(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
15 October 2009 (15.10.2009)

PCT

(10) International Publication Number
WO 2009/124585 A1

(51) International Patent Classification:
F02C 3/10 (2006.01) *F02C 6/18* (2006.01)
F02C 6/02 (2006.01) *F01D 5/18* (2006.01)

(21) International Application Number:
PCT/EP2008/054228

(22) International Filing Date:
8 April 2008 (08.04.2008)

(25) Filing Language: English

(26) Publication Language: English

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(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MT, NL, NO, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report (Art. 21(3))*

(54) Title: TURBINE DEVICE

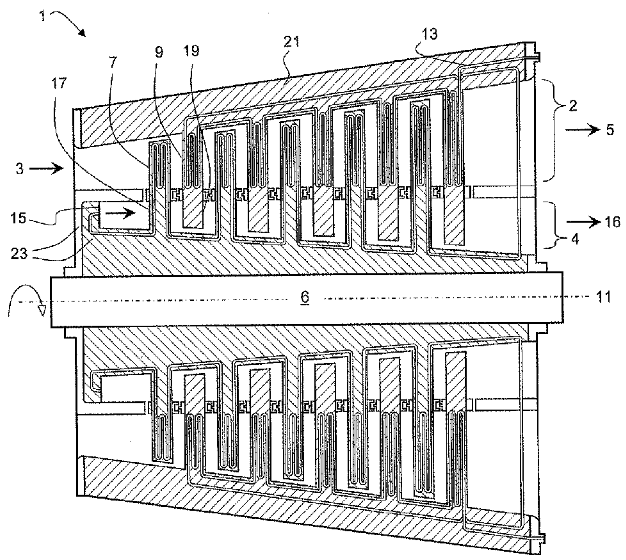

Fig 1

(57) Abstract: The invention relates to a method for conversion of a gas turbine engine (37) to a turbine engine with a combined gas and steam turbine device (33). The invention also relates to improvements of a turbine device (1) comprising concentrically arranged gas and steam turbine portions (2, 4), especially with regards to the turbine blades (7, 17, 9, 19). Further, a method for regulating a turbine engine comprising such a turbine device is proposed.

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Turbine device

TECHNICAL FIELD

The present invention relates to improvements of a turbine device comprising concentrically arranged gas turbine and steam turbine portions. The invention further relates to a method for regulating a turbine engine comprising such a turbine device.

BACKGROUND ART

Gas turbine engines are used for the conversion of the chemical energy of a fuel into mechanical energy in a number of situations. There, a gas turbine is driven by a gas flow which is generated by combustion of the fuel. The gas turbine usually drives a compressor in order to compress air and supply the combustion chamber with an increased amount of oxygen.

The advantage of the gas turbine engine is, in general, that the engine can provide high power at low weight. A drawback has traditionally been that the efficiency, i.e. the utilisation of the chemical energy of the fuel, is low.

A turbine device of high efficiency comprising concentric gas turbine and steam turbine portions is known from Swedish Patent No. SE530142 C2, US Provisional Application No. 60/969997 and PCT Application No. PCT/SE2008/050258.

Such a turbine device can replace conventional turbines in a number of applications, as has been discussed in the prior art referred to above. If an existing gas turbine engine is to be retrofitted with a turbine device which comprises concentric gas turbine and steam turbine portions, certain design considerations must be taken into account in order to maximise the utilisation coefficient.

SUMMARY OF THE INVENTION

The objective of the present invention is to provide a method for optimising a turbine engine which has been retrofitted with a turbine device that comprises concentrically arranged gas and steam turbine portions.

This objective has been achieved by a method for conversion of a gas turbine engine to a turbine engine with a combined gas and steam turbine device. Here, the gas turbine engine comprises a compressor, a combustion chamber that is supplied with air from the compressor, a compressor turbine and a power turbine. The compressor turbine drives the compressor and the power turbine provides output power. The compressor turbine is a gas turbine comprising a plurality of gas stages. During the conversion, the compressor turbine is replaced by a turbine device which includes a gas turbine portion and a steam turbine portion. The gas turbine portion and the steam turbine portion are concentrically arranged. Now, the number of stages of the gas turbine portion within the turbine device is chosen to be smaller than the number of stages of the replaced compressor turbine. Further, the number of stages within the steam turbine portion is larger than the number of gas turbine portion stages comprised within the turbine device.

By the reduction of gas stages within the compressor turbine, a higher amount of energy for the power turbine remains in the combustion gas. Further, the steam pressure at the inlet of the compressor turbine steam portion can be higher than the gas pressure at the inlet of the compressor turbine gas portion. Thereby, the power contribution from the steam turbine portion can be increased.

The invention further relates to the problem of increasing the utilisation coefficient of a turbine device with concentrically arranged gas and steam turbine portions. An efficient cooling of the turbine blades is also desired.

This has been obtained by a rotor blade for a turbine device that comprises a gas turbine portion and a concentrically arranged steam turbine portion. The turbine rotor blade comprises channels that are adapted to lead steam from the steam turbine portion to the gas turbine portion and back to the steam turbine portion within the rotor blade. Hereby, simple blade design, efficient cooling of the blades, and also energy supply to the steam turbine portion is achieved.

The objectives have also been achieved by a turbine stator blade for a turbine device that comprises a gas turbine portion and a concentrically arranged steam turbine portion and also a steam generator. Now, the turbine stator blade comprises a steam channel that is adapted to lead steam from the steam generator, through the gas turbine portion and to the steam turbine portion. In this manner, the stator blade is efficiently cooled.

In a turbine device with concentrically arranged gas and steam turbine portions, it is desirable to vent air from the hub of the turbine device. This can be achieved by means of an air channel that is adapted to lead air from the hub, through the steam turbine portion and to the gas turbine portion.

In a turbine device with concentrically arranged gas and steam turbine portions, the load on the turbine blade increase since the same blade extends through both portions. This problem can be solved by introducing a partition wall that separates the gas turbine portion from the steam turbine portion. If the gas turbine rotor blades are attached to the partition wall, the centrifugal forces caused by the rotation of the gas turbine rotor blades are partly carried and counter balanced by the partition wall.

Further, in accordance with the invention, the utilisation coefficient of a turbine device with concentrically arranged gas and steam turbine portions can be increased by using steam turbine rotor blades and gas turbine rotor blades of different cross-section. Then, the cross-section of the steam turbine rotor blades can be optimised for the steam flow in the steam turbine portion and the cross-section of the gas turbine rotor blades can be optimised for the gas flow in the gas turbine portion.

Either the steam turbine rotor blades may be divided into a first and a second rotor blade part, whereby a flow-through channel is formed in the rotor blade, or the steam turbine rotor blades may be of a smaller cross-section, allowing the arrangement of more steam turbine rotor blades than gas turbine rotor blades.

Efficient cooling of the blades is ensured by a method for regulating a turbine engine that comprises a compressor, a combustion chamber, a compressor turbine and a power turbine. The compressor turbine and/or the power turbine is a turbine device which comprises a gas turbine portion and a concentrically arranged steam turbine portion. The compressor turbine and/or the power turbine further comprises rotor blades and stator blades with fluid channels, and a steam generator which generates steam for the fluid channels in order to cool the blades and drive the steam turbine portion. According to the method, compressed air from the compressor is during start-up led to the blades of the turbine device.

Efficient cooling is also ensured, and overspeed prevented, if during shutdown, the steam supply to the steam turbine portion of the turbine device is interrupted, and a relatively small amount of air is led from the compressor to the steam turbine portion of the turbine device.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will now be described in greater detail with reference to the enclosed drawings, where

figure 1 shows an axial cross-section of a known turbine device 1 which comprises a gas turbine portion 2 and a steam turbine portion 4;

figure 2 schematically illustrates a turbine engine 37 comprising a compressor 45, a combustion chamber 43, a compressor turbine 31 and a power turbine 41;

figure 3a illustrates conventional compressor and power turbines 31, 41;

figure 3b illustrates converted compressor and power turbines 32, 41, which now comprise a gas turbine portion 2 and a steam turbine portion 4;

figure 3c illustrates converted compressor and power turbines 33, 41, whereby, in the compressor turbine 33, the number of stages of the gas turbine portion 2 and a steam turbine portion 4 are optimised;

figure 4 shows a turbine rotor blade 7, 17 including channels 101, 103 for conducting steam from a steam turbine portion 4 to a gas turbine portion 2 and back to the steam turbine portion 4;

figure 5 shows a turbine stator blade 9, 19 including a steam channel 201 for supplying steam to a steam turbine portion 4 of a turbine device and an air channel 203 for leading air from a hub 205 of a turbine device to a gas turbine portion 2;

figure 6 illustrates a plurality of turbine rotor blades 7, 17 and a partition wall 301 that is arranged between a gas turbine portion 2 and a steam turbine portion 4;

figure 7 illustrates two alternatives for designing the steam turbine rotor blades when different cross-sections are used for the steam turbine rotor blades and the gas turbine rotor blades; and figure 8 is a block diagram illustrating a method for regulating a turbine engine comprising a turbine device with a gas portion and a steam portion.

Neither the drawings nor the description below shall limit the scope of the present invention. Throughout the drawings, the same reference numerals have been used for the same components.

DETAILED DESCRIPTION

Figure 1 illustrates a turbine device 1 comprising a gas turbine portion 2 and a steam turbine portion 4, wherein the gas turbine portion 2 and the steam turbine portion 4 are concentrically arranged. This principle is known from Swedish Patent No. SE530142 C2, US Provisional Application No. 60/969997 and PCT Application No. PCT/SE2008/050258.

Combustion gas from a combustion chamber enters (indicated by arrow 3) the gas turbine portion 2 of the turbine device 1. In figure 1, the combustion gas passes from left to right (indicated by arrows 3 and 5) through the gas turbine portion 2, whereby the gas drives a turbine shaft 6 by acting on a plurality of gas turbine rotor blades 7. The gas turbine portion 2 also comprises a plurality of guide vanes or gas turbine stator blades 9. The rotor blades 7 and stator blades 9 are intermittently arranged along the longitudinal turbine axis 11.

Fluid channels 13 are arranged within the gas turbine rotor blades 7 and the gas turbine stator blades 9. By means of a fluid flowing in said channels 13, heat is absorbed from the combustion gas in the gas turbine portion 2. The fluid channels 13 lead to an inlet 15 of the steam turbine portion 4. In this manner, the temperature of the fluid which runs through the gas turbine portion 2 is increased, and the high pressure fluid is injected into the inlet 15 of the steam turbine portion 4. At this point, the fluid is normally in the form of steam.

The steam turbine portion 4 is arranged radially inside the gas turbine portion 2, as can be seen in figure 1. The steam passes from left to right (indicated by the arrow at the steam inlet 15 and by the arrow 16) through the steam turbine portion 4, whereby the steam drives the turbine shaft 6 by acting on a plurality of steam turbine rotor blades 17. Thus, the steam and the combustion gas both drive the same turbine shaft 6. The steam turbine portion 4 further comprises a plurality of guide vanes or steam turbine stator blades 19. As in the gas turbine portion 2, the steam turbine rotor blades 17 and the steam turbine stator blades 19 are intermittently arranged.

The rotor blades 7, 17 are mounted on a rotor 21, and the stator blades 9, 19 are mounted on a stator 23.

In the schematical illustration of figure 1, the most upstream blade is a rotor blade 7, 17, which is followed by a stator blade 9, 19. The situation can also be the reversed, i.e. the most upstream blade can be a stator blade, see figure 3.

Reference is now made to figures 2 and 3. One aspect of the invention relates to a method for conversion of a gas turbine engine 37 to a turbine engine with a combined gas and steam turbine device 33. Hereby, the coefficient of utilisation of a turbine engine, which contains the gas turbine 31, can be increased.

A conventional gas turbine 35 of a turbine engine 37 can be divided into a compressor turbine 31 and a power turbine 41, respectively. The compressor turbine 31 is driven by combustion gas from a combustion chamber 43 and drives, in turn, a compressor 45 which provides the combustion chamber 43 with air. The power turbine 41 is arranged downstream the compressor turbine 31 and converts the remaining energy of the combustion gas to shaft power. In this connection, the compressor turbine 31 can be coupled to the compressor 45 by means of a first turbine shaft 47. The power turbine 41 can be coupled to a generator or to a transmission box (not shown) via a second turbine shaft 49. Such a turbine engine is generally referred to as a twin-spool engine.

The compressor turbine 31 of the present example is initially a two-stage gas turbine. I.e., the compressor turbine 31 comprises two axially separated sets of gas turbine blades, see figure 3a. In the figures 3a, 3b and 3c, a gas turbine stage is denoted G and a steam turbine stage is denoted S.

A straightforward method for increasing the power of the turbine engine 37 might be to convert it by replacing both the compressor turbine 31 and the power turbine 41 with turbine devices 1 comprising a gas turbine portion 2 and a concentric steam turbine portion 4. The result of such a conversion is shown in figure 3b, where the compressor turbine 32 comprises two gas stages G and two steam stages S. However, the increased power of the compressor turbine 32 will not be needed for driving the compressor 45, and is thus not optimally utilised.

The inventive method for increasing the power of the turbine engine 37 is shown in figure 3c. Here, a compressor turbine 33 comprising one gas turbine stage G and three steam turbine stages S is put to use. The introduction of a three-stage steam turbine portion 4 makes one of the gas stages redundant. One gas stage G together with three steam stages S suffice for generating the power needed by the compressor. Thus, one of the gas turbine stages of the compressor turbine 31, 32 can be removed. The removal of a turbine stage implies the removal of one plurality of rotor blades and one plurality of stator blades.

If an existing turbine engine 37 is converted in this manner, i.e. from the design of figure 3a to the design of figure 3c, the gas temperature and the gas pressure at the outlet of the compressor turbine 33 are increased. Consequently, the gas temperature and the gas pressure at the inlet of the power turbine 41 are increased, whereby the power turbine 41 can yield more power.

In a turbine device 1 with concentrically arranged gas turbine portion 2 and steam turbine portion 4, it is desirable to design the device such that the gas pressure of the gas turbine portion 2 is essentially equal to the steam pressure of the steam turbine portion 4 along the longitudinal turbine axis 11. If the gas turbine portion 2 and the steam turbine portion 4 are arranged with axially coinciding inlets and outlets, see figure 1, the respective gas and steam pressures must be matched. However, as has been described with reference to figures 3b and 3c, the number of gas turbine stages and steam turbine stages can be varied. E.g., if desired, a higher number of steam turbine stages than gas turbine stages can be put to use (figure 3c).

Typically, the combustion gas pressure of the combustion chamber 43, and thus the inlet pressure of the gas turbine portion 2, is around 1.5 MPa. Consequently, the turbine device 1 should be designed such that the steam pressure at the inlet of the steam turbine portion 4 is also around 1.5 MPa. With the addition of more steam turbine stages (figure 3c), however, the steam pressure at the inlet of the steam turbine portion 4 can be increased to e.g. 5 MPa. Thereby, the steam turbine power contribution is increased substantially. Since each turbine stage entails a drop of pressure, the additional steam turbine stages will lower the steam pressure to the desired 1.5 MPa at the axial location where the inlet of the gas turbine portion 2 is arranged.

The steam pressure is affected by the design of the fluid channels 13. A separate steam generator can also be used for generating sufficient steam at a predetermined pressure.

The power turbine 41 of figures 3b and 3c can be a conventional gas turbine or, as illustrated here, a turbine device 1 comprising a gas turbine portion 2 and a concentric steam turbine portion 4. If the power turbine 41 is a turbine device 1 comprising a gas turbine portion 2 and a concentric steam turbine portion 4, the steam turbine portion 4 can be lengthened by the addition of steam turbine stages at the end of the steam turbine portion 4. By such an arrangement, more steam energy can be utilised.

When a gas stage is removed, as is illustrated in figure 3c, an inner stator wall 34 can be arranged to constitute the outer wall for the steam turbine portion that is not located radially inside a gas turbine portion. The inner stator wall 34 can be held by rods (not shown) extending radially inwards from the stator wall. A similar solution applies if additional steam stages are added before and/or after a turbine device.

Figure 4 illustrates another aspect of the present invention. A turbine device 1 with concentric gas turbine portion 2 and steam turbine portion 4 (figure 1) is presumed. Here, steam is led from the steam turbine portion 4 to the gas turbine portion 2 and back to the steam turbine portion 4 by means of channels 101, 103 within rotor blades 7, 17. In this manner, the blades 7, 17 are cooled and the steam of the steam turbine portion 4 is superheated. The flow through the channels 101, 103 is propelled by the pressure difference between the front edge and the rear edge of the blade.

In the steam turbine portion 4, steam enters a steam turbine rotor blade 17 through an inlet opening 105 at the front, i.e. upstream, edge of the blade 17. The steam propagates radially outwards in the longitudinal direction of the blade 7, 17 through an outboard channel 101 from the steam turbine portion 4 to the gas turbine portion 2.

Although other embodiments are conceivable (see e.g. figure 7), in figure 4 the respective cross-sections of the steam turbine rotor blade 17 and the gas turbine rotor blade 7 are equal. The outboard channel 101 extends from the steam turbine rotor blade 17 to the gas turbine rotor blade 7. Within the gas turbine rotor blade 7, the outboard channel 101 is divided into a plurality of inboard channels 103. The inboard channels lead the steam radially inwards back to the steam turbine rotor blade 17, and terminate at an outlet opening 107. The outlet opening 107 is located at the rear, i.e. downstream, edge of the steam turbine rotor blade 17. In this example, one outboard channel 101 and four inboard channels 103 are used, but any desired flow geometry providing high heat transfer may be used.

In order to maximise the heat transfer from the combustion gas to the gas turbine rotor blades 7, and thus to the steam flowing in the outboard channels 101 and the inboard channels 103, said channels extend along essentially the whole length of the gas turbine rotor blades 7.

The arrangement 105, 101, 103, 107 for collecting heat from the gas turbine portion 2 and supplying said heat to the steam turbine portion 4 implies that steam is injected at the steam turbine portion 4 inlet 15. This steam can be generated in a separate steam generator, which will be discussed below.

The arrangement 105, 101, 103, 107 can also be used in combination with the fluid channels 13 described above. Each turbine rotor blade 7, 17 then contains the outboard channels 101, the inboard channels 103 and the fluid channels 13. Alternatively, the turbine rotor blades 7, 17 can comprise the outboard channels 101 and the inboard channels 103 as shown in figure 4, whereas only the turbine stator blades 9, 19 comprise the fluid channels 13 as shown in figure 1.

Figure 5 relates to yet another aspect of the present invention. This aspect addresses e.g. the problem of cooling the stator blades 9, 19. In a turbine device with concentrically arranged gas turbine portion 2 and steam turbine portion 4, see figure 1, the stator blades 9 within the gas turbine portion 2 can, in accordance with figure 5, be cooled by steam flowing inside the blades 9. The steam flows through the gas turbine portion 2 to the steam turbine portion 4. For this purpose, a steam channel 201 can be arranged within the turbine stator blades 9, 19. The steam can be generated in a separate steam generator, which will be discussed below. The steam can alternatively be generated within the fluid channels 13 of the turbine blades.

As can be seen in figure 5, the turbine stator blade 9, 19 comprises a steam channel 201. Said channel 201 extends through the stator blade 9, 19 and is adapted to lead steam from outside the stator wall, through the gas turbine portion 2 and to the steam turbine portion 4. In this way, the steam is heated and the blade 9, 19 is cooled. In the steam turbine portion 4, the steam may exit the blade 19 through openings (not shown) at the rear edge of the steam turbine stator blade 19. The steam may alternatively be led upstream by pipes (not shown) and be released into the steam turbine portion 4 prior to the stator blade 9, 19. Arrows 207 show the flow of the steam through the stator blade 19 in an illustrative manner.

The steam channel 201 can be arranged within the most upstream turbine blades of the turbine device 1. The subsequent stator blades along the turbine axis 11 can either be furnished with analogous steam channels 201, or with fluid channels 13 as illustrated in figure 1. The steam flow geometry within the blade is optimised for high heat transfer.

In figure 5, the turbine hub is indicated by reference numeral 205. Compressed air may leak from the compressor 45 e.g. through a shaft 47 seal (not shown) and rear shaft bearings (not shown) to the hub 205 of the turbine device 1. This air can be vented by means of an air channel 203 within the stator blades 9, 19. Such air channels 203 can, although not shown, alternatively be arranged within the rotor blades 7, 17.

The purpose of the air channel 203 is to lead air from the hub 205, through the steam turbine portion 4 and to the gas turbine portion 2. Thereby the rear edge of the turbine blade 7, 17, 9, 19 is cooled. Advantageously, the air channel may terminate in a plurality of outlet openings 209 or slots 209, arranged in the rear or trailing edge of the turbine blade. Such slots 209 may be arranged along essentially the entire turbine blade edge, whereby an effective cooling is obtained all along the edge.

Figure 6 schematically illustrates another aspect of the present invention. This aspect addresses the problem of designing a turbine device with concentrically arranged gas and steam turbine portions 2, 4, while avoiding exposing the rotor blades 7, 17 to high mechanical loading. The concentrically arranged turbine portions 2, 4 may imply that the rotor blades 7, 17 are longer than those of a conventional gas turbine, whereby the centrifugal forces acting on the radially inner section of the blades 7, 17 increase. This increased loading is to a certain part compensated for by the above described cooling of the rotor blades 7, 17. Lower temperature leads to higher strength. In figure 6, a supplementary solution for decreasing the mechanical loading on the rotor blades 7, 17 is shown.

A partition wall 301 is arranged between the gas turbine portion 2 and the steam turbine portion 4. The partition wall or outer seal ring 301 serves to separate the gas turbine portion 2 from the steam turbine portion 4, and can be made up by a number of plates (shown in figures 4 and 5) attached to the blades. However, by making the partition wall 301 as a full ring and attaching the gas turbine rotor blades 7 to said partition wall 301, part of the centrifugal forces caused by the respective gas turbine rotor blades 7 around the rotor are taken up by the partition wall 301.

Figure 6 further shows the stator wall 303, an inner seal ring 305, and turbine blade feet 307. The gas turbine portion 4 is delimited by the partition wall 301 and the inner seal ring 305. A corresponding partition wall and inner seal ring is carried by the stator blades 9, 19.

Figure 7 relates to a further aspect of the present invention. Here, the gas turbine blades 7, 9 and the steam turbine blades 17, 19 are optimised for the gas flow and the steam flow of a turbine device 1, respectively. A turbine device 1 with concentric gas turbine portion 2 and steam turbine portion 4 (figure 1) is presumed.

As indicated in e.g. figure 6, the volume of the steam turbine portion 4 is much smaller than the volume of the gas turbine portion 2. This is indicated by the radial position of the partition wall 301. The steam flow through the steam portion 4 constitutes in fact merely around 10 % of the gas flow through the gas portion 2. Thus, the radial length of the steam turbine blades 17, 19 is smaller than the radial length of the gas turbine blades 7, 9.

If the steam turbine rotor blades 17 are to be able to carry the centrifugal load of the gas turbine rotor blades 7 (i.e., if no load carrying partition wall 301 is put to use), the cross-section of the steam turbine blades 17 must be essentially the same as the cross-section of the gas turbine blades 7.

Assuming that the same cross-section is used for the steam turbine rotor blades 17 and the gas turbine rotor blades 7, the steam turbine rotor blades 17 will have a comparatively large chord 401 to blade length ratio. By length is meant the radial length of the rotor blade 17. A large chord 401 to blade length ratio implies high flow resistance, and is thus unfavourable.

Thus, it is desirable to use a different design for the steam turbine rotor blades 17 and the gas turbine rotor blades 7, so that the respective blades 17, 7 are optimised for the flow in the steam turbine portion 4 and the gas turbine portion 2. In particular, a large chord 401 to blade length ratio is to be avoided.

In the left part of figure 7, a first proposed design for the cross-section of the steam turbine rotor blades is shown. The cross-section of a gas turbine rotor blade 7 is also indicated. Each steam turbine rotor blade is divided into a first blade part 17a and a second blade part 17b. Thereby, a flow-through channel 403 is formed in the rotor blade. The flow through channel 403 reduces the flow resistance of the steam turbine rotor blade 17a, 17b. Furthermore, chord to blade length ratio is reduced.

Figure 7 further illustrates, on the right hand side, a second possible design for the cross-section of the steam turbine rotor blades. For comparison, the cross-section of a gas turbine rotor blade 7 is again indicated. Here, a plurality of smaller steam turbine blades 17c, 17d, 17e is used instead of one larger turbine blade. Thus, the chord is reduced while the radial length of the steam turbine rotor blade is unaltered, which means that the chord to blade length ratio is reduced.

In accordance with the present invention, the use of two to five smaller steam turbine blades per corresponding gas turbine blade provides an appropriate chord to blade length ratio. Three smaller steam turbine blades 17c, 17d, 17e result in an especially suitable chord to blade length ratio.

The optimisation of the steam turbine rotor blades can be realised jointly with the use of a partition wall 301, which has been described with reference to figure 6. In this manner, the steam turbine blades 17a, 17b; 17c, 17d, 17e do not have to carry the entire centrifugal load caused by the gas turbine blades 7. Said optimisation may however also be carried out without the partition wall 301, then the steam turbine blades 17a, 17b; 17c, 17d, 17e must be designed so that they are able to carry the centrifugal forces caused by the gas turbine blades 7.

The block diagram of figure 8 illustrates a method for regulating a power plant turbine engine comprising a turbine device 1 with a gas portion 2 and a steam portion 4. This block diagram is consistent with the illustration of figure 2, but figure 8 further discloses a steam generator 51, a condenser 53, an electric generator 55, and valves V1-V5. Both the compressor turbine 31 and the power turbine 41 are turbine devices of the kind illustrated in figure 1.

The steam generator 51 is connected to the outlet of the gas turbine portion 2 of the power turbine 41. Further, the steam generator 51 is connected to the steam portion inlet of compressor turbine 31, via a valve V1. Via a valve V2, the steam generator 51 is also connected to the steam portion inlet of power turbine 41. Thereby, the steam generator 51 makes use of the heat from the combustion gas in order to generate steam, which is supplied to the compressor turbine 31 and the power turbine 41. An arrow at the top of the steam generator 51 in figure 8 indicates the combustion gas outlet. The steam generator 51 can also be powered by a separate burner or by electrical means.

The valves V1, V2 are control valves that ensure that a maximal amount of steam is supplied to the steam turbine portions 4 of the compressor turbine 31 and the power turbine 41, without substantial leakage of steam from the steam portions 4 to the gas portions 2 of the respective turbines 31, 41. The valves V1, V1 are governed by the combustion gas pressure before the compressor turbine 31 and power turbine 41, respectively. A blow off valve V4 is arranged at the steam generator 51 steam outlet.

The condenser 53 is connected to the steam generator 51 and can supply condensed fluid such as water to the steam generator 51. Said steam is led to the condenser 53 through a connection with the steam turbine portion 4 of the power turbine 41. As can be seen in figure 8, said connection between the power turbine 41 and the condenser 53 comprises a blow off valve V5. The heat generated during the condensing can be used for heating purposes.

The arrows to the left of the condenser in figure 8 illustrate a connection to e.g. a district heating system.

The electric generator 55 is coupled to the power turbine 41 via the second turbine shaft 49.

The outlet of the compressor 45 is connected to the steam inlet of the compressor turbine 31. As can be seen in figure 8, a valve V3 is arranged to regulate the air flow from the compressor 45 to the compressor turbine 31. The compressor 45 can also be connected to the steam inlet of the power turbine 41.

The regulation of the present turbine engine is in principle concordant with the regulation of conventional combined gas and steam turbine engines. However, since the gas turbine portion 2 and the steam turbine portion 4 (within the compressor turbine 31 and the power turbine 41, respectively) are arranged within the same housing, and share the same rotor, the steam turbine portion 4 will be in operation even if no steam is generated by the gas turbine portion 2. This is the case at transient conditions, such as start-up or emergency shut-down. During such conditions, the lack of steam means that the compressor turbine 31 and the power turbine 41 are insufficiently cooled.

In order to obtain sufficient cooling at start-up, the valves V1, V2 between the steam generator 51 and the compressor turbine 31 and the power turbines 41 are closed. The remaining valves V3, V4, V5 are open so that air from the compressor 45 is led through the compressor and power turbines 31, 41 and provide cooling for these. The air is led through fluid channels 13 (see figure 1) arranged within the turbine blades of the turbines 31, 41. A starter motor is used to help bringing the turbines 31, 41 to idle, which generally takes about 2-3 minutes. Subsequently, steam is being generated by the steam generator 51 and by means of the fluid channels 13 within the compressor turbine 31 and the power turbine 41. Now the valves V1, V2 between the steam generator 51 and the compressor turbine 31 and the power turbines 41 can be opened, and the remaining valves V3, V4, V5 can be closed.

At emergency shut-down, caused e.g. by a sudden loss of load on shaft 49, turbine 31, 41 overspeed must be prevented. In this connection, the fuel supply is immediately cut. The steam supply to the steam turbine portions 4 of the compressor turbine 31 and the power turbine 41 is interrupted by closing of the valves V1, V2 between the steam generator 51 and the turbines 31, 41. The blow off valve V4 at the steam generator 51 steam outlet is opened in order to ventilate the steam generator 51. The remaining valves V3 and V5 are gradually opened in order to lead air from the compressor through the steam turbine portions 4 of the turbines 31, 41 for cooling. The air is led through fluid channels 13 (see figure 1) arranged within the turbine blades of the turbines 31, 41. By this gradual opening, the air flow is sufficient for cooling, but not strong enough to provide undesired driving force to the turbines 31, 41.

CLAIMS

1. A method for conversion of a gas turbine engine (37) to a turbine engine with a combined gas and steam turbine device (33), which gas turbine engine (37) comprises

a compressor (45),

a combustion chamber (43), which is supplied with air from the compressor (45),

a compressor turbine (31) and

a power turbine (41),

wherein the compressor turbine (31) drives the compressor (45) and the power turbine (41) provides output power, and wherein the compressor turbine (31) is a gas turbine comprising a plurality of gas stages (G),

characterised by the steps of

replacing the compressor turbine (31) by a turbine device (33) which includes a gas turbine portion (2) and a steam turbine portion (4), in which turbine device (33) the gas turbine portion (2) and the steam turbine portion (4) are concentrically arranged,

wherein the number of stages (G) of the gas turbine portion (2) within the turbine device (33) is chosen to be smaller than the number of stages (G) of the replaced compressor turbine (31), and wherein the number of stages (S) within the steam turbine portion (4) is larger than the number of gas turbine portion (2) stages (G) comprised within the turbine device (33).

2. A method according to claim 1, wherein the compressor turbine (31) originally comprises two gas stages (G), and wherein after conversion, the compressor turbine (33) comprises one gas stage (G) and three steam stages (S).

3. A method according to claim 1 or 2, wherein at least one of the steam stages are arranged axially in front of the inlet of the gas turbine portion (2), allowing the inlet pressure of the steam turbine portion (4) to be higher than the inlet pressure of the gas turbine portion (2).

4. A turbine rotor blade (7, 17) for a turbine device (1), which device (1) comprises

a gas turbine portion (2) and

a concentrically arranged steam turbine portion (4),

characterised by that

the turbine rotor blade (7, 17) comprises channels (101, 103) that are adapted to lead steam from the steam turbine portion (4) to the gas turbine portion (2) and back to the steam turbine portion (4) within the rotor blade (7, 17).

5. A turbine blade according to claim 4, wherein the channels (101, 103) comprise at least one outboard channel (101), which extends from the steam turbine portion (4) to the gas turbine portion (2), and a plurality of

inboard channels (103), which extend from the gas turbine portion (2) to the steam turbine portion (4).

6. A turbine stator blade (9, 19) for a turbine device (1), which device (1) comprises

an outer gas turbine portion (2) and

a concentrically arranged inner steam turbine portion (4), and

a steam generator,

characterised by that

the turbine stator blade (9, 19) comprises a steam channel (201) that is adapted to lead steam from the steam generator, through the gas turbine portion (2) and to the steam turbine portion (4).

7. A turbine blade (7, 17, 9, 19) for a turbine device (1), which device (1) comprises

an outer gas turbine portion (2) and

a concentrically arranged inner steam turbine portion (4), and

wherein the steam turbine portion (4) surrounds a hub (205) of the turbine device (1),

characterised by that

the turbine blade (7, 17, 9, 19) further comprises an air channel (203) that is adapted to lead air from the hub (205), through the steam turbine portion (4) and to the gas turbine portion (2).

8. A blade according to claim 7, wherein the air channel (203) terminates in a plurality of slots (209), arranged in the rear edge of the turbine blade.

9. A turbine device (1) comprising

a gas turbine portion (2) and

a concentrically arranged steam turbine portion (4), and

steam turbine rotor blades (17) and gas turbine rotor blades (7) which extend from a turbine hub of the device (1) through the steam turbine portion (4) and through the gas turbine portion (2),

characterised by

a partition wall (301) which separates the gas turbine portion (2) from the steam turbine portion (4),

wherein the gas turbine rotor blades (7) are attached to the partition wall (301), so that centrifugal forces caused by the rotation of the hub and thus the gas turbine rotor blades (7) are partly carried and counter balanced by the partition wall (301).

10. A turbine device (1) comprising

a gas turbine portion (2) and

a concentrically arranged steam turbine portion 4, and steam turbine rotor blades (17) and gas turbine rotor blades (7) which extend from a turbine hub of the device (1) through the steam turbine portion (4) and through the gas turbine portion (2),

characterised by that

the steam turbine rotor blades (17) and the gas turbine rotor blades (7) are of different cross-section, whereby the cross-section of the steam turbine rotor blades (17) is optimised for the steam flow in the steam turbine portion (4) and the cross-section of the gas turbine rotor blades (7) is optimised for the gas flow in the gas turbine portion (2).

11. A turbine device according to claim 10, wherein each steam turbine rotor blade (17) is divided into a first and a second rotor blade part (17a, 17b), whereby a flow-through channel (403) is formed in the rotor blade (17).

12. A turbine device according to claim 10, wherein the steam turbine rotor blades (17a, 17b, 17c) have a smaller cross-section than the gas turbine rotor blades (7), allowing the arrangement of more steam turbine rotor blades (17a, 17b, 17c) than gas turbine rotor blades (7).

13. A method for regulating a turbine engine, which turbine engine comprises

a compressor (45), a combustion chamber (43), a compressor turbine (31) and a power turbine (41),

wherein the compressor turbine (31) and/or the power turbine (41) is a turbine device (1) which comprises a gas turbine portion (2) and a concentrically arranged steam turbine portion (4) and also rotor blades (7, 17) and stator blades (9, 19) with fluid channels (13), and a steam generator (51), which generates steam for the fluid channels (13) in order to cool the blades (7, 17, 9, 19) and drive the steam turbine portion (4),

characterised by that

during start-up, i.e. before the steam generator (51) supplies sufficient steam for cooling the blades (7, 17, 9, 19), compressed air from the compressor (45) is led to the blades (7, 17, 9, 19) of the turbine device (1), in order to prevent overheating.

14. A method according to the pre-characterising portion of claim 13,

characterised by that

during shut-down, the steam supply to the steam turbine portion (4) of the turbine device (1) is interrupted to prevent turbine overspeed, and a relatively small amount of air is led from the compressor (45) to the steam turbine portion (4) of the turbine device (1) to prevent overeating.

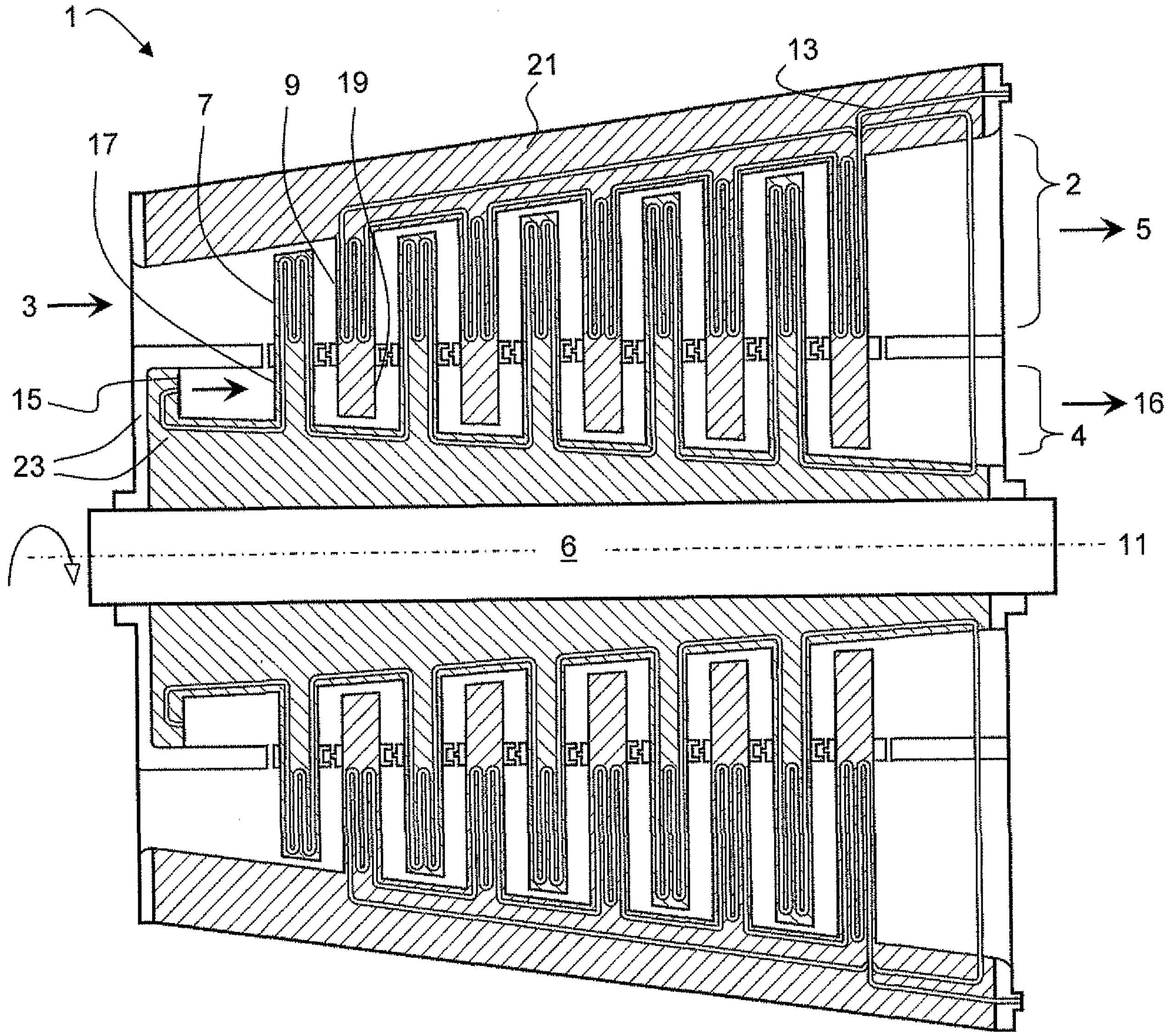

Fig 1

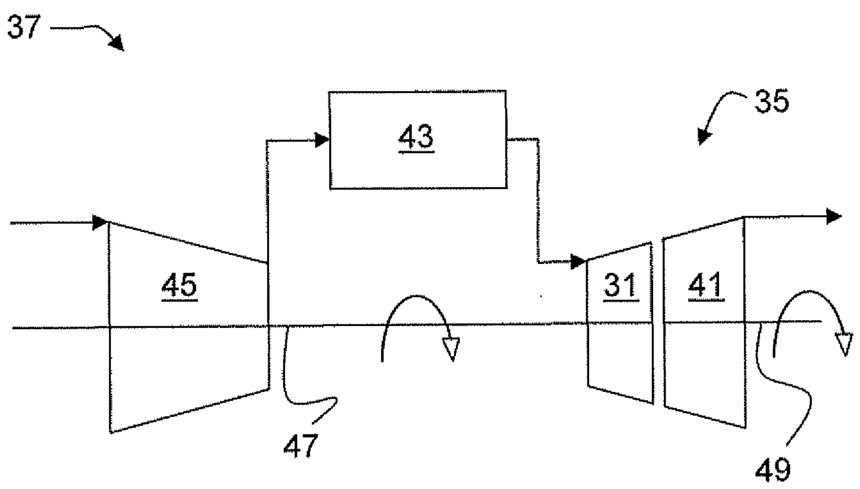

Fig 2

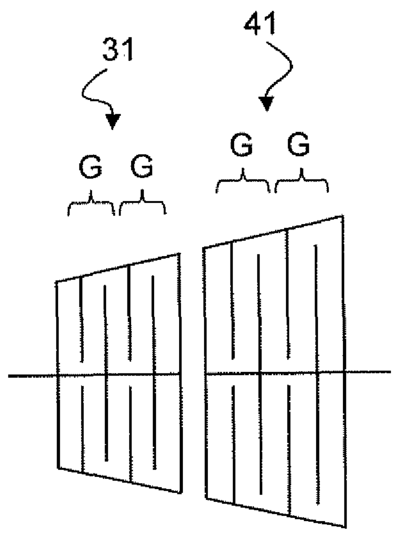

Fig 3a

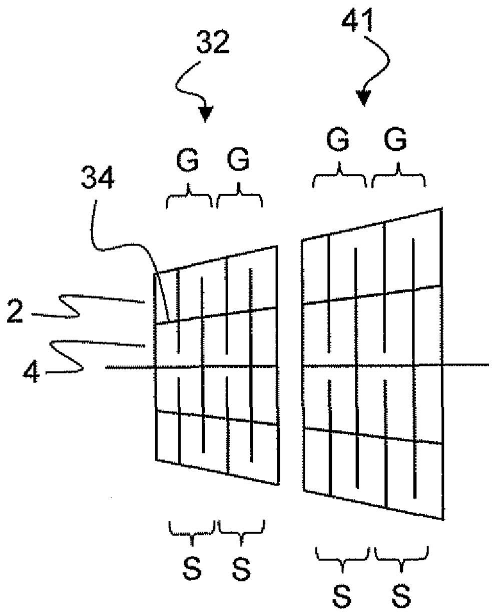

Fig 3b

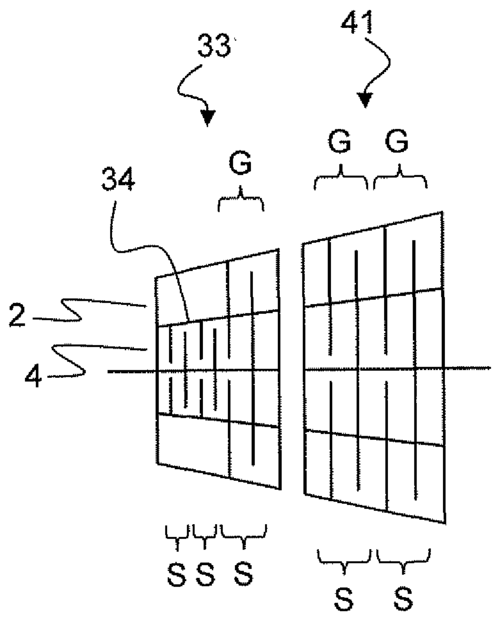

Fig 3c

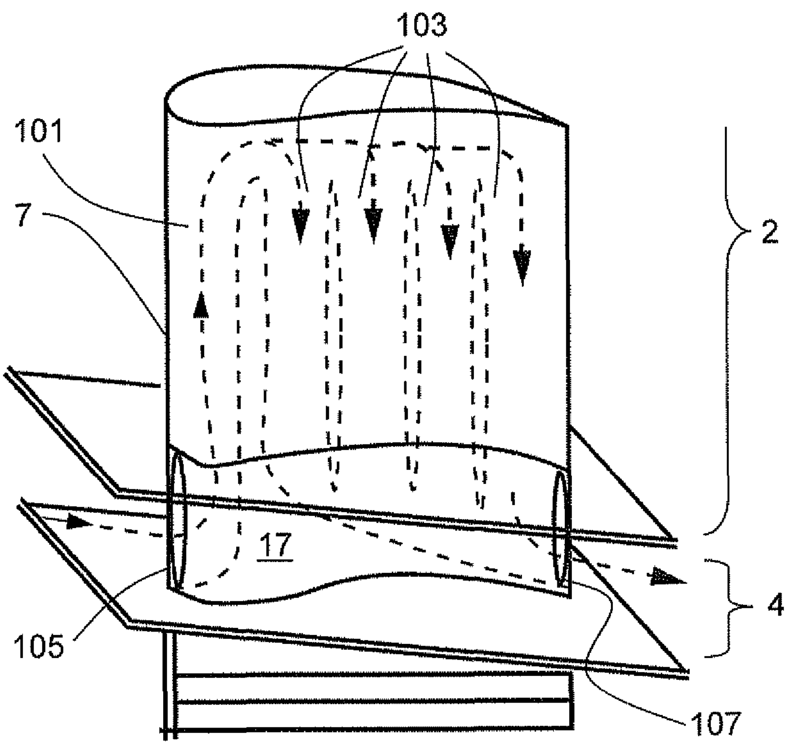

Fig 4

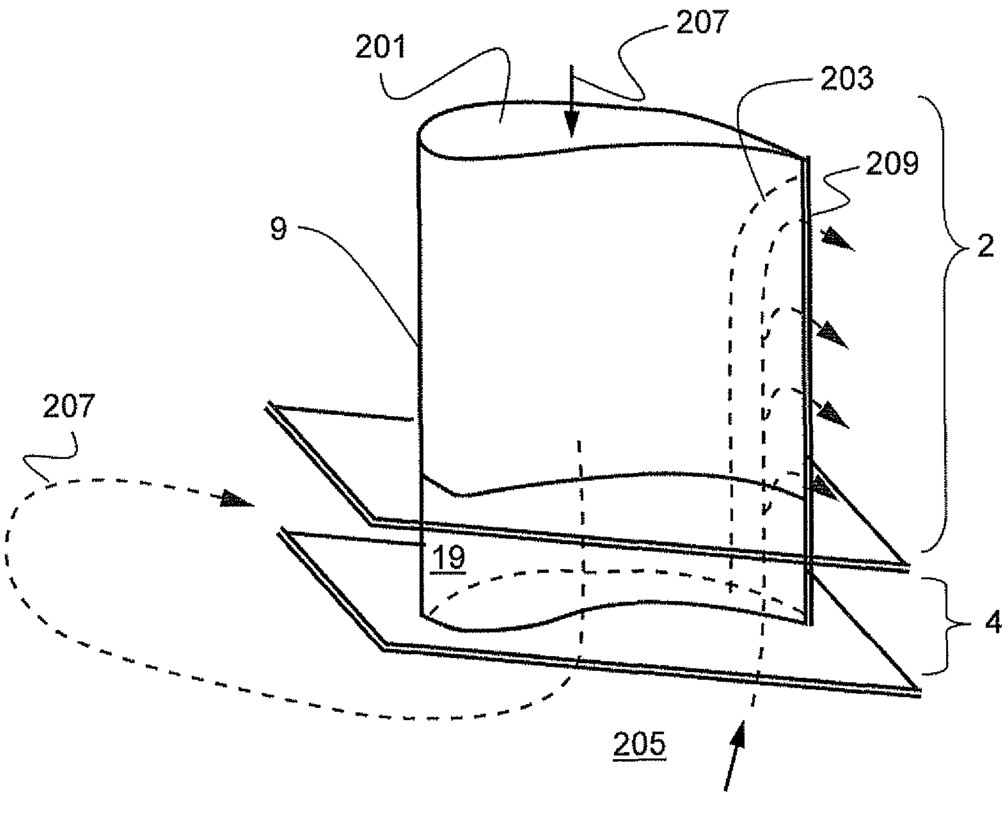

Fig 5

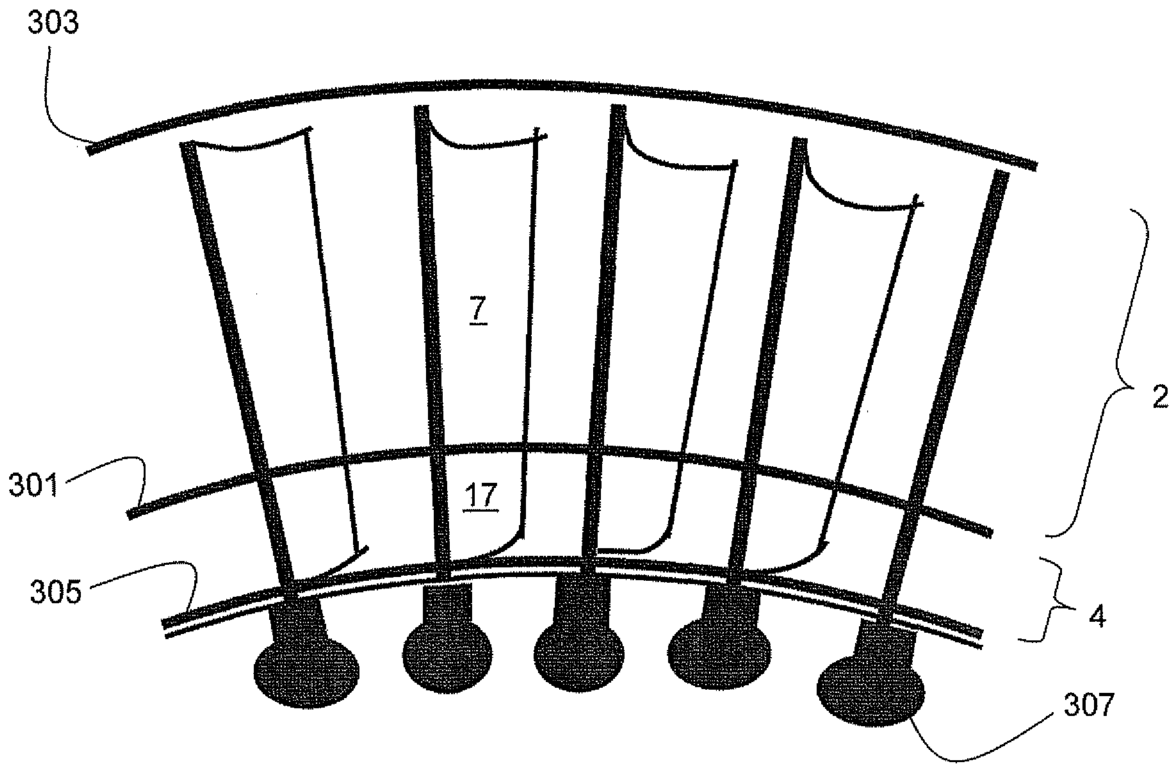

Fig 6

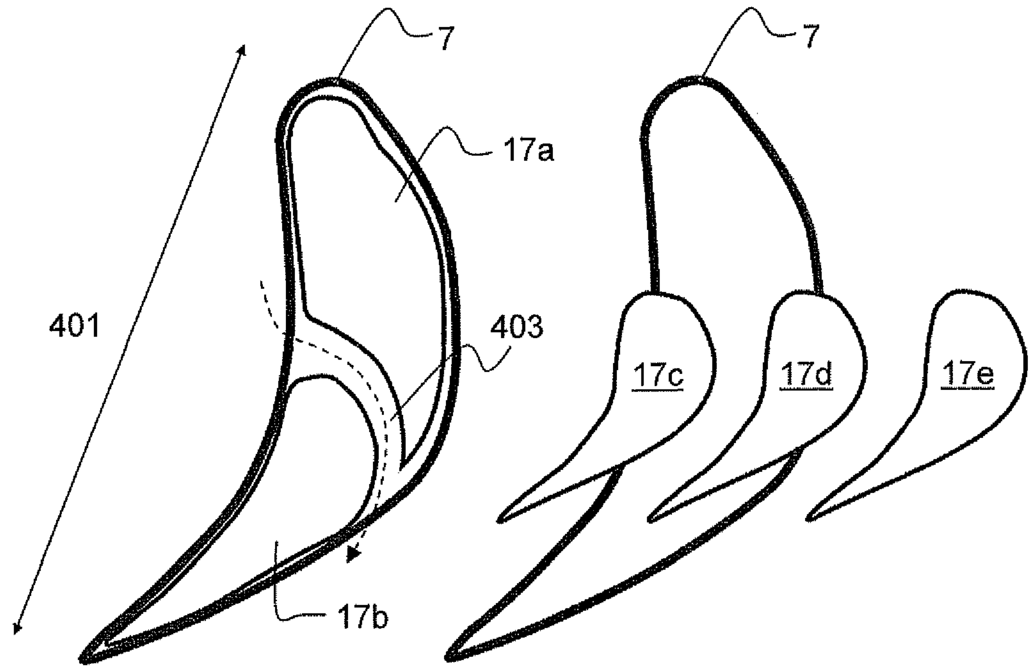

Fig 7

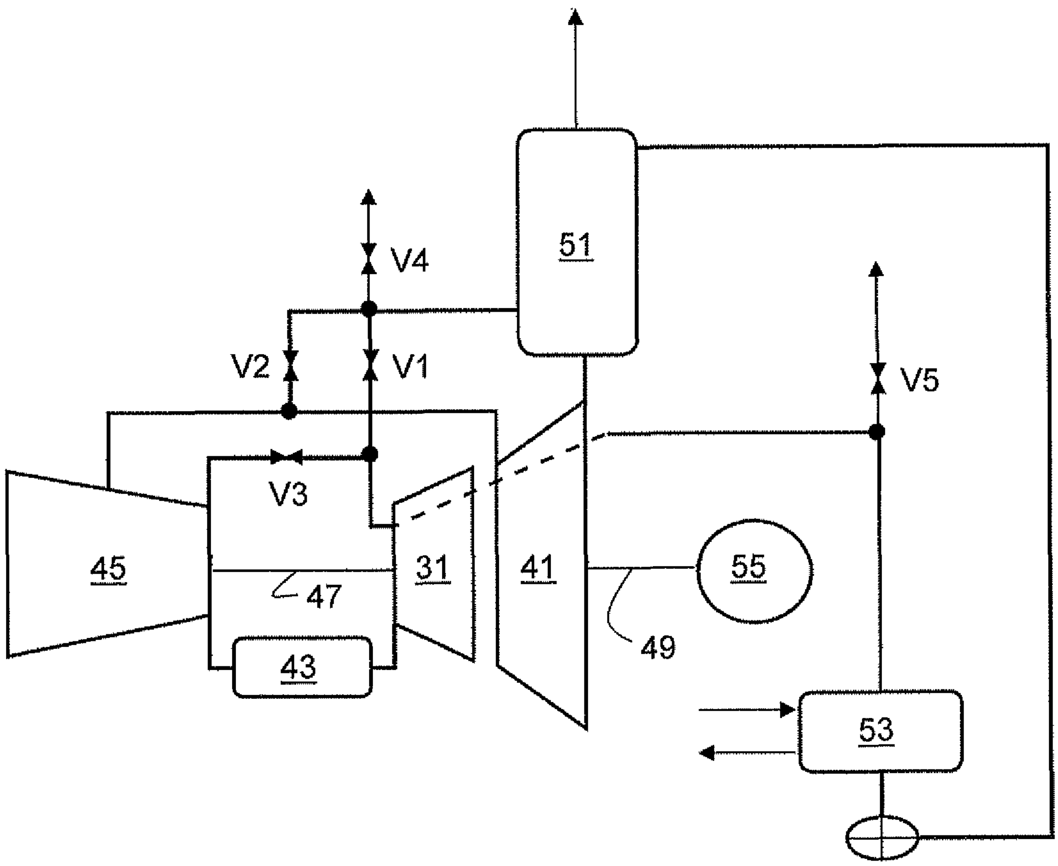

Fig 8

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2008/054228

A. CLASSIFICATION OF SUBJECT MATTER
INV. F02C3/10 F02C6/02 F02C6/18 F01D5/18

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F02C F01D F01K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CH 308 991 A (SCHMALFELDT HANS [DE]) 15 August 1955 (1955-08-15) page 1, lines 61-67; figures 2-4 page 2, lines 10-90	7,8
Y	US 4 141 672 A (WIELAND KURT H ET AL) 27 February 1979 (1979-02-27) column 1, line 29 - column 2, line 60; figure 7	4-6,9
Y	US 5 253 976 A (CUNHA FRANCISCO J [US]) 19 October 1993 (1993-10-19) column 5, line 55 - column 6, line 11; figures 1,4,5	4,5
Y	EP 0 979 932 A (MITSUBISHI HEAVY IND LTD [JP]) 16 February 2000 (2000-02-16) paragraph [0012]; figures 1,2	6

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[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
25 February 2009	04/03/2009

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Oechsner de Coninck

Form PCT/ISA/210 (second sheet) (April 2005)

International application No
PCT/EP2008/054228

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 3 132 842 A (THARP ROBERT L) 12 May 1964 (1964-05-12) column 2, lines 15-51; figures 1-4	9
A	US 6 003 298 A (HORNER MICHAEL W [US]) 21 December 1999 (1999-12-21) column 3, lines 2-62; figure 1	1-3
A	US 2004/194467 A1 (HERZOG MAURUS [CH] ET AL) 7 October 2004 (2004-10-07) paragraph [0063]; figures 1-7	1-3
A	US 6 263 664 B1 (TANIGAWA HIROYASU [JP] ET AL) 24 July 2001 (2001-07-24) column 6, lines 6-63; figures 2,6	1-3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/EP2008/054228

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers allsearchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.

3. ☒ As only some of the required additional search fees were timely paid by the applicant, this international search reportcovers only those claims for which fees were paid, specifically claims Nos.:

1-9

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☒ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-3

   a method for conversion of a gas turbine engine

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2. claims: 4-5

   a blade having a gas and steam turbine portions

   ---

3. claim: 6

   steam generator for a turbine device

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4. claims: 7-8

   air cooling for a dual airfoils blade

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5. claim: 9

   Airfoil portion attached on a partition wall

   ---

6. claims: 10-12

   Dual airfoils rotor blade

   ---

7. claim: 13

   Method for starting a combined gas turbine engine

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8. claim: 14

   Method for shutting down a combined gas turbine engine

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2008/054228

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
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			WO	02084080	A1	24-10-2002
US 6263664	B1	24-07-2001	AU	3276397	A	21-01-1998
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