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(54) DEVICE AND METHOD FOR HEAT TREATING A ROTOR OR ROTOR DISC OF A TURBOMACHINE

(57) A device (7) for heat treating a rotor (2) or rotor disc of a turbomachine has an element (8) with at least a surface area (9) arranged for contacting a surface (10) to be treated of the rotor (2) or rotor disc, connectors (12) arranged for elastically pressing the surface areas (9) of the element (8) against the surface (10) to be treated of the rotor (2) or rotor disc, heaters (15) connected to the element (8), temperature sensors (16) connected to the element (8), a control unit (17) for driving the heater (15) based on a temperature measured by the temperature sensor (16).

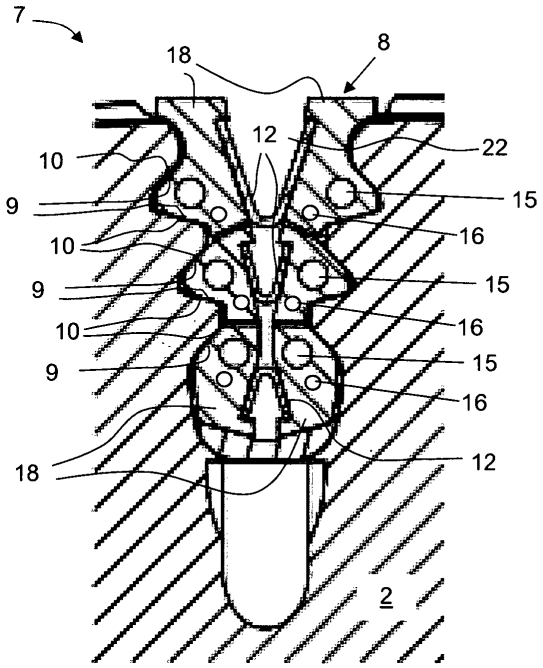

Fig. 4

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Description

TECHNICAL FIELD

[0001] The present invention relates to a device and method for heat treating a rotor or rotor disc of a turbomachine.

[0002] The turbomachine can for example be a gas turbine, a steam turbine or another turbomachine, such as a turbogenerator or a hydro generator.

BACKGROUND

[0003] Rotors or rotor discs (in the following both addressed as rotors) during manufacturing undergo a heat treatment to relax stress and to improve material properties. After this initial heat treatment, rotors as a rule do not undergo further heat treatments, because material properties would be inevitably affected. For example, rotors of a gas turbine may be manufactured by welding together a plurality of discs; typically, after welding, the rotor discs undergo a heat treatment to relax stress in the heated affected zones.

[0004] During operation, rotors undergo large stress that may cause crack initiation; for example, areas of the rotor prone to crack initiation are the teeth defining slots where blades (e.g. turbine blades or compressor blades) or generator windings are connected. When this happen, the cracks as a rule are monitored and in case their size becomes too large, the rotors are replaced. Thus, the impossibility to carry out heat treatments on the rotors after manufacturing prevents the rotors from being repaired when cracks are identified.

SUMMARY

[0005] An aspect of the invention includes providing a device and a method for heat treating rotors or rotor discs after the initial heat treatment carried out during manufacturing.

[0006] These and further aspects are attained by providing a device and a method in accordance with the accompanying claims.

[0007] For example, a heat treatment after the initial heat treatment can be required during servicing of a turbomachine, when cracks on the rotor are identified. In such a case the cracks could be repaired e.g. by welding and a heat treatment to relax the stress caused by the welding and improve the material properties of at the area where welding was carried out could be required.

[0008] Advantageously, the heat treatment is a localised heat treatment, so that the bulk of the rotor material is not affected by the heat treatment and the material properties thereof are thus not affected, but a localised area where e.g. reparation occurred or stress relaxation was required undergoes the heating/staying/cooling cycle foreseen by the heat treatment.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] Further characteristics and advantages will be more apparent from the description of a preferred but non-exclusive embodiment of the device and method, illustrated by way of non-limiting example in the accompanying drawings, in which:

Figure 1 shows a side view of a rotor of a turbomachine, such as a gas turbine;

Figure 2 shows a portion of a cross section through line II-II of the rotor of figure 1;

Figures 3A through 5B show embodiments of a device with parts thereof pressed outwardly;

Figure 6 shows an embodiment of the device with parts thereof pressed inwardly;

Figure 7 shows a plurality of devices applied onto a rotor for carrying out the method;

Figure 8 is a particular of a device connected to a tooth of a rotor or rotor disc of a gas turbine.

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

[0010] With reference to the figures, figure 1 shows a rotor 1 for a turbomachine, such as a gas turbine or a steam turbine or a turbogenerator or a hydro generator.

[0011] The rotor 1 is typically made of a plurality of rotor discs 2 connected together, e.g. by bolts or welding. Alternatively the rotor may also be made in one piece, e.g. forged in one piece.

[0012] Figure 2 shows a portion of a cross section through line II-II of figure 1 and shows the profile of the rotor or rotor disc with teeth 3 defining slots 4 inbetween; the slots 4 house and hold blades, e.g. of a turbine or compressor. In different embodiments the slots may also hold the winding of a turbogenerator or a hydro generator. Figure 2 specifically shows the teeth 3 and slots 4 of a gas turbine where turbine rotor blades are connected via their root.

[0013] The device 7 for heat treating the rotor or rotor disc has an element 8 with at least a surface area 9 arranged for contacting a surface 10 to be treated of the rotor or rotor disc 2.

[0014] The device 7 has a connector 12, which is arranged for elastically pressing the surface areas 9 of the element 8 against the surface 10 to be treated of the rotor or rotor disc 2.

[0015] The device 7 further has one or more heaters 15, such as electric resistors, connected to the element 8 and one or more temperature sensors 16, such as thermocouples, connected to the element 8 as well.

[0016] A control unit 17 is provided, for driving the heat-

ers 15 based on a temperature measured by the temperature sensors 16.

[0017] In preferred embodiments, the element 8 comprises at least two parts 18 having at least a heater 15 and at least a temperature sensor 16.

[0018] In this connection, the parts 18 have at least a first hole that houses the heater 15. The heater may be interchangeable, such that a specific heater, able to supply the required heat flux, can be provided according to the heat treatment to be carried out.

[0019] Advantageously, the first hole is adjacent the surface area 9 of the element. This because the heat is transferred to the rotor or rotor disc via the contacting surface areas 9 of the element 8 and surface 10 of the rotor or rotor disc.

[0020] The parts 18 further have one or more second holes housing the temperature sensor or sensors 16. For example, the second holes are blind holes that open at the opposite sides of the part 18; a thermocouple as a temperature sensor 16 is inserted in each of the second holes.

[0021] The parts 18 are advantageously at opposite sides of the element 8, such that the element 8 can be steadly connected into a slot 4. In such a case, between the parts 8 a thermal insulator 22 is provided, so that heat provided at one side of the element 8 does not affect the other side. For example, in case the heat treatment is only carried out at one side of the element 8, the other side is not heated or is heated in a non effective manner, i.e. in a manner non effective to alter the properties of the rotor or rotor disc. The thermal insulator may be defined by an air gap or by thermally insulating material.

[0022] Different embodiments are foreseeable for the connector 12.

[0023] The connector 12 can be provided between the parts 18 and can be arranged for elastically pressing the parts outwardly.

[0024] For example the connector 12 can comprise one or more springs, such as leaf springs, special springs (like V shaped springs), helical springs, etc..

[0025] In a different embodiment, the connector 12 can comprise one or more wedge shaped bodies 23, 34; accordingly, the parts 18 at opposite sides of the element 8 can define a wedge shaped seat 24 and the surfaces of the wedge shaped bodies 23, 34 are slidingly connected to the wedge shaped seat 24. Springs are also provided that press the wedge shaped bodies 23, 34 against the wedge shaped seat 24.

[0026] In addition, the element 8 can further comprise a bottom part 25, also having heater 15. Bolts 27 are connected to the bottom part 25 and extends through the wedge shaped bodies 23, 34. The springs 28 are inserted on the bolt 27 between stops 29 provided at the bolt end opposite the end connected to the bottom part 25 and the wedge shaped bodies 23, 34. For example, two bolts 27 can press the wedge shaped body 23 to the bottom part 25 and two further bolts 27 can press the wedge shaped body 34 to the bottom part 25. Thanks to the shape of the wedge shaped bodies 23, 34 and the shape of the wedge shaped seat 24, the surface areas 9 are pressed to the surface 10 to guarantee thermal conductivity.

[0027] The figures show embodiments where the element 8 has a fir tree surface profile 30, with the fir tree surface profile 30 defining side projections 32. Advantageously, each side projection 32 is defined by one part 18.

[0028] The connector 12 can also be provided around the parts 18 and can be arranged for elastically pressing the parts 18 inwardly. In this case the connector 12 can comprise one or preferably more than one elastic band, provided around the elements. Other embodiments of connector 12 may include bands made of a rigid element with ends of the rigid element connected by an elastic element; for example a metal wire whose ends are connected by a helical spring may be envisaged.

[0029] Particular embodiments are now described with specific reference to the figures.

[0030] Figure 3A shows an embodiment of a device 7 with an element 8 made of five parts 18. Each part 18 at the sides of the element 8 has a first hole housing a heat resistance as a heater 15 and second holes opening at opposite sides thereof and each housing a thermocouple as temperature sensor 16. Leaf springs are provided between side-by-side parts 18 as connectors 12, to guarantee the contact and thermal conductivity between the surface areas 9 and the surfaces 10.

[0031] Likewise, figure 3B shows an embodiment similar to the one of figure 3A; this embodiment is arranged for heat treating a tooth 3 only at a side thereof and consequently the parts 18 at the right of figure 3B are not provided with heaters and temperature sensors. In this case it is possible that parts without hole for housing the heater 15 or temperature sensors 16 are provided or the holes may be left empty or also the heaters 15 and temperature sensors 16, even if provided, are not used, i.e. are not connected to the control unit 17 or their signal is not used to drive the heat treatment. The temperature measurement can anyway be used to control the temperature at the tooth 3 that does not undergo heat treatment. Figure 3B also shows the bottom part 18 with an asymmetric shape defining a cutout 35, so that it only contacts the tooth 3 to be treated (tooth on the left in figure 3B) but not the tooth 3 that does not have to undergo heat treatment (tooth on the right in figure 3B).

[0032] Figure 4 shows an embodiment of a device 7 with an element 8 made of six parts 18.

[0033] Each part 18 has a first hole housing a heat resistance as a heater 15 and second holes housing thermocouples as temperature sensors 16. V-shaped springs as connectors 12 are provided between side-by-side parts 18 to guarantee the contact and the thermal conductivity between surface areas 9 and surfaces 10.

[0034] Figures 5A-5B show an embodiment of a device 7 with an element 8 made of four parts 18 and an additional bottom part 25. The parts 18 at the sides have first holes housing heat resistances as a heater 15 and sec-

ond holes housing thermocouples as temperature sensors 16. The side parts 18 define a wedge shaped seat 24 and wedge shaped bodies 23 and 34 are slidingly provided in the seat 24. The bottom part 25 has first holes housing heat resistances as a heater 15, and second holes housing thermocouples as temperature sensors 16.

[0035] Figure 6 shows an embodiment of a device 7 with an element 8 made of six parts 18.

[0036] Each part 18 has one first hole housing a heat resistance as a heater 15 and second holes housing thermocouples as temperature sensors 16. Elastic bands are provided around the parts 18 as connectors 12.

[0037] In the following, with reference to figure 7, the arrangement of the rotor or rotor disc connected to one or more devices 7 for heat treating it is described.

[0038] The surface profile 30 of the element 8 fits a surface profile 31 of a tooth 3; the element 8 is housed in a groove 4 with its surface profile 30 matching the surface profile 31 of the tooth 4. Surface areas 9 of the element 8 contact surfaces 10 to be treated of the rotor or rotor disc and surface portions 33 of the element 8 adjacent the surface areas 9 do not contact the surface profile 31.

[0039] Thanks to the device the rotor or rotor disc can be locally heat treated.

[0040] In fact, since the surfaces area 9 through which heat is transferred from the device 7 to the rotor or rotor disc are in contact with the surfaces 10 to be treated, the heat treatment can be carried out at the surfaces 10 and zones of the rotor or rotor disc adjacent thereto. These are the zones of the rotor or rotor disc, which e.g. got a welding repair and require a heat treatment to reduce the stress. In contrast, since the surface portions 33 of the element 8 do not contact the surface profile 31, there is no or no appreciable heat transferred trough these surfaces. This way, the heat transferred and thus the heat treatment can be easily controlled.

[0041] The present invention also refers to a method for heat treating a rotor or rotor disc of a turbomachine.

[0042] The method comprises heating a rotor tooth 3 at both its sides by one or more devices 7.

[0043] Advantageously, thanks to the devices 7, the heat treatment can be carried out while maintaining the temperature through the tooth 3 uniform or substantially uniform, i.e. differences of temperature through the tooth are in a limited range, e.g. 20 °C or 10°C or less. This uniformity of temperature during the heat treatment guarantees that stress is not induced in the tooth 3 because of the heat treatment but to the contrary stress can be relieved. In addition, the material properties of the whole of the rotor or rotor disc are not affected, because the heat treatment is carried out only at a portion thereof.

[0044] The operation of the device 7 is apparent from that described and illustrated and is substantially the following.

[0045] In the following specific reference to the embodiments of figures 3 through 5 is made.

[0046] Devices 7 are provided in slots 4 at the opposite sides of one tooth 3.

[0047] The control unit 17 then drives the heaters 15, such that they supply heat to the parts 18 and via the surface areas 9 to the surfaces 10 to be treated and zones adjacent thereto.

[0048] The control unit 17 can drive the heater 15 based on the temperature measured by the temperature sensors 16. In this connection, the control unit 17 can drive each heater 15 independently from the others and only based on the temperature measured by the temperature sensors 16 adjacent to it and housed in the same part 18. Different controls are naturally possible, and the control unit 17 can drive the heaters 15 based on average temperatures measured by all or part of the temperature sensors 16.

[0049] In addition, the control unit 17 can drive the heaters 15 based on the measurements of the temperature sensors 16 in order to cause a predefined temperature profile over time through the tooth 3.

[0050] In particularly advantageous embodiments, the heating to be provided or the temperature cycle the rotor tooth 3 has to undergo is calculated first and the control unit 17 drives the heaters 15 based on the measurements of the temperature sensors 16 to reproduce the calculated heating or temperature cycle.

[0051] Advantageously, thanks to the devices 7, heat treatment is carried out only at the teeth 3. The surfaces 10 of the teeth through which heat is transferred (i.e. the surfaces 10 in contact with the surface areas 9) are those more stressed during operation, because of the interaction with the blade roots.

[0052] The parts 18 defining the element 8, heaters 15, temperature sensors 16, connectors 12 may define a kit of components that may be assembled to carry out the heat treatment and then disassembled, as required for each specific heat treatment to be carried out in terms of heating to be transferred and teeth to be treated.

[0053] Naturally the features described may be independently provided from one another. In practice the materials used and the dimensions can be chosen at will according to requirements and to the state of the art.

Claims

1. A device (7) for heat treating a rotor (2) or rotor disc of a turbomachine, **characterised by** comprising

   an element (8) with at least a surface area (9) arranged for contacting a surface (10) to be treated of the rotor (2) or rotor disc,
   at least a connector (12) arranged for elastically pressing the at least a surface area (9) of the element (8) against the surface (10) to be treated of the rotor (2) or rotor disc,
   at least a heater (15) connected to the element (8),

at least a temperature sensor (16) connected to the element (8),
a control unit (17) for driving the heater (15) based on a temperature measured by the temperature sensor (16).

2. The device (7) of claim 1, **characterised in that** the element (8) comprises at least two parts (18) having at least a heater (15) and at least a temperature sensor (16).

3. The device (7) of claim 2, **characterised in that** the at least two parts (18) are at opposite sides of the element (8), wherein a thermal insulator (22) is provided between the parts (8).

4. The device (7) of any of the previous claims, **characterised in that** each part (18) has at least a first hole housing the at least a heater (15).

5. The device (7) of claim 4, **characterised in that** the first hole is adjacent the surface area (9) of the element (8).

6. The device (7) of any of any of the previous claims, **characterised in that** each part (18) has at least a second hole housing the at least a temperature sensor (16).

7. The device (7) of any of claims 1 through 6, **characterised in that** the connector (12) is provided between the at least two parts (18) and is arranged for elastically pressing the two parts (18) outwardly.

8. The device (7) of claim 7, **characterised in that** the connector (12) comprises a spring.

9. The device (7) of claim 8, **characterised in that**

the parts (18) at opposite sides of the element (8) define a wedge shaped seat (24),
wherein
the connector (12) further comprises at least a wedge shaped body (23, 34), surfaces of the wedge shaped body (23, 34) are slidingly connected to the wedge shaped seat (24),
the spring presses the wedge shaped body (23, 34) against the wedge shaped seat (24).

10. The device of any of claims 1 through 6, **characterised in that** the connector (12) is provided between the at least two parts (18) and is arranged for elastically pressing the two parts inwardly.

11. The device (7) of any of any of the previous claims, **characterised in that** the element (8) has a fir tree surface profile (30),
the fir tree surface profile (30) of the element (8) defines side projections (32), each side projection (32) is defined by one part (18).

12. A kit of components comprising parts (18) arranged for defining an element (8), heaters (15), temperature sensors (16), connectors (12), control unit (17), wherein the components can be assembled defining a device (7) according to any of claims 1 through 11.

13. An arrangement of a rotor (2) or rotor disc and a device (7) according to any of claims 1 through 11, **characterized in that**

the rotor (2) or rotor disc has teeth (3) defining grooves (4) arranged for housing blades or windings,
the element (8) is housed in a groove (4) with its surface profile (30) matching a surface profile (31) of the tooth (3),
surface areas (9) of the element (8) contact surfaces (10) to be treated of the rotor (2) or rotor disc,
surface portions (33) of the element (8) adjacent the surface areas (9) do not contact the surface profile (31) of the rotor (2) or rotor disc.

14. A method for heat treating a rotor (2) or rotor disc of a turbomachine, comprising heating a rotor tooth (3) at both its sides by at least a device (7) according to any of claims 1 through 11.

15. The method of claim 14, **characterized in that**

a heating to be provided to the rotor tooth (3) or a temperature cycle the rotor tooth (3) has to undergo is calculated, and
a control unit (17) drives heaters (15) based on measurements of temperature sensors (16) of the at least a device (7), to reproduce the calculated heating or temperature cycle.

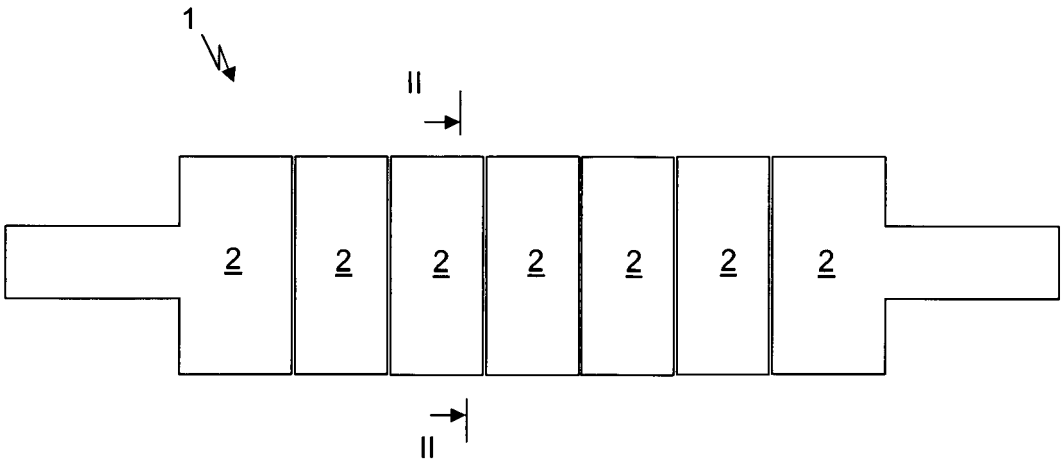

Fig. 1

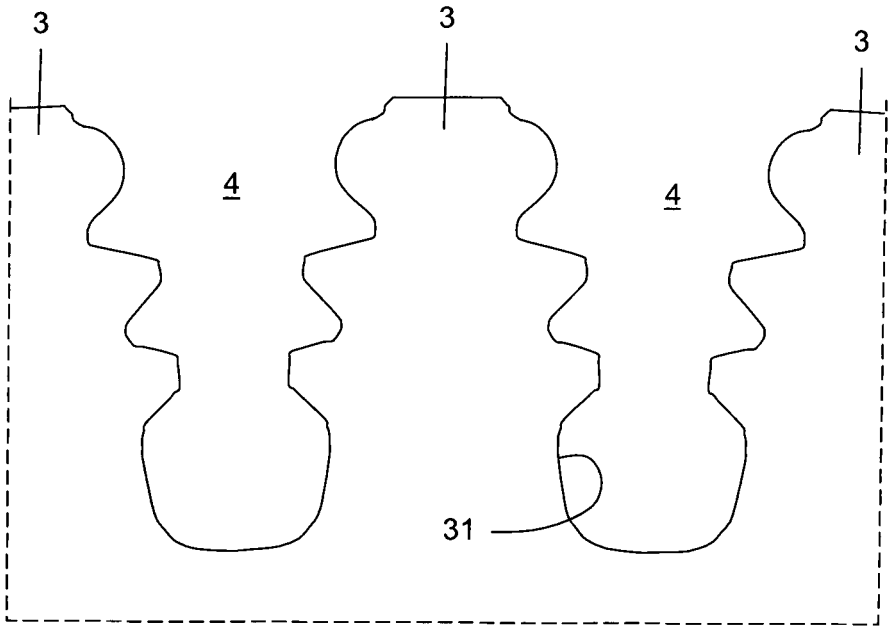

Fig. 2

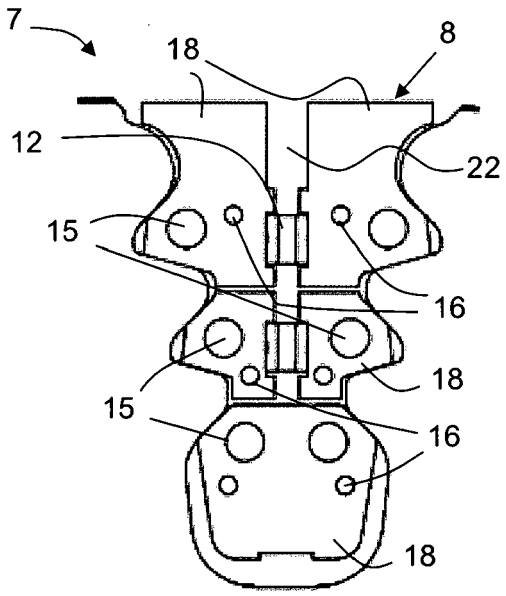

Fig. 3A

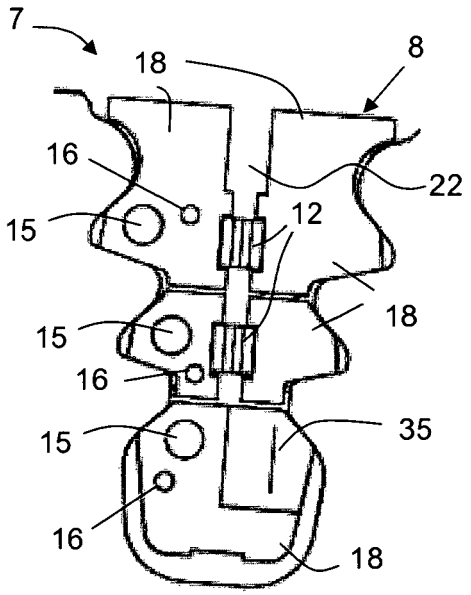

Fig. 3B

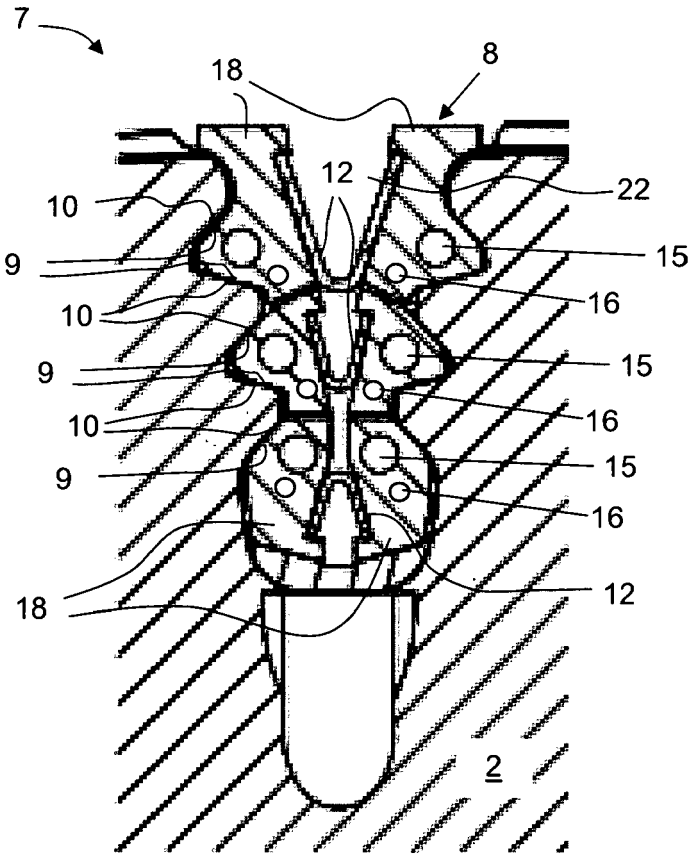

Fig. 4

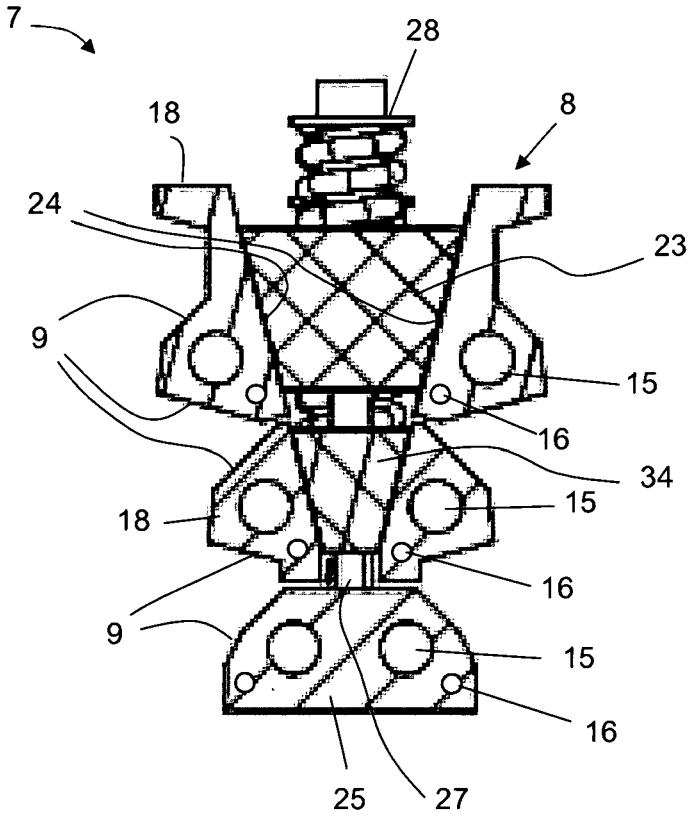
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Fig. 5A

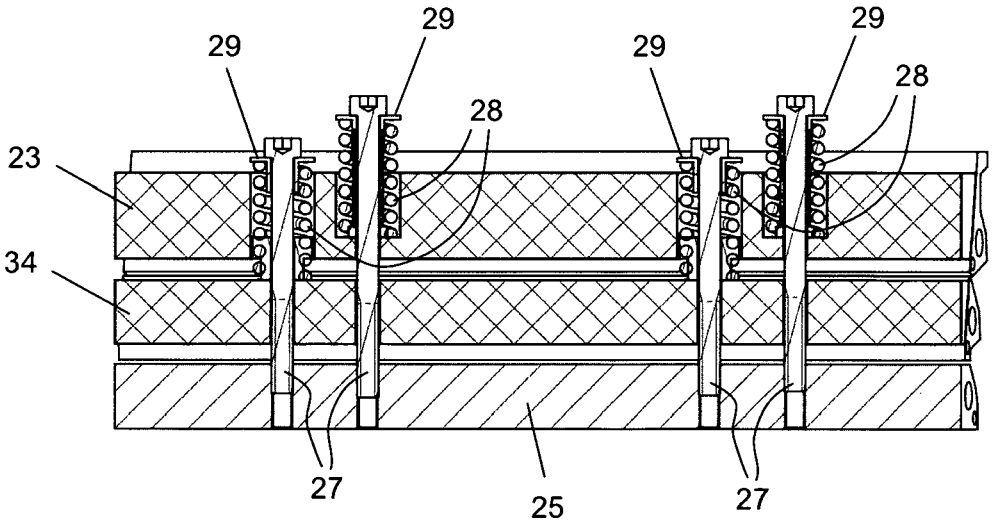
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Fig. 5B

Fig. 6

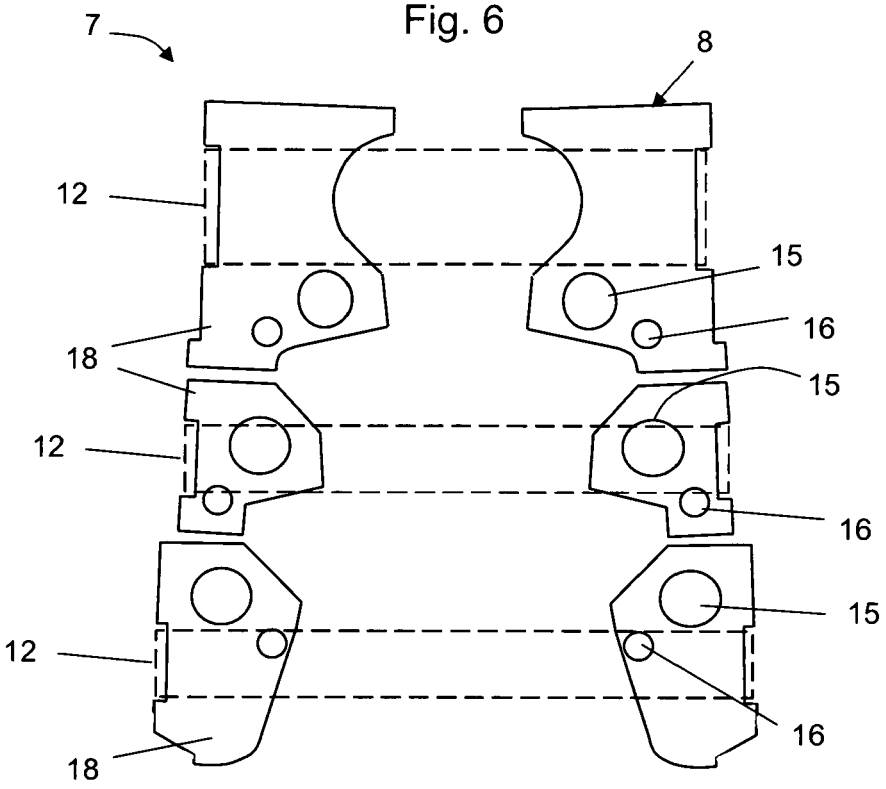


Fig.7

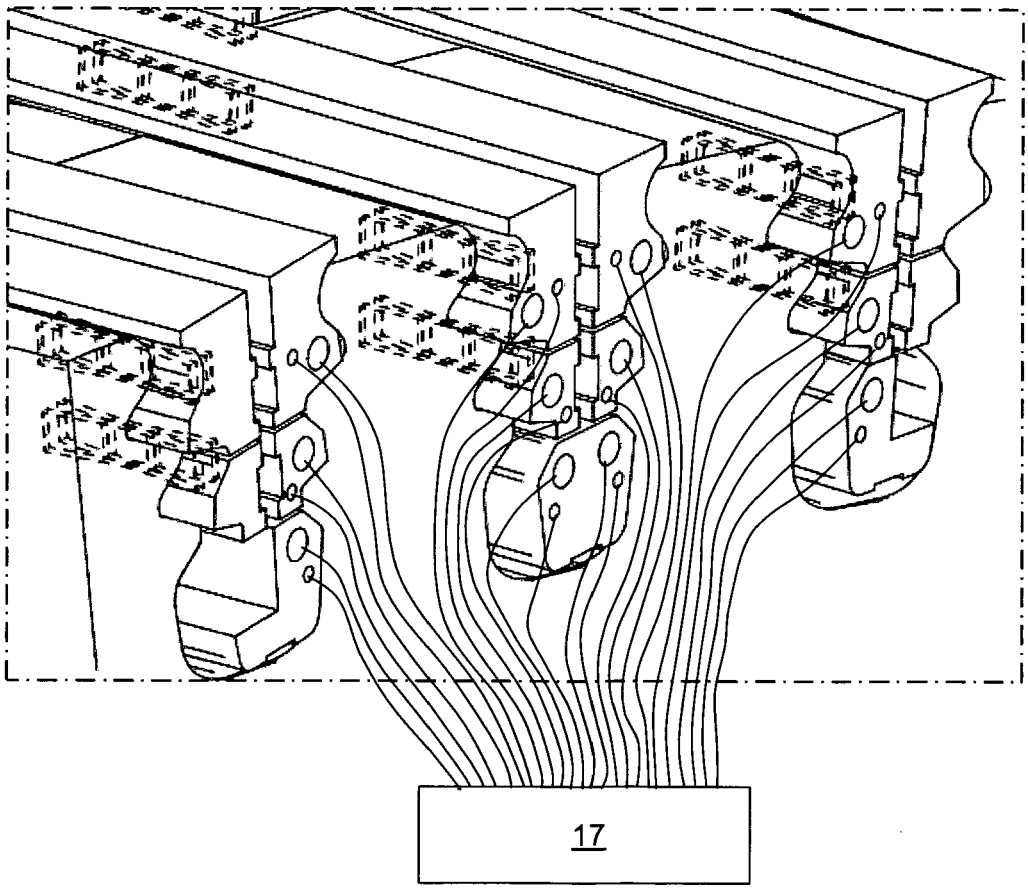
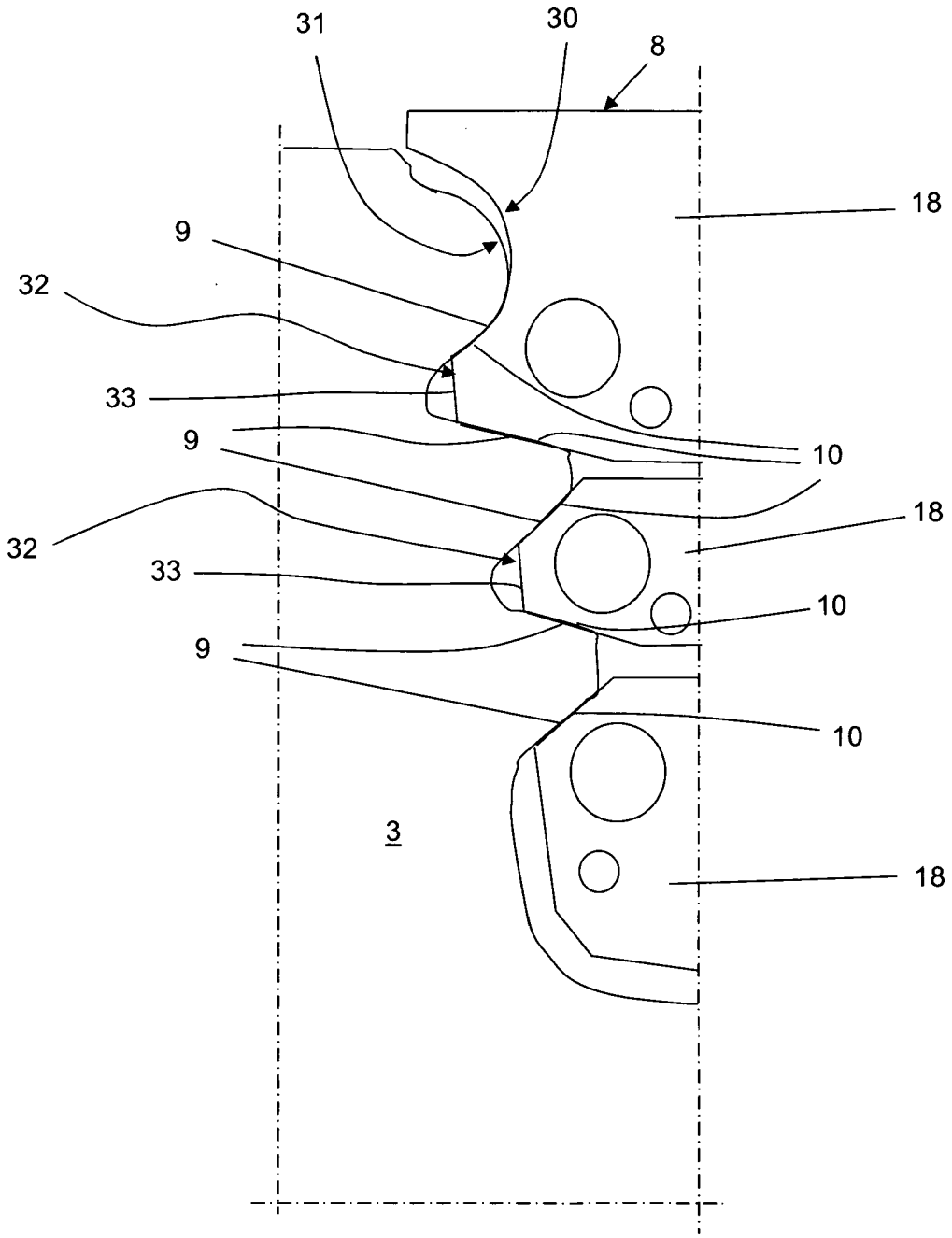


Fig.8



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EUROPEAN SEARCH REPORT

Application Number
EP 21 42 5058

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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A	CA 2 889 339 A1 (GEN ELECTRIC [US]) 15 May 2014 (2014-05-15) * claim 1; figures 3-9 * * abstract * -----	1-15	
			TECHNICAL FIELDS SEARCHED (IPC) F01D

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	22 March 2022	Klados, Iason

CATEGORY OF CITED DOCUMENTS

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