meet at a leading edge 58 and a trailing edge 60. In operation, working gases flow in a general direction from the leading edge 58 towards the trailing edge 60. The shroud 56 has radially outwardly extending first and second fins 66, 68 which along with the surrounding casing seal against over tip leakage of hot working gases. The first fins 66 and second fins 68 generally align with and abut to respective first and second fins on circumferentially adjacent blades 51 to form a circumferential ring of first and second fins. The second fins 68 have widened end surfaces 70, 72 and immediately adjacent blades have opposing ends surfaces 70, 72 contacting or abutting one another.

[0029] The shroud 56 has shaped circumferential ends 74 and 75, only one of which is shown, having three planar portions 78, 70, 76 which abut or have a minimum gap between respective planar portions on the adjacent blade shroud. These three planar portions 78, 70, 76 are generally aligned with the radial direction and are angled relative to the rotational axis 20 in an orthogonal direction when in situ. The three planar portions 78, 70, 76 are angled to one another such that their surfaces form a Z-shape when viewed radially inwardly. The middle planar portion is the widened end surface 70, 72. This type of shroud arrangement can be referred to as an interlocked shrouded tip. Where two blades 80 abut one another at their respective circumferential end 74 and circumferential end 75, the joint is referred to as an interlock joint. Thus the interlock joint comprises the three planar portions 78, 70, 76. This is just one example of an interlock joint and other blades may have other interlock joint arrangements.

[0030] During engine operation the blades and therefore shrouds are subjected to vibrations which are

damped by the action and friction of the surface contact between the interlock faces or planar portions 78, 70, 76. Damping is controlled by the level of force between each pair of interlock faces. The contact and sliding of these interlock faces results in wear of the surfaces. As wear increases, the interlock surface coating thickness decreases, or in the case of no coating, the parent material is reduced. The force on the interlock faces, particularly the widened end surface 70, 72, is provided by twist or torsion in the blades during operation. The twist or torsion is created by an angular rotation about a generally radial line through the blade. The angular rotation is created between a blade unassembled and assembled states. From an unassembled state to an assembled state, in which an annular array of blades are mounted to a disc, the blade's tip is rotated about a radial axis and relative to the root such that the interlock joints of adjacent blade's mate or are flush with one another.

[0031] The root portion 50 has two lateral sides 81A, 81B each defining at least one bearing surface 80 and at least one end surface 82R, 82F. The root portion 50 can have a generally bulb-shaped cross-section, but in a turbine the root portion 50 is often a fir-tree shape with multiple bearing surfaces 80 on each lateral side 81A, 81B as shown in the FIG.3. The blade's bearing surfaces 81A, 81B engage complimentary bearing surfaces formed in the rotor disc.

[0032] The blade's bearing surfaces 81A, 81B are straight whereas the interlock surfaces 78, 70, 76 are Z-shaped and generally are not parallel to the bearing surfaces 81A, 81B. Therefore, during assembly of the blades to the disc, it is not possible to simply slide each blade in turn into its disc slot because the shrouds will foul one another. During operation the interlocked shrouded tips are subjected to vibrations which are damped by the use of a sliding contact between the interlock faces. These interlock surfaces may be in contact during cold build which means the blades cannot be assembled singly but need to be assembled to the disc as a set, i.e. the array of blades. The force between adjacent blade's interlock surfaces is related to the blade torsion and so a twisting force is required to be imparted on the blade during assembly to the disc as an array of blades. Depending on blade geometry, including the degree of twist, desired torsion and the size of the blades, the amount of force required to assemble the blades may be considerable.

[0033] Also, it is important to control the assembly force so as not to damage the blades or the disc. The use of excessive force on a blade during assembly may result in component damage. Specifically, impact forces on blades applied manually via a hammer can be particularly detrimental to the life of the blades and disc.

[0034] This problem also applies to dismantling the blades from the disc after service. Although the blades may be deemed end-of-life, it may be a requirement for the disc to be used again. In certain cases the blades may be refurbished for further use, and so it is important not to damage the blades or the disc during removal.

[0035] The blade 51 has a centre-of-resistance line 84 which passes through the root portion 50 and in this example is generally parallel to a plane of at least one bearing surface 80. The centre-of-resistance line 84 intersects the end surfaces 82R, 82F at an intersection point 85. The centre-of-resistance line 84 is a line or axis that represents the position on the end surface 82R, 82F, the intersection point 85, and direction, along the line 84, where a point contact will be balanced with respect to resistance encountered in forcing the blade 51 into the corresponding slot on the disc 35. The resistance is caused by friction between bearing surfaces 80 on the blade and disc slot resulting from twisting of the blades 51 by engagement of the interlocking shrouds. The end surface 82R and/or 82F of the blade 51 comprises an assembly feature 86 which is arranged about the intersection point 85.

[0036] In FIG.4 the root portion 50 can be seen to have a central axis 91 which is parallel to the bearing surfaces 80 of both lateral sides 81A, 81B. The central axis 91 is angled ϑ relative to the engine's rotational axis 26. The rotational axis of the rotor disc the blades are attached to is common with the engine's rotational axis. The central axis 91 is generally parallel to the centre-of-resistance line 84. Thus the root portions 50 and respective disc slots are angled ϑ from the rotational axis 26 when viewed along a radial line. It is possible that the root portion and disc slot are arranged parallel to the engine's rotational axis in other examples.

[0037] The assembly feature 86 is configured to engage with an assembly tool 87 as seen in FIG.5 and FIG.6. The assembly tool 87 comprises a ring 88 mountable to the slave disc 101 via a slidable mounting 89. In this exemplary embodiment, the slidable mounting 89 is defined by an annular array of root features 89 on the radially inner part of the ring 88 and slot features 102 on the slave disc 101. The root features 89 engage with the complimentary slot features 102 on the slave disc 101 which is arranged about an axis 26'. The assembly tool 87 further comprises an annular array of fingers 90, which each have a longitudinal axis 92. The fingers 90 extended in a generally axial direction, but their longitudinal axes 92 are arranged to have an angle ϑ from the axis 26'. When the assembly tool 87 is in position to insert the blades into the disc, the axis 26' is coaxial with the rotational axis 26.

[0038] The slidable mounting 89 is arranged to have a slide angle ϑ to the axis 26', 26. Here the central axis 91 and the longitudinal axis 92 are generally parallel to one another and both subtend approximately the same angle ϑ relative to the axis 26. Similarly, the root features 89 and the slot features 102 on the slave disc 101 are angled approximately the same angle ϑ relative to the axis 26.

[0039] To assemble the blades 51 to the disc 35, the blades 51 are first manually fed into the disc slot a short distance of the length of the slot/root portion. The interlocking nature of the shrouds 56 causes a twist in the blade and once the blades are inserted a short distance of the slot no further manual insertion is possible. The

disc 35, with the blades partially assembled, is held in place to prevent any movement. The assembly tool 87, located in its assembly disc, is brought nearby and the assembly disc is clamped in position to prevent any movement of the assembly disc. Forcing means, such as hydraulic rams, then drive the assembly tool 87 which travels along the assembly disc slot in a direction along the longitudinal axis 92 so that a free end 93 of the fingers 90 each engage with one assembly feature 86 on each of the blades 51. As the forcing means continues to drive the assembly tool 87 along its assembly disc slot the blades 51 are forced into their desired location in their disc slots.

[0040] Previous assembly of the blades to the disc 35 was manual forcing via a hammer or vibratory hammer applied to a plane (featureless) end surface 82R, 82F. The direction of the force was through the root portion 50 and in a direction parallel to the axis 26. This assembly technique often caused damage to the end surface of the blade and caused distress to the bearing surfaces, blade root and disc slot. The manual force was applied in an axial direction to stop the hammer scraping and slipping off the end surface and possibly damaging the disc. The direction of application, at an angle to the bearing surfaces and centre-of-resistance line 84 caused the features of the root and slot to clash. Furthermore, different manual forcing pressures from one blade to another were inevitable causing different or uneven insertion distances and subsequently often the blades locked against each other resulting in partial disassembly and reassembly.

[0041] The present invention solves these problems by virtue of the assembly tool 87 and by virtue of the assembly feature 86 as will now be described in further detail.

[0042] In the exemplary embodiment shown in FIG.3 and FIG.4, the assembly feature 86 of the blade defines a generally flat contact surface 94. The flat contact surface 94 is generally perpendicular to the centre-of-resistance line 84. Therefore, the generally flat contact surface 94 is not parallel to the end surface 82R, 82F. In this exemplary embodiment the flat contact surface 94 is symmetrical about the centre-of-resistance line 84. The flat contact surface 94 is recessed into the end surface 82R, 82F and as such is more deeply recessed towards one lateral side 81B than the other lateral side 81A. Thus the flat contact surface 94 and the end surface(s) 82R, 82F are not in the same plane as one another. The flat contact surface 94 and the end surface(s) 82R, 82F can have an angle ϑ between their respective planes. The flat contact surface 94 is at an approximate angle ϑ to the axis 26. A small radius 96 is formed between the flat contact surface 94 and the recess sides 95. The recess sides 95 prevent the fingers 90 from sliding across the end surfaces 82R, 82F and undesirable causing damage.

[0043] A coating 97 may be applied to the assembly feature 86 to prevent damage to the underlying base material. Such a coating 97 may be a harder material over-

lying the root material or may be a composition diffused into the surface of the root material to harden it and increase its resistance to assembly damage such as scratching or crushing or cracking.

[0044] The flat contact surface 94 is shown as a generally circular shape although in other embodiments the flat contact surface can be oval, triangular or rectangular. Preferably, the free end 93 of the fingers 90 has the same general shape as the flat contact surface 94 although the free end 93 will be slightly smaller in area than the flat contact surface 94 so that it fits into or against the assembly feature.

[0045] In **FIGS.7A and 7B** the assembly feature 86 defines a curved contact surface 100 that is generally perpendicular to the centre-of-resistance line 91. In **FIG. 7A** at least a portion of the curved contact surface 100 defines a concave shape and in **FIG.7B** the curved contact surface 100 is a convex shape. The free end 93 of the finger 90 has a complimentary shape, such that the corresponding finger shapes for **FIG.7A** is a convex contact surface and for **FIG.7B** a concave shape. In use, the complimentary contact surfaces of the assembly feature 86 and fingers 90 are largely contact one another over their contact surfaces and are therefore similar in curvature. These complimentary contact surface shapes are intended to further prevent slipping of the fingers 90 across the end surfaces 82R, 82F by one of the surfaces being recessed. Nonetheless, where either the assembly feature 86 or the fingers 90 have a convex shape the other surface may be flat such that there is a smaller contact area than the two identically shaped contact surfaces e.g. both contact surfaces being flat or being concave-convex and convex-concave contact surfaces having the same radius. In this case the sides or lip 95 of the recess will prevent the fingers 90 from disengaging with the assembly feature 86 and scoring or damaging the end surface.

[0046] In all cases, the convex and concave shapes of the contact surfaces preferably have a centre-line 91 which is approximately located at the intersection point 85. As shown in **FIGS.7A and 7B**, the centre-of-resistance line 84 is coincident and coaxial with the centre-line of the convex and concave contact surfaces.

[0047] The assembly feature 86 has a generally cylindrical shape with a longitudinal axis of the cylinder aligned with and preferably coaxial with the centre-of-resistance line 84. In other examples, the assembly feature 86 may be conical and frusto-conical in shape and similarly aligned.

[0048] As can be seen in **Figs.3 and 4** the assembly feature 86 is recessed into the end surface 82R, 82F of the blade root. However, the assembly feature 86 may be proud of the main or datum or existing end surface 82R, 82F such as shown in **Figs.8 and 9**. In other words the assembly feature 86 extends or projects from the end surface 82R, 82F and generally along the centre-of-resistance line 84. This embodiment of the assembly feature 86 is cylindrical but may be rectangular, conical and

frusto-conical in cross-sectional shape and similarly aligned to the previously described embodiments.

[0049] In **FIG.8** the assembly feature 86 defines the generally flat contact surface 94 which is recessed into the assembly feature 86 projection and defines the recess sides 95. The finger 90 is formed similarly to the **FIG.5** embodiment and does not need further explanation. In similar fashion to the **FIG.7A and 7B** embodiments, the assembly feature 86 and finger 90 may have complimentary curved contact surfaces 100, 93 as shown by the dashed lines. In the **FIG.8** and indeed the **FIGs.4-7** examples the finger 90 fits into the recess formed by the assembly feature 86.

[0050] In **FIG.9** the finger 90 forms the recess and has recess sides 95. The assembly feature 86 then fits into the recess. The complimentary contact surfaces of the assembly feature and the fingers are configured in the various embodiments as hereinbefore described.

[0051] The terms assembly feature and assembly tool are not intended to be limited solely to the assembly of blades 51 to the disc 35, but instead these terms also include disassembly of the blades 51 and the disc 35. Thus the terms assembly feature and assembly tool can be read as assembly/disassembly feature and assembly/disassembly tool. Simply, the assembly tool can be positioned on the opposite side of the blades 51 and disc 35 as shown in **FIG.7** and a force applied to slide the blades out of their slots in the disc.

Claims

1. A blade (51) for assembling to a rotor disc (35) comprises
 - a root portion (50), an aerofoil (54) and a shroud (56), the root portion (50) has two lateral sides each defining at least one bearing surface (80) and at least one end surface (82R, 82F),
 - the blade (51) has a centre-of-resistance line (84) which passes through the root portion (50) and is generally parallel to a plane of at least one bearing surface (80),
 - the centre-of-resistance line (84) intersects the at least one end surface (82R, 82F) at an intersection point (85),
 - the at least one end surface (82R, 82F) comprises an assembly feature (86) having a contact surface (94, 100) arranged about the intersection point (95).
2. A blade (51) as claimed in claim 1 wherein the centre-of-resistance line (84) is generally parallel to a plane of at least one bearing surface (80).
3. A blade (51) as claimed in any one of claims 1-2 wherein the assembly feature (86) comprises the contact surface (94) recessed in the at least one end surface (82R, 82F).

4. A blade (51) as claimed in any one of claims 1-2 wherein the assembly feature (86) comprises a projection extending from the at least one end surface (82R, 82F). 10-12 wherein the finger (90) defines a recess in which the contact surface (93) is located.
5. A blade (51) as claimed in any one of claims 1-4 wherein the assembly feature (86) defines a generally flat contact surface (94) that is generally perpendicular to the centre-of-resistance line (84). 5 14. An assembly tool (87) as claimed in any one of claims 10-13 wherein the contact surface (93) has a shape of any one of the group comprising flat, curved, convex and concave. 10
6. A blade (51) as claimed in claim 5 wherein the generally flat contact surface (94) is not parallel to the at least one end surface (82R, 82F). 15
7. A blade (51) as claimed in any one of claims 1-6 wherein the assembly feature (86) defines a curved contact surface (100) that intersects the centre-of-resistance line (84), the curved contact surface (100) can be any one of the group comprising convex or concave shapes. 20
8. A blade (51) as claimed in any one of claims 1-7 wherein the assembly feature (86) defines a lip at least partly surrounding the contact surface (94, 100). 25
9. A blade (51) as claimed in any one of claims 1-8 wherein the shroud (56) is an interlocking shroud. 30
10. An assembly tool (87) for assembling an array of blades (51) to a rotor disc (35), the assembly tool (87) comprising 35
a slave disc (101) having an axis (26'),
a ring (88) mountable to the slave disc (101) via a slidable mounting (89) and defining an array of generally axially extending fingers (90) for engaging an assembly feature (86) on each blade of the array of blades (51), 40
the slidable mounting (89) is arranged to have a slide angle ϑ to the axis (26'),
the fingers (90) comprise a contact surface (93) configured for engagement with a contact surface (94, 100) of an assembly feature (86) on the blades (51). 45
11. An assembly tool (87) as claimed in claim 10 wherein each finger (90) of the annular array of fingers extending from the ring in a direction along a longitudinal axis (92), the longitudinal axis (92) is arranged to have an angle ϑ from the axis (26'). 50
12. An assembly tool (87) as claimed in any one of claims 10-11 wherein the contact surface (93) is flat or curved. 55
13. An assembly tool (87) as claimed in any one of claims

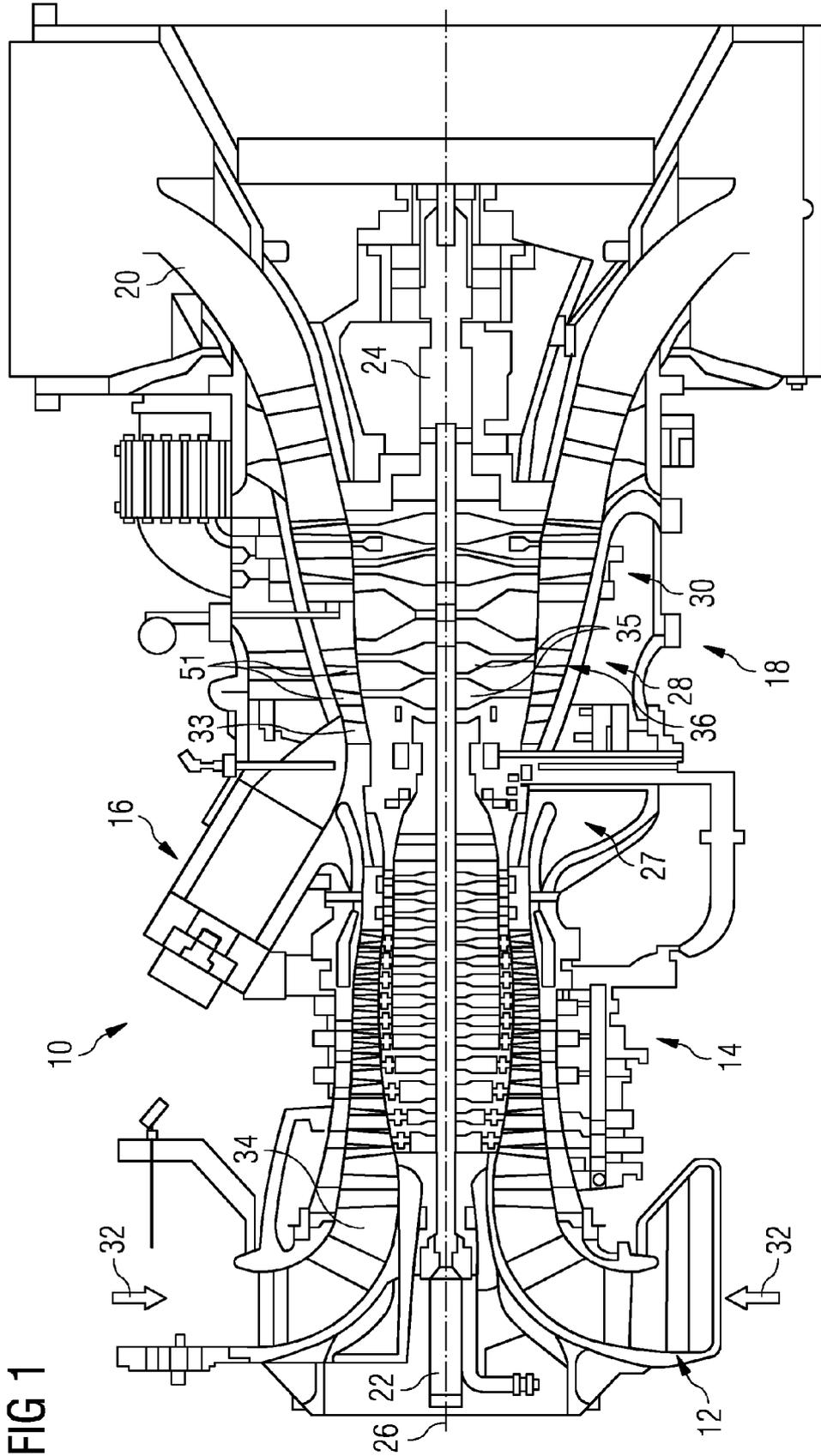


FIG 2

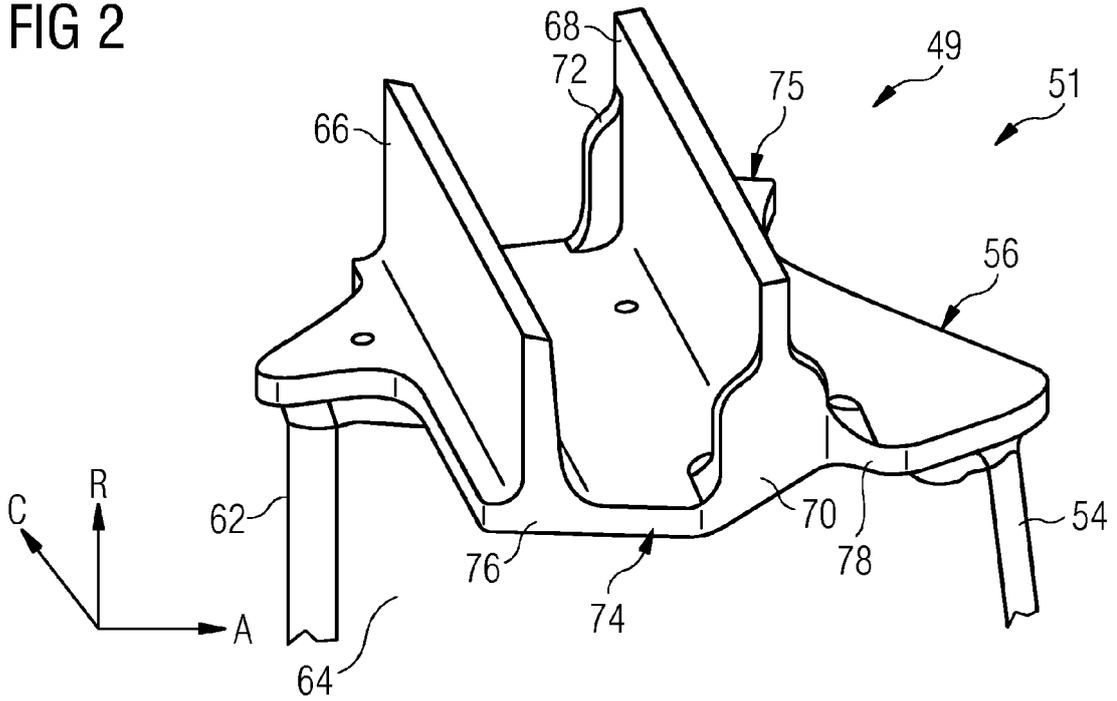


FIG 3

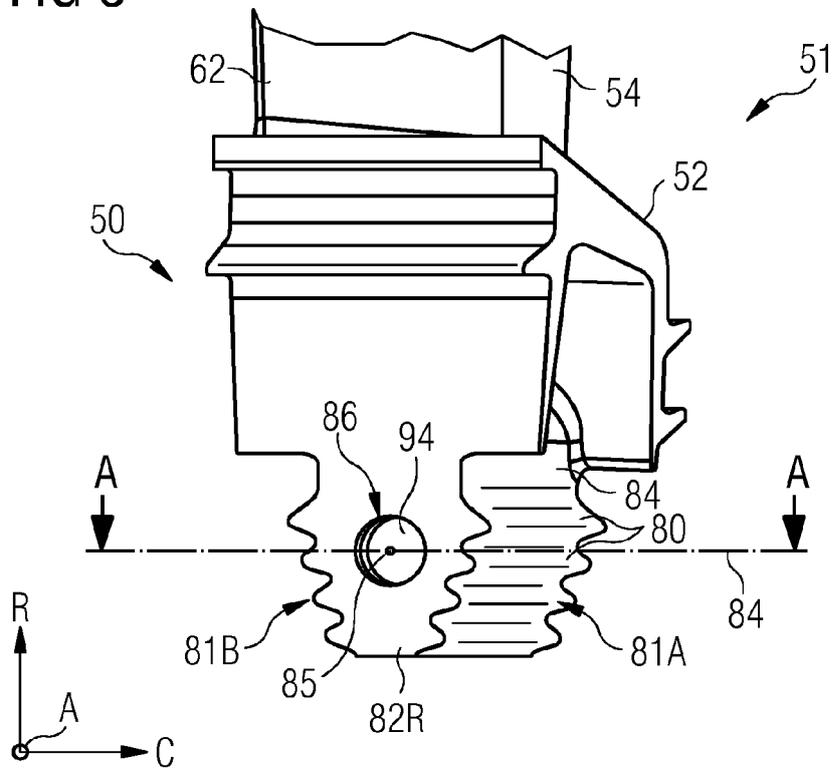


FIG 4

Section A-A

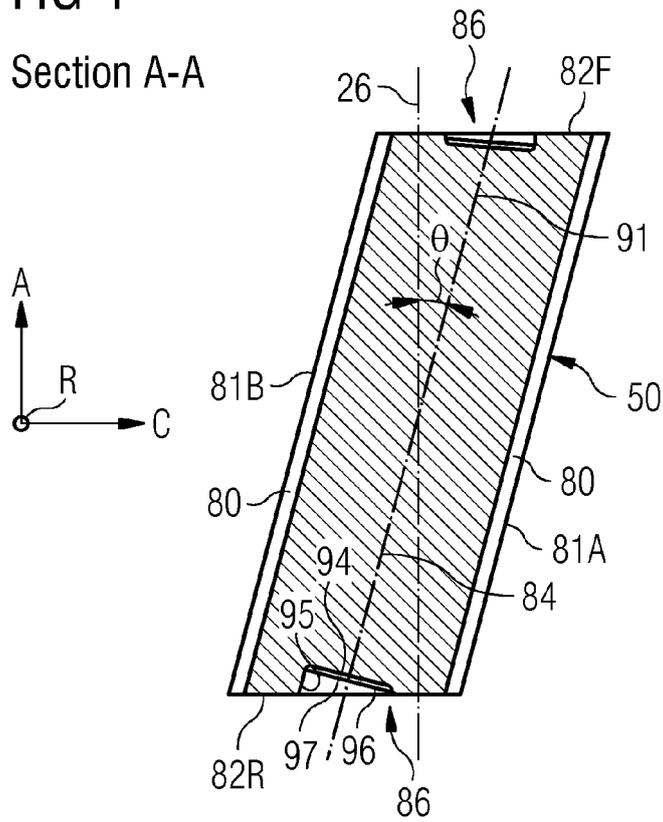


FIG 5

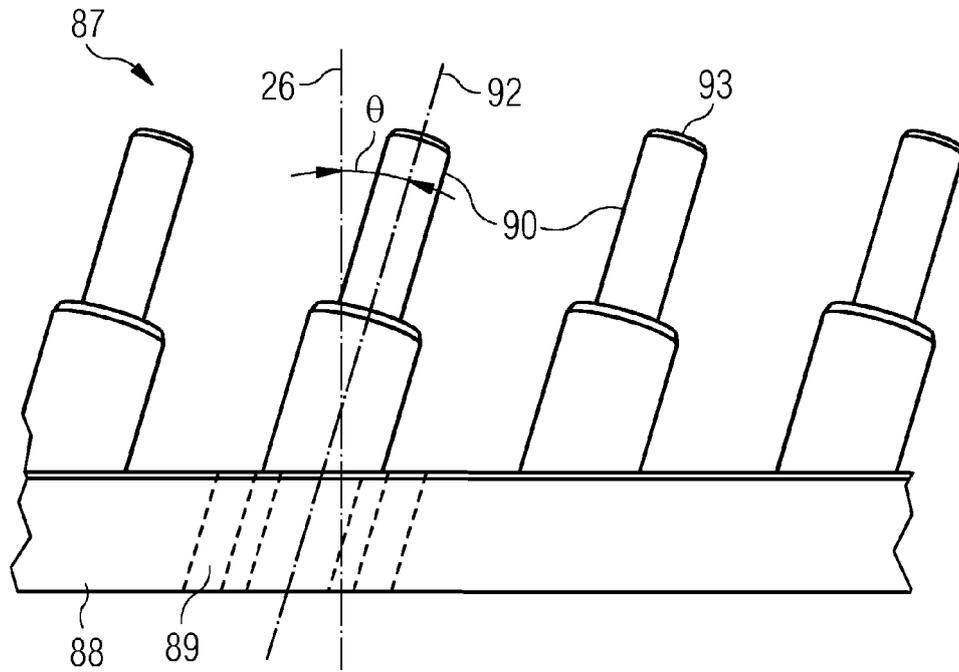


FIG 6

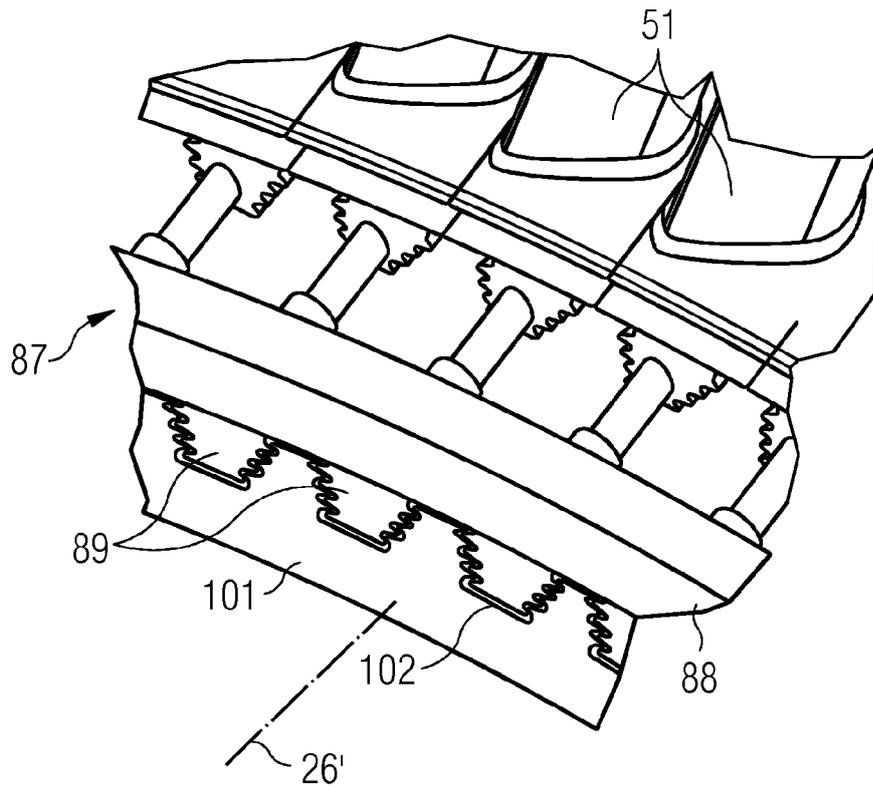


FIG 7A

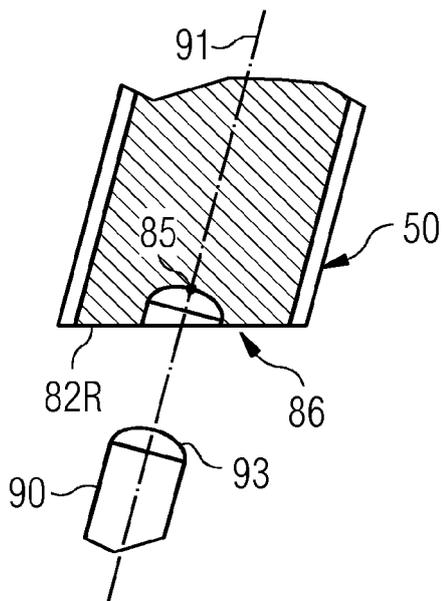


FIG 7B

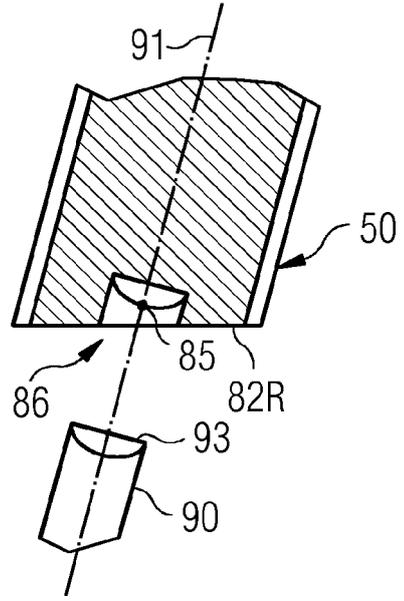


FIG 8

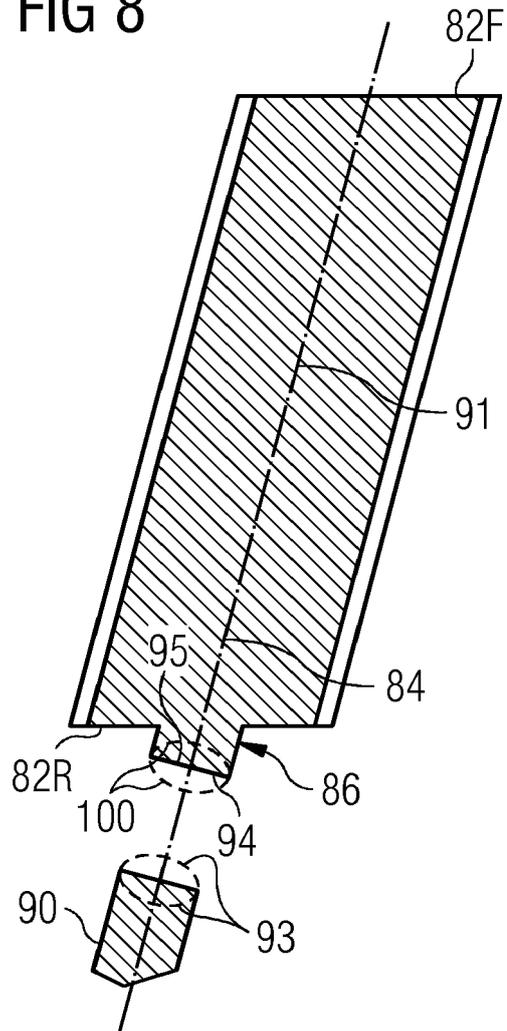
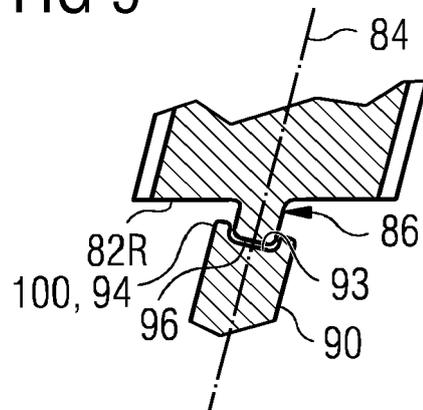


FIG 9





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