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(54) **THERMAL EXPANSION ACTUATOR**

(57) A thermal expansion actuator includes a first actuation interface (18), configured to couple to a first body, a second actuation interface (20), configured to be moved toward or away from the first actuation interface (18) in an actuation direction (D), and a plurality of actuating members (21, 22), configured to expand and retract in the actuation direction (D) in response to temperature variations. The actuating members (21, 22) include first actuating members (21) and second actuating members (22) connected alternated in series between the first actuation interface (18) and the second actuation interface (20) and arranged so that expansion of the first actuating members (21) tends to move the second actuation interface (20) away from the first actuation interface (18) in the actuation direction (D) and expansion of the second actuating members (22) tends to retract the second actuation interface (20) toward the first actuation interface (18) in the actuation direction (D). The first actuating members (21) and the second actuating members (22) have respective different thermal expansion coefficients (K1, K2).

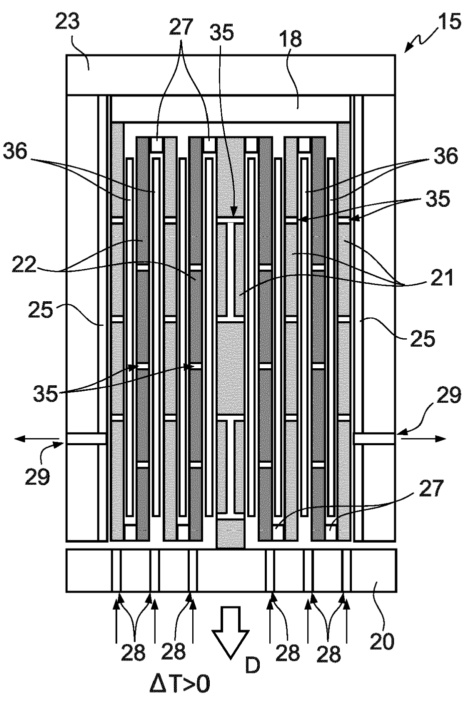

FIG. 3

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Description

TECHNICAL FIELD

[0001] The present invention relates to a thermal expansion actuator.

BACKGROUND

[0002] As already known, components of gas turbine engines are subject to temperature variations for many reasons and may require adjustment to be able to perform their functions. For example, most components of the hot gas path, such as rotor blades, vanes and heat shields on the vane carriers, undergo huge temperature variations and comparatively large thermal expansion and contraction during startup, shut-down or even load changes. The static parts in the turbine hot gas path (vanes and heat shields) are attached to a turbine vane carrier (TVC) which is cooled by air extracted from the compressor at a suitable pressure level to avoid hot gas entering in the sealing gaps between the individual vanes and heat shields. During startup, shut-down or even load change transients, there are conflicting needs in respect e.g. of clearance between blade tips and stator casing components that delimit the hot gas path, especially heat shields. On the one side, in fact, the clearance should be kept as low as possible especially at steady state operation in order to minimize fluid leakage between the blade tips and the stator casing, which would result in loss of efficiency. On the other side, too low clearance during transient or steady state operation involves risks that static and rotating components may collide because of different thermal expansion rates and respective thermal movements. Such risks should be avoided, as major damages may result for the whole gas turbine engine.

[0003] Other components require adjustment based on temperature, even though less critical conditions may arise. For example, the temperature of fuel supplied through fuel nozzles may vary depending on several factors and thermal expansion or contraction of nozzle components may affect fuel delivery conditions, such as pressure and rate.

SUMMARY OF THE INVENTION

[0004] It is an aim of the present invention to provide a thermal expansion actuator that allows the above limitations to be overcome or at least reduced.

[0005] According to the present invention there is provided a thermal expansion actuator comprising:

a first actuation interface, configured to couple to a first body;
a second actuation interface, configured to be moved toward or away from the first actuation interface in an actuation direction;
a plurality of actuating members, configured to expand and retract in the actuation direction in response to temperature variations;
wherein the actuating members include first actuating members and second actuating members connected alternated in series between the first actuation interface and the second actuation interface and are arranged so that expansion of the first actuating members tends to move the second actuation interface away from the first actuation interface in the actuation direction and expansion of the second actuating members tends to retract the second actuation interface toward the first actuation interface in the actuation direction; and
wherein the first actuating members have different thermal expansion coefficient with respect to the second actuating.

[0006] The difference in the thermal expansion coefficients causes different overall contributions to expansion or retraction of the second actuation interface with respect to the first actuation interface and that results in a net displacement (also called actuator stroke in the following text). The size, shape and configuration of the first and second actuating members and the difference of the thermal expansion coefficients provide several degrees of freedom to design thermal expansion actuators with desired response. Design is therefore made simple and flexible. For example, overall positive or negative thermal expansion coefficient of the actuator may be obtained depending of design choices, i.e. the thermal expansion actuator may be designed to expand or retract in response to a positive temperature variation.

[0007] The thermal expansion actuator responds exclusively to temperature changes and does not need external controlled. Moreover, the thermal expansion actuator is not subject to wear or ageing, so expected lifetime is long. Also, manufacturing is not expensive.

[0008] According to an aspect of the invention, the second actuation interface moves in the actuation direction away from the first actuation interface in response to positive temperature variations.

[0009] According to an aspect of the invention, the first the first actuating members have greater thermal expansion coefficient than the second actuating members.

[0010] According to an aspect of the invention, the second actuation interface moves in the actuation direction toward the first actuation interface in response to positive temperature variations.

[0011] According to an aspect of the invention, the first actuating members have smaller thermal expansion coefficient than the second actuating members.

[0012] According to an aspect of the invention, all the first actuating members have a first thermal expansion coefficient and all the second actuating members have a second thermal expansion coefficient different from the first thermal expansion coefficient.

[0013] Appropriate choice of the first and second thermal expansion coefficients is a straightforward manner to determine the desired overall thermal expansion coefficient for the thermal expansion actuator as a whole. The greatest of the first and second thermal expansion coefficients in fact determines which of the first and second actuating members yields the greatest contribution and, accordingly, positive or negative displacement of the second actuation interface in the actuation direction. The difference, along with the shape and size of the first and second actuating members, determines the exact value of the overall thermal expansion coefficient, i.e. the amount of expansion or retraction in response to a given variation of temperature.

[0014] According to an aspect of the invention, pairs of consecutive first actuating members and second actuating members are arranged facing each other along the actuation direction.

[0015] According to an aspect of the invention, the actuating members include terminal actuating members at opposite ends of the series of first actuating members and second actuating members, and intermediate actuating members between the terminal actuating members, the terminal actuating members and the intermediate actuating members being defined by respective first actuating members or second actuating members; and wherein each intermediate actuating member has opposite sides parallel to the actuation direction and a first end in the actuation direction coupled on one of the respective sides to a consecutively preceding actuating member and a second end in the actuation direction coupled on the other of the respective sides to a consecutively following actuating member.

[0016] According to an aspect of the invention, each first actuating member defining an intermediate actuating member is coupled to a respective preceding consecutive second actuating member and to a respective following consecutive second actuating member and each second actuating member defining an intermediate actuating member is coupled to a respective preceding consecutive first actuating member and to a respective following consecutive first actuating member.

[0017] Constraints at opposite ends and facing arrangement cause all the first actuating members to provide concurring contributions. Likewise, all the second actuating members provide concurring contributions, but opposite to those of the first actuating members.

[0018] According to an aspect of the invention, the actuating members are symmetrically arranged with respect to the actuation direction.

[0019] According to an aspect of the invention, the thermal expansion actuator comprises a casing accommodating the actuating members.

[0020] According to an aspect of the invention, the thermal expansion actuator comprises a thermally insulating layer between the casing and the actuating members at least in part of the casing and/or between the actuating members and/or on at least part of surfaces of the actuating members.

[0021] According to an aspect of the invention, the thermal expansion actuator comprises fluid inlets, configured to admit a fluid into the casing between the actuating members, and fluid outlets, configured to discharge out of the casing the fluid admitted through the fluid inlets wherein the actuating members optionally comprise through channels configured to allow fluid flow through or along the actuating members.

[0022] The number, size and distribution of the fluid inlets and of the fluid outlets determines fluid circulation and heat transfer to the first and second actuating members and allows to set a thermal time constant of the thermal expansion actuator. The thermal time constant may be defined as the time required for the actuator to reach a given fraction, e.g. 90%, of maximum expansion or contraction in response to a temperature step. Fluid circulation inside the casing affects the thermal time constant, as the greater the fluid flow, the faster the response of the actuator.

[0023] According to an aspect of the invention, a gas turbine engine comprises a thermal expansion actuator as defined above.

[0024] According to an aspect of the invention, the gas turbine engine comprises a vane carrier, a rotor, provided with rotating blades, and a heat shield facing the rotating blades, wherein the heat shield is connected to the vane carrier by the thermal expansion actuator and the thermal expansion actuator is configured to adjust a gap between the heat shield and the rotating blades in response to temperature variations.

[0025] According to an aspect of the invention, the gas turbine engine comprises a fuel lance having a lance body, a nozzle and nozzle insert, wherein the thermal expansion actuator is arranged between the lance body and the nozzle insert and is configured to axially displace the nozzle insert in an axial direction in response to temperature variations to adjust a fuel flow through the nozzle.

BRIEF DESCRIPTION OF THE DRAWINGS

[0026] The present invention will now be described with reference to the accompanying drawings, which show a number of non-limitative embodiments thereof, in which:

- figure 1 is a longitudinal cross section of a gas turbine assembly;
- figure 2 shows an enlarged detail of the gas turbine engine of figure 1, including a thermal expansion actuator in accordance with an embodiment of the present invention;
- figure 3 is a longitudinal cross section through the thermal expansion actuator of figure 2;
- figures 4 and 5 are perspective views showing details of a thermal expansion actuator in accordance with respective different embodiments of the present invention;
- figure 6 and 7 are front views showing details of a

thermal expansion actuator in accordance with respective different embodiments of the present invention;

- figure 8 is a longitudinal cross section through a thermal expansion actuator in accordance with another embodiment of the present invention; and
- figure 9 is a longitudinal cross section through a thermal expansion actuator in accordance with a further embodiment of the present invention.

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

[0027] With reference to figure 1, a gas turbine engine 1 of a plant for the production of electrical energy is designated as a whole by numeral 1.

[0028] The gas turbine engine 1 comprises an outer turbine housing 2, a rotor 3 and a stator that includes a vane carrier 4. The rotor 3 is rotatably housed in the vane carrier 4 about a main axis A. The vane carrier 4 is itself housed in the outer turbine housing 2. The vane carrier 4 and the rotor 3 form a compressor 5 and a turbine 6. Moreover, the gas turbine engine 1 comprises a combustor assembly 7 arranged around the rotor 3 between the compressor 5 and the turbine 6. Cooling air 8 is extracted at one or more locations of the compressor 5 and is admitted in the outer turbine housing 2.

[0029] Figure 2 shows an enlarged detail of a portion of a hot gas path 10 downstream of the combustor assembly 7 at an inlet of the turbine 6. Specifically, figure 2 shows a portion of the rotor 3, with a rotor blade 11, a portion of the vane carrier 4, a heat shield 12 (more precisely, a segment thereof) and a thermal expansion actuator 15 in accordance with an embodiment of the present invention.

[0030] The heat shield 12 extends in a circumferential direction and is radially separated from the tip of the rotor blade 11 by a gap 16. Moreover, the heat shield 12 is connected to the vane carrier 4 by the thermal expansion actuator 15, which is configured to adjust a width of the gap 16 by moving the heat shield 12 radially inward and outward in response to temperature variations (and the resulting thermal expansion) of the vane carrier 4. The vane carrier 4 is cooled by cooling air 8 extracted from the compressor 5.

[0031] With reference to figure 3, the thermal expansion actuator 15 comprises a first actuation interface 18, a second actuation interface 20 and a plurality of first actuating members 21 and second actuating members 22, configured to expand and retract in an actuation direction D in response to temperature variations. In one embodiment, the thermal expansion actuator 15 also comprises a cup-shaped casing 23, housing the first actuating members 21 and the second actuating members 22, and a thermal barrier layer 25 inside at least part of the casing 23 around the first actuating members 21 and the second actuating members 22. The first actuation interface 18 is configured to couple to a first body. In the example of figure 3, the first actuation interface 18 is fitted to the inside of the casing 23, which is in turn secured to the vane carrier 4. According to design preferences, the first actuation interface 18 may be coupled to a bottom portion or to side walls of the casing 23, so that in any case actuation forces are applied to the casing 23 and, in turn, to the vane carrier 4.

[0032] The second actuation interface 20 is configured to couple to a second body and to be moved toward and away from the first actuation interface 18. In the example of figure 3, the second actuation interface 20 includes a plate that projects outside of the casing 23 and is coupled to the heat shield 12 (here not shown).

[0033] The first actuating members 21 have a first thermal expansion coefficient and the second actuating members 22 have a second thermal expansion coefficient different from the first thermal expansion coefficient. Moreover, the first actuating members 21 and second actuating members 22 are connected alternated in series between the first actuation interface 18 and the second actuation interface 20 and are arranged so that expansion of the first actuating members 21 tends to move the second actuation interface 20 away from the first actuation interface 21 in the actuation direction D and expansion of the second actuating members 22 tends to retract the second actuation interface 20 toward the first actuation interface 18 in the actuation direction. Specifically (but not limited to), the first actuating members 21 and the second actuating members 22 are symmetrically arranged as a whole with respect to the actuation direction D. A non-symmetric arrangement is as well possible. The first actuating members 21 and the second actuating members 22 may be defined e.g. by bars, plates (see figure 4) or concentric cylindrical walls (see figure 5) that extend parallel to one another in the actuation direction D. A length in the actuation direction D is substantially the same for the first actuating members 21 and for the second actuating members 22. Pairs of consecutive first actuating members 21 and second actuating members 22 are arranged facing each other along the actuation direction D. The first actuating members 21 include terminal actuating members at opposite ends of the series of first actuating members 21 and second actuating members 22, while intermediate actuating members are defined by alternated first actuating members 21 and second actuating members 22. At least one of the terminal members is rigidly connected to the first actuation interface 18, e.g. integral therewith. At least another of the terminal members is rigidly connected to the second actuation interface 20, e.g. integral therewith too. Each intermediate actuating member has opposite sides parallel to the actuation direction D. A first end of each intermediate actuating member with respect to the actuation direction D is coupled on one of the respective sides to a consecutively preceding actuating member 20, 21; and a second end of each intermediate actuating member with respect to the actuation direction D is coupled on the other of the respective sides to a consecutively following intermediate or terminal actuating member. Thus, each intermediate first actuating member 21 has opposite ends connected to a consecutively preceding and to a consecutively following second actuating members 22, one end on one side and the opposite end on the opposite side; likewise, each intermediate second actuating member 22 has opposite ends connected to a consecutively preceding and to a consecutively following consecutive first actuating members 21, one end on one side and the opposite end on the opposite side. The terminal first actuating members 21 have respective free ends (i.e. ends not directly connected to the first actuation interface 18 or to the second actuation interface 20) connected to an end of a respective consecutive second actuation member 22.

[0034] Connection is obtained in such a manner that relative displacement of consecutive first actuating members 21 and second actuating members 22 in the actuation direction D is prevented at the connected ends. On the contrary, opposite ends of each first actuating member 21 and second actuating member 22 are free to move with respect to each other in the actuation direction D on account of thermal expansion or contraction. Connection may be obtained by welded bridges 27 (figure 6) or by protrusions 30 of actuating members 21, 22 engaging in a form-fit manner recesses 31 in sides of consecutive actuating members 21, 22 (figure 7). Other connections like threads connecting the actuation members 21 with 22 or bolted connections are as well possible. In this way, a cross section of the first actuating members 21 and second actuating members 22 is serpentine shaped.

[0035] The thermal expansion actuator 15 has fluid inlets 28, configured to admit a fluid from the surrounding environment into the casing between the actuating members 21, 22, and fluid outlets 29, configured to discharge out of the casing 23 the fluid admitted through the fluid inlets 28. In one embodiment, the fluid may be cooling fluid (air) 8 extracted from the compressor 5 to cool the turbine vane carrier 2 and other components exposed to high temperatures. In the embodiment of figure 3, the fluid inlets 28 are provided through the plate forming the second actuation interface 20 and the fluid outlets 29 are formed through the side wall of the casing 23, in an upper part thereof (e.g. at a distance from the second actuation interface 20 comprised between one quarter and one third of the overall length of the casing 23 in the actuation direction D).

[0036] Moreover, the actuating members 21, 22 have through passages 35, such as holes, pores or channels, which are configured to allow fluid flow through or along the actuating members 21, 22 and to establish desired flow circulation within the casing 23 of the thermal expansion actuator 15. Further thermal barrier layers 36 are provided between adjacent actuating members 21, 22 and, in the embodiment of figure 3, may be attached to the casing 23.

[0037] The number, size, shape and position of the fluid inlets 28, fluid outlets 29 and through passages 35, as well as the number, size, shape and position of the thermal barrier layers 36 may be selected to determine a flowrate of fluid and heat conduction conditions in the actuating members 21, 22 in accordance with design preferences. The through passages 35 may also extend in part inside the actuating members 21, 22 parallel to faces thereof. The heat conduction conditions allow to set a thermal time constant of the thermal expansion actuator 15, i.e. how fast the thermal expansion actuator 15 responds to temperature variations.

[0038] In the embodiment of figure 3, the first thermal expansion coefficient of the first actuating members 21 is greater than the second thermal expansion coefficient of the second actuating members 22. For the sake of clarity, regions with greater and smaller thermal expansion coefficient are indicated in light grey and dark grey, respectively. The difference in thermal expansion coefficient of the actuating members 21, 22 causes the thermal expansion actuator 15 to have a positive overall thermal expansion coefficient. In other words, an overall length of the thermal expansion actuator 15, i.e. a distance between the first actuation interface 18 and the second actuation interface 20 in the actuation direction increases in response to positive temperature variations and decreases otherwise. Because of the connection between consecutive actuating members 21, 22 and of the alternated series arrangement, in fact, thermal expansion of the first actuating members 21 on account of an increase in temperature tends to displace the second actuation interface 20 away from the first actuation interface 18. Conversely, thermal expansion of the second actuating members 22 tends to retract the second actuation interface 20 toward the first actuation interface 18. Since the first thermal expansion coefficient of the first actuating members 21 is greater than the second thermal expansion coefficient of the second actuating members 22 and the actuating members 21, 22 have substantially the same length, the overall contribution of expansion of the first actuating members 21 prevails over the contribution of the second actuating members 22 and causes a net displacement of the second actuation interface 20 away from the first actuation interface 18. In other words, the thermal expansion actuator 15 expands in response to increase in temperature and retracts otherwise (and the second actuation interface 20 moves in the actuation direction away from and toward the first actuation interface 18, respectively). The amount of the overall expansion is determined by the number of consecutive first actuating members 21 and second actuating members 22, the size thereof and the difference in thermal expansion coefficient as follows:

$$\Delta L = K_T L_0$$

$$K_T = N_1 K_1 - N_2 K_2$$

where ΔL is the thermal expansion, L_0 is the starting length of the actuating members 21, 22, K_T is the overall thermal expansion coefficient, K_1 and K_2 are the thermal expansion coefficient of the first actuating members 21 and of the second actuating members 22, respectively, and N_1 and N_2 are the number of first actuating members 21 and of second actuating members 22 connected in series, respectively. Since the terminal actuating members are all of the same type (first actuating members 21) and the first actuating members 21 and second actuating members 22 are arranged in series and alternated, the difference N_1 - N_2 is 1. Examples of convenient values for the thermal expansion coefficients are as follows:

$$K_1 = 29*10^{-6}\ K^{-1}$$

$$K_2 = 1*10^{-6}\ K^{-1}$$

[0039] This analysis is presented for sake of simplicity assuming, as in the present embodiment, that the length of the actuating members 21, 22 are identical as well as their temperature and that the all of the first actuating members 21 and second actuating members 22 have the same first thermal expansion coefficient K1 and second thermal expansion coefficient K2, respectively. Other configurations with different lengths or different thermal expansion coefficients of each of the first actuating members 21 and/or second actuating members 22 may as well be selected and the behaviour can be predicted considering these differences. The transient behaviour of the stroke of the thermal expansion actuator 15 can be determined by numerical simulation of the transient temperature change of the actuating members 21, 22 with a coupled fuid dynamics, heat transfer and heat conduction solver.

[0040] According to another embodiment of the present invention, which is illustrated in figure 8, a thermal expansion actuator 115 comprises a first actuation interface 118, a second actuation interface 120, a plurality of first actuating members 121 and second actuating members 122, configured to expand and retract in an actuation direction D' in response to temperature variations. The thermal expansion actuator 15 also comprises a cup-shaped casing 123, housing the first actuating members 121 and the second actuating members 122, and a thermal barrier layer 125 inside part of the casing 123 around the first actuating members 121 and the second actuating members 122.

[0041] The first actuating members 121 and second actuating members 122 are connected alternated in series between the first actuation interface 118 and the second actuation interface 120 and are arranged so that expansion of the first actuating members 121 tends to move the second actuation interface 120 away from the first actuation interface 121 in the actuation direction D' and expansion of the second actuating members 122 tends to retract the second actuation interface 120 toward the first actuation interface 118 in the actuation direction, as already described.

[0042] In this case, however, the first thermal expansion coefficient K_1 of the first actuating members 121 is smaller than the second thermal expansion coefficient K_2 of the second actuating members 122. For example

$$K_1 = 1*10^{-6}\ K^{-1}$$

$$K_2 = 29*10^{-6}\ K^{-1}$$

[0043] Accordingly, the overall contribution of expansion of the second actuating members 122 on account of temperature increase prevails over the contribution of the first actuating members 121 and causes a net displacement of the second actuation interface 120 toward the first actuation interface 118. In other words, the thermal expansion actuator 15 retracts in response to increase in temperature and expands otherwise (and the second actuation interface 120 moves in the actuation direction toward and away from the first actuation interface 118, respectively). Thus, the thermal expansion actuator 15 has a negative overall thermal expansion coefficient.

[0044] In the embodiment of figure 8, fluid inlets 128 and fluid outlets 129 are provided through the side wall of the casing 123 and through the first actuation interface 118 and a bottom wall of the casing 123, respectively. Specifically, the fluid inlets 128 are located in a central portion of the side wall of the casing 123. The first actuating members 121 and the second actuating members 122 may have through passages 135 in the form of holes or pores to allow passage of fluid and allow efficient distribution within the casing 123. Further thermal barrier layers 136 are provided on at least part of the surfaces of the first actuating members 121 and of the second actuating members 122. Also in this case, the number, size, shape and position of the fluid inlets 128, fluid outlets 129, through passages 135 and thermal barrier layers 136 may be selected to determine a desired flowrate of fluid and corresponding heat conduction conditions in the actuating members 121, 122 in accordance with design preferences.

[0045] With reference to figure 9, a thermal expansion actuator 215 is used in a fuel lance 200 of the gas turbine engine 1. The fuel lance 200 has a lance body 201, that defines a fuel duct 202, and a nozzle 203 at an end of the fuel duct 202. The nozzle 203 is in fluidic communication with a combustion chamber, here not shown. A flowrate of a liquid or gas fuel is supplied to the combustion chamber through the lance 200.

[0046] The thermal expansion actuator 215 is fitted into the fuel duct 202 in the vicinity of the nozzle 203 and is coupled to an nozzle insert 204 to adjust an axial position of the nozzle insert 204 with respect to the nozzle 203 in response to variations of a fuel temperature.

[0047] The thermal expansion actuator 215 comprises a first actuation interface 218, a second actuation interface 220, first actuating members 221 and second actuating members 222, configured to expand and retract in an actuation direction D" in response to temperature variations.

[0048] The first actuation interface 218 is defined by a hollow cylindrical body, which is inserted into the fuel duct 202 against an annular shoulder 205 around the nozzle 203.

[0049] A terminal actuating member, defined by one of the first actuating members 221, is in the form of a needle and is arranged along a central axis of the lance 200. The central axis is coincident with the actuation direction D" of the thermal expansion actuator 215. The nozzle insert 204 is fitted to or integral with an end of the terminal actuating member nearer to the nozzle 203. The end of the terminal actuating member defines the second actuation interface 220.

[0050] The first actuating members 221 and second actuating members 222 are connected alternated in series between the first actuation interface 218 and the second actuation interface 220 and are arranged so that expansion of the first actuating members 221 tends to extract the second actuation interface 220 away from the first actuation interface 221 in the actuation direction D and expansion of the second actuating members 222 tends to retract the second actuation interface 220 toward the first actuation interface 218 in the actuation direction, as already described.

[0051] The first actuating members 221 have a first thermal expansion coefficient and the second actuating members 222 have a second thermal expansion coefficient different from the first thermal expansion coefficient, e.g. greater. Moreover, the first actuation interface 218 is made of the same material as the second actuating members 222 and takes part in causing axial displacement of the second actuation interface 220 and of the nozzle insert 204.

[0052] Finally, it is clear that modifications and variants can be made to the thermal expansion actuator described herein without departing from the scope of the present invention, as defined in the appended claims.

[0053] First, the thermal expansion actuator may be used not only in combination with heat shields or fuel lances, but in general every time adjustment of relative position of a first and a second body is required in response to temperature changes. For example, the thermal expansion actuator may be exploited to control valves in a sealed environment. The temperature outside the casing, which may be sealed, can be controlled or anyway changed to cause displacement of the actuating interfaces inside the casing. The actuator stroke may thus be used to open and close a valve from the outside without direct contact with the valve members.

[0054] The first and the second actuation interfaces may have any suitable shape and relative arrangement in accordance with the design preferences.

[0055] Likewise, the number, shape, size and configuration of the first and second actuating members are not limited to those specifically disclosed in the examples above illustrated. In particular, the first and second actuating members need not be of the same shape and/or size. For example, some of the first and/or second actuating members may be longer than the others or have a different shape.

[0056] The first actuating members may not have all the same first thermal expansion coefficient; likewise, the second actuating members may not have all the same second thermal expansion coefficient. It is however preferred that all the first actuating members have lower thermal expansion coefficient than second actuating members.

[0057] Different combinations of flow inlets, outlets and through passages, insulation materials and arrangement thereof may be flexibly selected in accordance with design preferences. For example thermal barrier layers may be provided on or between part of the actuating members instead of all actuating members. Portions of the actuating members may be left exposed to fluid flow without interactions with thermal barrier layers. Also for these designs the transient behaviour of the thermal expansion actuator can be determined by numerical simulation of the transient temperature change of the actuating members with a coupled fluid dynamics, heat transfer and heat conduction solver.

Claims

1. A thermal expansion actuator comprising:

a first actuation interface (18; 118; 218), configured to couple to a first body;
a second actuation interface (20; 120; 220), configured to be moved toward or away from the first actuation interface (18; 118; 218) in an actuation direction (D; D'; D");
a plurality of actuating members (21, 22; 121, 122; 221, 222), configured to expand and retract in the actuation direction (D; D'; D") in response to temperature variations;
wherein the actuating members (21, 22; 121, 122; 221, 222) include first actuating members (21; 121; 221) and second actuating members (22; 122; 222) connected alternated in series between the first actuation interface (18; 118; 218) and the second actuation interface (20; 120; 220) and are arranged so that expansion of the first actuating members (21; 121; 221) tends to move the second actuation interface (20; 120; 220) away from the first actuation interface (18; 118; 218) in the actuation direction (D; D'; D") and expansion of the second actuat-

ing members (22; 122; 222) tends to retract the second actuation interface (20; 120; 220) toward the first actuation interface (18; 118; 218) in the actuation direction (D; D'; D"); and
wherein the first actuating members (21; 121; 221) have different thermal expansion coefficient with respect to the second actuating members (22; 122; 222).

2. The thermal expansion actuator according to claim 1, wherein the second actuation interface (20; 120; 220) moves in the actuation direction (D; D'; D") away from the first actuation interface (18; 118; 218) in response to positive temperature variations.

3. The thermal expansion actuator according to claim 2, wherein the first actuating members (21; 221) have greater thermal expansion coefficient than the second actuating members (22; 222).

4. The thermal expansion actuator according to claim 1, wherein the second actuation interface (20; 120; 220) moves in the actuation direction (D; D'; D") toward the first actuation interface (18; 118; 218) in response to positive temperature variations.

5. The thermal expansion actuator according to claim 4, wherein the first actuating members (121) have smaller thermal expansion coefficient than the second actuating members (122).

6. The thermal expansion actuator according to any one of the preceding claims, wherein all the first actuating members (21; 121; 221) have a first thermal expansion coefficient (K1) and all the second actuating members (22; 122; 222) have a second thermal expansion coefficient (K2) different from the first thermal expansion coefficient (K1).

7. The thermal expansion actuator according to any one of the preceding claims, wherein pairs of consecutive first actuating members (21; 121; 221) and second actuating members (22; 122; 222) are arranged facing each other along the actuation direction (D; D'; D").

8. The thermal expansion actuator according to any one of the preceding claims, wherein the actuating members (21, 22; 121, 122; 221, 222) include terminal actuating members at opposite ends of the series of first actuating members (21; 121; 221) and second actuating members (22; 122; 222), and intermediate actuating members between the terminal actuating members, the terminal actuating members and the intermediate actuating members being defined by respective first actuating members (21; 121; 221) or second actuating members (22; 122; 222); and wherein each intermediate actuating member has opposite sides parallel to the actuation direction (D; D'; D") and a first end in the actuation direction (D; D'; D") coupled on one of the respective sides to a consecutively preceding actuating member (21, 22; 121, 122; 221, 222) and a second end in the actuation direction (D; D'; D") coupled on the other of the respective sides to a consecutively following actuating member (21, 22; 121, 122; 221, 222).

9. The thermal expansion actuator according to claim 8, wherein each first actuating member (21; 121; 221) defining an intermediate actuating member is coupled to a respective preceding consecutive second actuating member (22; 122; 222) and to a respective following consecutive second actuating member (22; 122; 222) and each second actuating member (22; 122; 222) defining an intermediate actuating member is coupled to a respective preceding consecutive first actuating member (21; 121; 221) and to a respective following consecutive first actuating member (21; 121; 221).

10. The thermal expansion actuator according to any one of the preceding claims, comprising a casing (23; 123) accommodating the actuating members (21, 22; 121, 122; 221, 222) .

11. The thermal expansion actuator according to claim 10, comprising a thermally insulating layer (25, 36; 125, 136) between the casing (23; 123) and the actuating members (21, 22; 121, 122; 221, 222) at least in part of the casing (23; 123) and/or between the actuating members (21, 22; 121, 122; 221, 222) and/or on at least part of surfaces of the actuating members (21, 22; 121, 122; 221, 222).

12. The thermal expansion actuator according to claim 10 or 11, comprising fluid inlets (28; 128), configured to admit a fluid into the casing (23; 123) between the actuating members (21, 22; 121, 122; 221, 222), and fluid outlets (29; 129), configured to discharge out of the casing (23; 123) the fluid admitted through the fluid inlets (28; 128), wherein the actuating members (21, 22; 121, 122; 221, 222) optionally comprise through channels (35; 135) configured to allow fluid flow through or along the actuating members (21, 22; 121, 122; 221, 222).

13. A gas turbine engine comprising a thermal expansion actuator (15; 115; 215) according to any one of the preceding claims.

14. The gas turbine engine according to claim 13, comprising vane carrier (4), a rotor (3), provided with rotating blades (11), and a heat shield (12) facing the rotating blades (11), wherein the heat shield (12) is connected to the vane carrier (4) by the thermal expansion actuator (15; 115) and the thermal expan-

sion actuator (15; 115) is configured to adjust a gap (16) between the heat shield (12) and the rotating blades (11) in response to temperature variations.

15. The gas turbine engine according to claim 13 or 14, comprising a fuel lance (200) having a lance body (201), a nozzle (203) and an nozzle insert (204), wherein the thermal expansion actuator (215) is arranged between the lance body (201) and the nozzle insert (204) and is configured to axially displace the nozzle insert (204) in an axial direction in response to temperature variations to adjust a fuel flow through the nozzle (203).

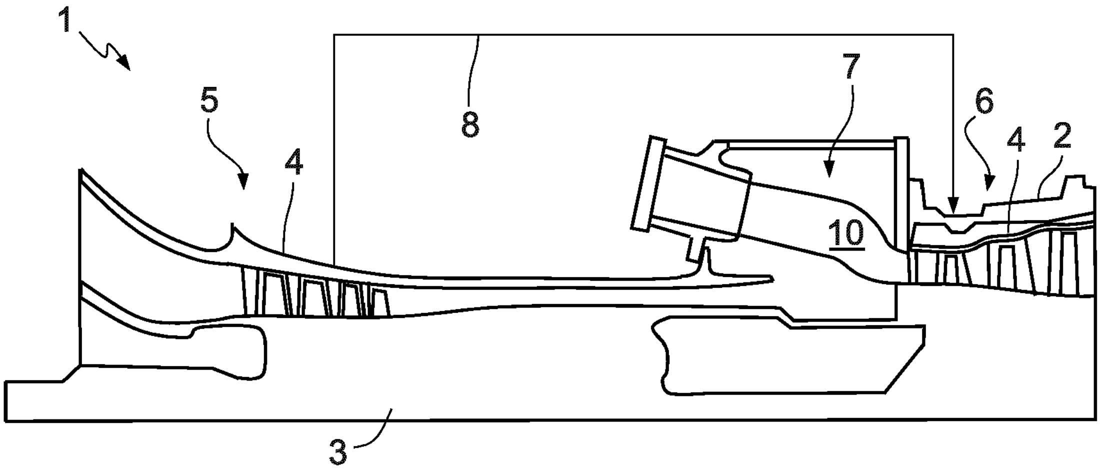

FIG. 1

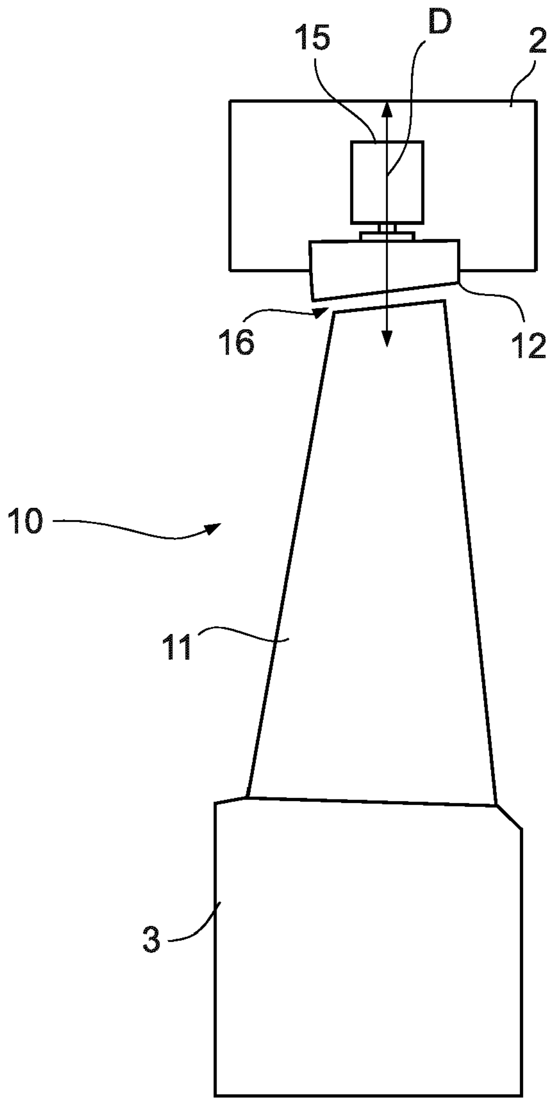

FIG. 2

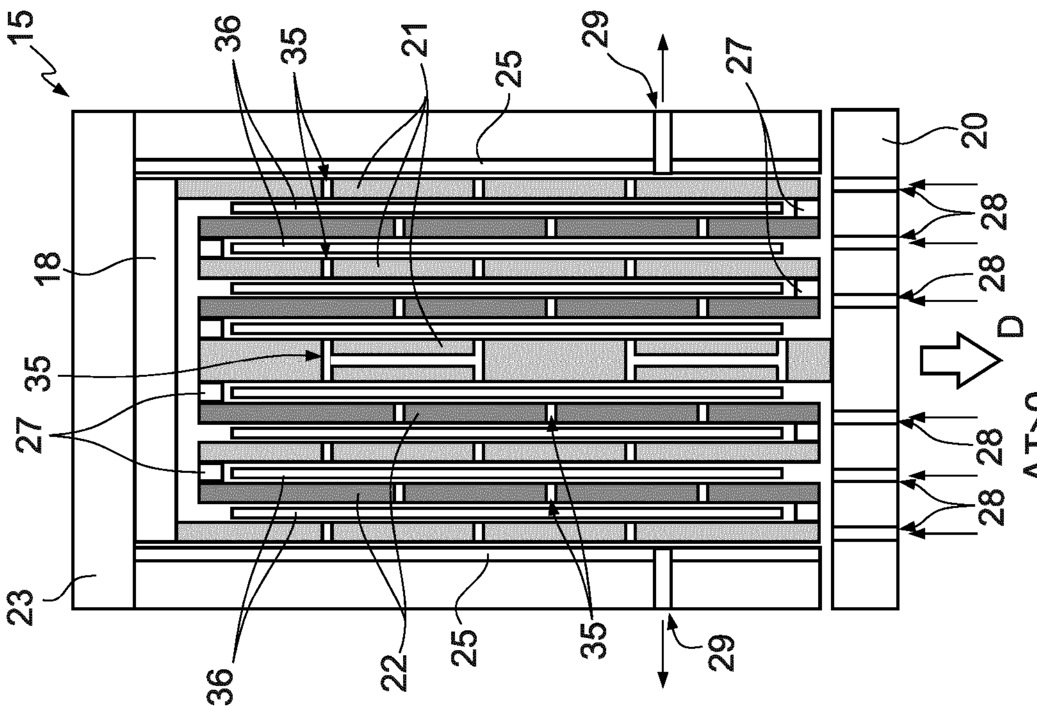

FIG. 3

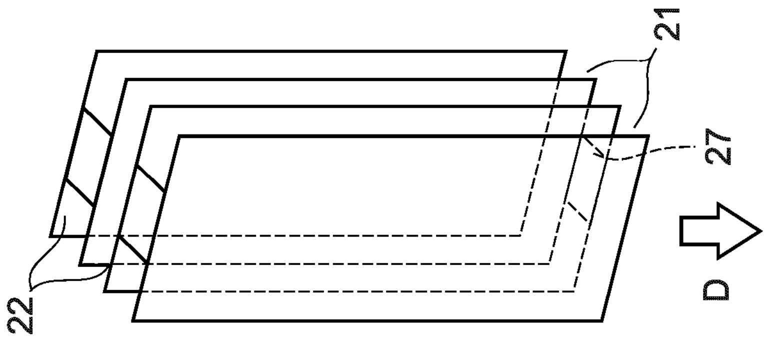

FIG. 4

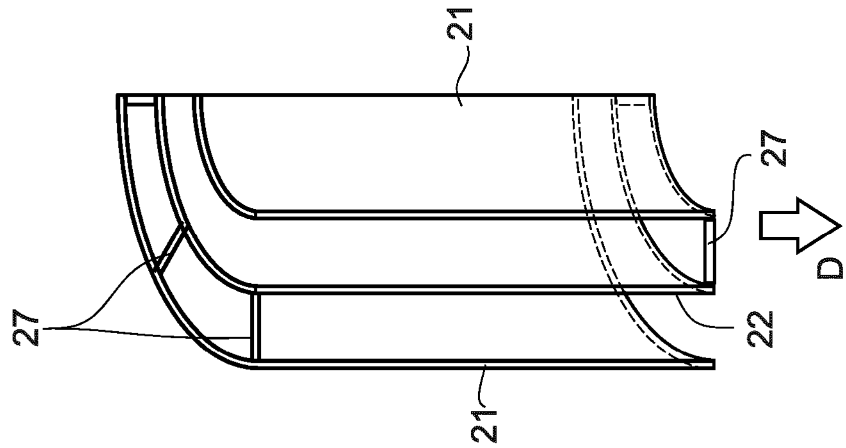

FIG. 5

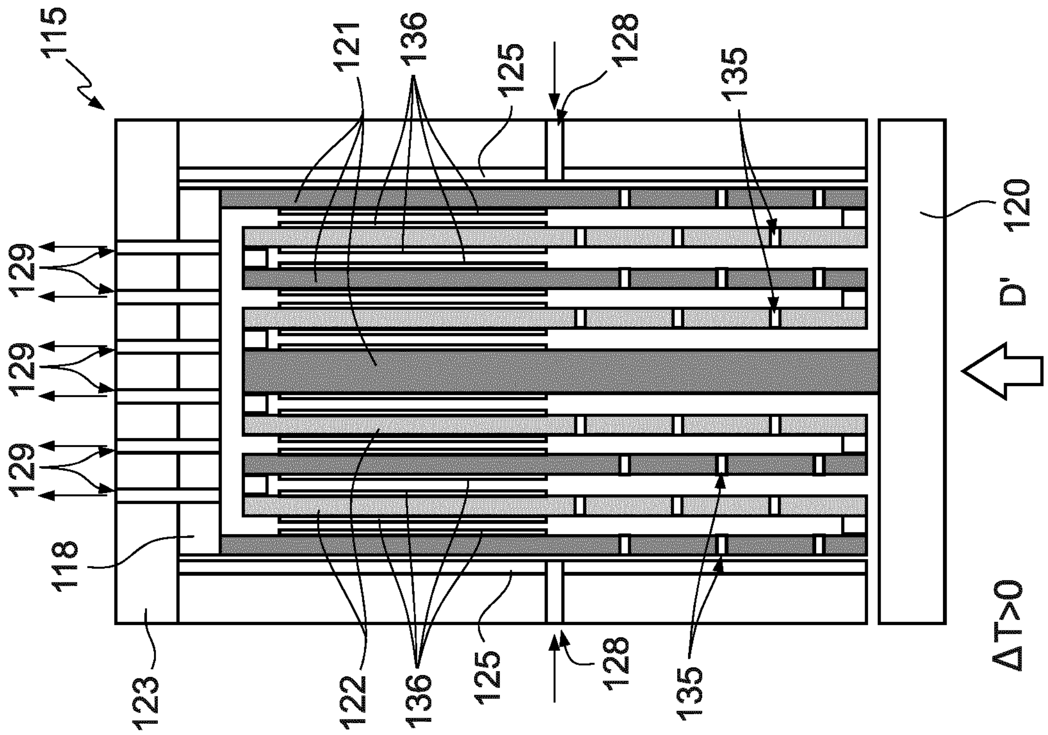

FIG. 8

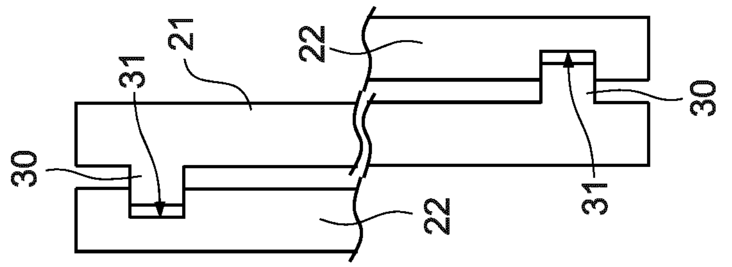

FIG. 7

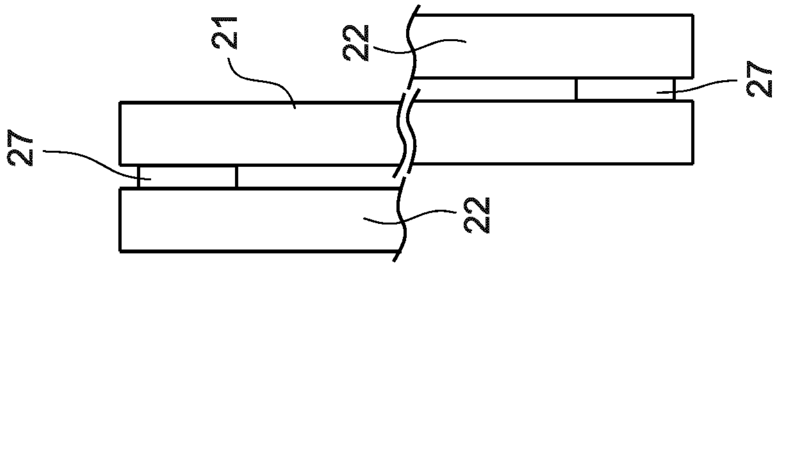

FIG. 6

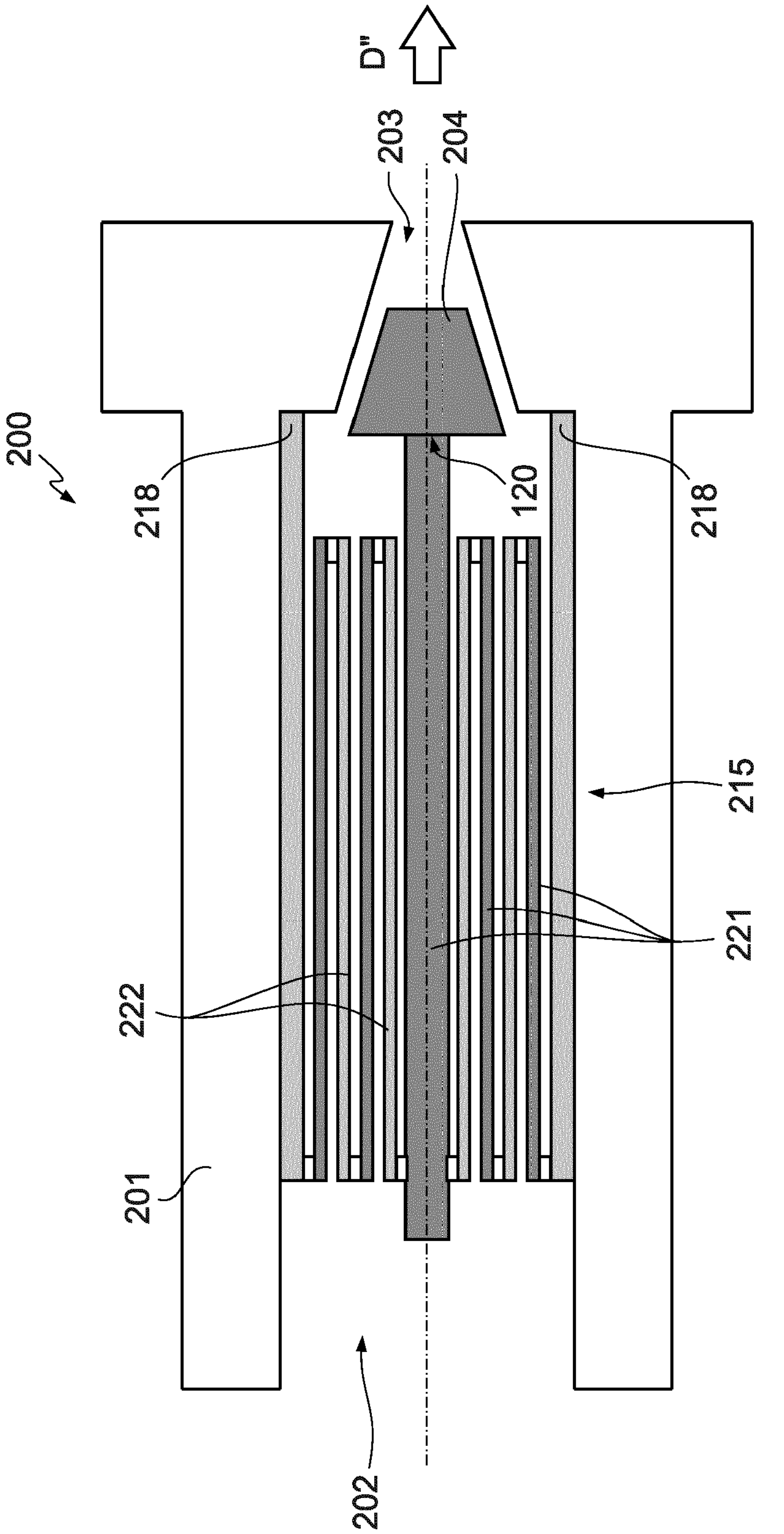

FIG. 9

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EUROPEAN SEARCH REPORT

Application Number
EP 21 16 8422

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 2010/054912 A1 (WILSON IAN DAVID [US] ET AL) 4 March 2010 (2010-03-04) * the whole document * -----	1-15	INV. F01D11/18
A	US 2013/101391 A1 (SZWEDOWICZ JAROSLAW LESZEK [CH] ET AL) 25 April 2013 (2013-04-25) * paragraphs [0055] - [0084] * * figures 1-8 * -----	1-15	

TECHNICAL FIELDS SEARCHED (IPC)

F01D

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	24 September 2021	de la Loma, Andrés

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EP 21 16 8422

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24-09-2021

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2010054912 A1	04-03-2010	CN 101660508 A	03-03-2010
		DE 102009043860 A1	15-04-2010
		JP 2010053863 A	11-03-2010
		US 2010054912 A1	04-03-2010
US 2013101391 A1	25-04-2013	CH 705551 A1	28-03-2013
		EP 2570615 A1	20-03-2013
		JP 5955176 B2	20-07-2016
		JP 2013064404 A	11-04-2013
		US 2013101391 A1	25-04-2013

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