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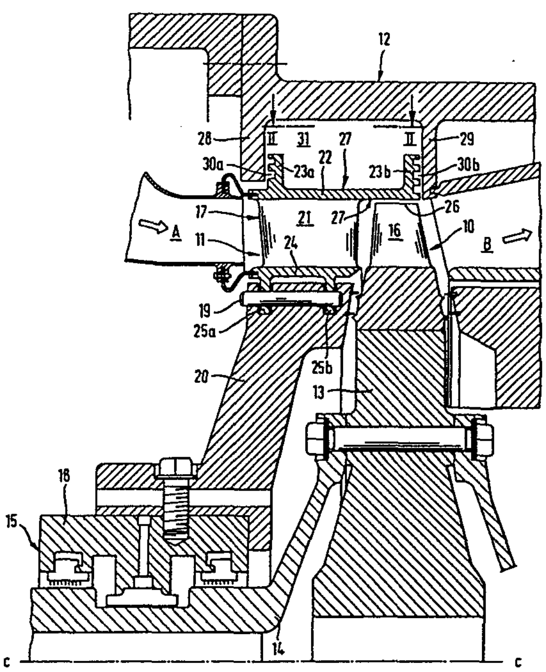
(54) Clearance control for turbine blade tips.

(57) A turbine comprising a casing in which are disposed a turbine rotor assembly which provides a plurality of turbine blades and a guide vane assembly which provides a plurality of guide vane segments, and there being shrouds spaced from turbine blade tips. To control the clearance between the turbine blade tips and the shrouds at a small value by simple structure, the guide vane segments are made movable freely in the radial direction and inside parts of the guide vane segments are fixed to a stationary member.



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Description

Clearance control for turbine blade tips

This invention relates to a turbine in which clearance between turbine blade tips and shrouds is controlled.

The clearance between turbine blade tips and shrouds causes fluid used to drive the turbine to leak. If the clearance is large, the amount of the leakage increases, resulting in deteriorated heat efficiency of turbines such as a gas turbine or a steam turbine.

In a conventional turbine whose shrouds are mounted to a turbine casing, it is known that the clearance changes transiently during operation of the turbine due to relative thermal expansion among members constructing the turbine. There have been proposals to control such a transient change of the clearance. However, methods controlling such relative thermal expansion by blowing cold air onto the casing and shrouds or heating the above-mentioned structure of the turbine require lots of devices such as gap detectors, valves and their control apparatuses. A method mounting shrouds to the casing through guide vane assemblies pivotally mounted thereto, which is shown in UK patent application GB 2 061 396A, causes its mechanism to be complex and also causes design of the mechanism to be difficult.

An object of the invention is to provide a turbine whose clearance between turbine blade tips and shrouds can be controlled automatically during operation by simple structure.

According to one aspect of the invention shrouds are mounted to a body stationary in the rotating direction of a turbine rotor and movable freely in a radial direction under expansion thereof, and which can be expanded radially from the centre of said turbine rotor substantially in the same manner as said turbine blades. This invention makes it possible to keep the clearance at a small value in all the operation modes without providing a complex clearance control device.

Other advantages and optional features of the invention will be described in more detail with reference to preferred embodiments illustrated in the accompanying drawings, in which:

Figure 1 is a schematic view of a turbine in accordance with the present invention;

Figure 2 is a plan view taken along line II-II of Figure 1;

Figure 3 is a sectional view taken along line III-III of Figure 2;

Figure 4 shows a relationship between the clearance and time of operation; and

Figure 5 is a schematic view, corresponding to Figure 1, of another embodiment.

In Figure 1, there is illustrated a part of a gas turbine in which a turbine rotor assembly 10 is disposed downstream of a guide vane assembly 11 inside a turbine casing 12. The turbine rotor assembly 10 is rotated by high temperature gas which flows from an entrance site A of the turbine, i.e. an exit of combustion chamber to an exit site B of the turbine rotor assembly 10.

The turbine rotor assembly 10 comprises an annular disc 13 fixed to a turbine rotor 14 which is supported rotatably by a bearing 15 and a plurality of turbine blades 16 attached by dave-tail structure around the annular disc 13. The turbine blades 16 exposed to the high temperature gas expand radially from the centre of the turbine rotor 14 corresponding to a standard position of expansion.

The guide vane assembly 11 comprises a plurality of guide vane segments 17, each of which forming a body, which are mounted to a stationary part 18 of a bearing 15 through pins 19 respectively and an annular member 20. The guide vane segments 17 are disposed around the annular member 20 as shown Figure 2. On the other hand, as described below, the guide vane segments 17 are diposed radially free against the casing 12. The guide vane segments 17 expand radially from the center line of the stationary part of the bearing 18, i.e. the centre of the bearing 15 or the centre line (c-c) of the turbine rotor 14, in the same manner as the turbine blades 16.

The guide vane segments 17 each is a united body providing guide vanes 21, an outer endwall 22, a pair of projections 23a, 23b, an inner endwall 24 and a pair of flanges 25a, 25b. The inner endwall 24 extended substantially in parallel with the shaft of the turbine at the inner side of the guide vanes 21. The flanges 25a, 25b provide pin holes for pin 19 to be inserted. The outer endwall 22 extends substantially in parallel with the shaft of the turbine at the outer side of the guide vanes 21 and also extends downstream so as to face the turbine blade tip 26. Thus extended portion of the outer endwall 22 corresponds to a shroud 27. The shroud 27 may be constructed separately and be fixed to the outer endwall 22. A pair of projections 23a, 23b extending outward from the guide vanes 21 are disposed respectively so as to face a pair of support rings 28, 29 which extend inward from the casing 12. The projections 23a, 23b provide a plurality of coaxial slots 30a, 30b so that cooling fluid which may be flown in a space 31 to cool the guide vane segments 17 can be sealed by labyrinth effect based on the slots 30a, 30b. Furthermore there are provided slots 32 at circumferential end portions 33a, 33b of the outer endwall 22. In each slot adjacent to each other a seal plate 34 to seal in a radial direction is inserted as shown in figure 3. The same seal mechanism comprising the slot 32 and the seal plate 34 as mentioned above is adapted at circumferential end portions of the inner endwall 24 (not shown).

As shown in Figure 2, parallel meandering slots are formed at both ends 33a, 33b of the outer endwall 22 so that each slot of adjacent endwalls 22 can be engaged with each other, resulting in sealing contact surface of each outer endwall 22.

Thus the guide vane segments 17 are movable radially against the casing 12, sealing the space 31. Accordingly, as already mentioned above, the guide vane segments 17 can expand radially during operation from the centre of the shaft in the same manner as the turbine blades 16 without being undue affected by p.e. thermal expansion of the casing 12. Each amount of thermal expansion of the guide vane segments 17 and turbine blades 16 is almost the same because temperature of the gas is nearly the same both at the guide vane segments 17 and at the turbine blades 16. Therefore the clearance between the turbine blade tips 26 and the shrouds 27 mounted to the guide vane segments 17 is kept constant, as shown in Figure 4, in all the operation modes, i.e. during accelaration, steady state running and deceleration. Thus such clearance can be set very small without necessity to take into account conflict between the turbine blade tips 26 and the shrouds 27 due to transient change of the clearance during operation. Preferably, it is desired to select materials of the guide vane segments and the turbine blades whose coefficient of linear expansion each is close. In this case the clearance can be set much smaller.

In order to compare the above embodiment with a conventional one a characteristic of a conventional turbine of which guide vane segments are mounted to a casing is shown by a dotted line in Figure 4. That is, during acceleration increase of the temperature of the casing heat mass of which is extremely large tends to be delayed more than those of the guide vane segments and the turbine blades. As a result the turbine blades expands radially more rapidly than the guide vane segments whose thermal expansion is restricted by the casing. Therefore the clearance decreases first until the expansion of the turbine blades reaches steady-state (range C-D). Thereafter the clearance increases until the expansion of the guide vane segments reaches steady-state (range D-E). According to a conventional turbine, the clearance must be set relatively large so that the conflict between the turbine blades and the shrouds can be avoided at point D.

Furthermore minimum clearance at point D for the conventional turbine is required to be much bigger than that for the invention as shown in figure 4. This is because clearance distribution in the circumferential direction of the conventional turbine cannot be uniform due to differences in stiffness of the casing and conditions of heat conduction of surrounding parts. In other words it is possible with this invention to set the clearance much smaller since support members of the guide vane segments such as the annular member have the above-mentioned uniformity.

In the above embodiment the pressure of the cooling fluid in the space 31 is adjusted to the same static pressure as that of the gas passing the guide vanes 21 and the turbine blades 16 so that deformation of the shrouds 27 can be avoided by cancelling each force acting on each side of the shrouds 27. Such eliminatinq of deformation of the shrouds 27 can be further improved by the embodiment illustrated in Figure 5. That is, in practise two pressures of the gas are different at positions of the guide vane 21 and the turbine blade 16 respectively. In order to cancel different pressure acting on the outer endwall 22, and particularly on the shroud 27, more precisely the space for the cooling fluid is divided into two compartments, i.e. an upstream compartment 50 and a downstream compartment 51, by a dividing plate 52 of which one end is fixed to a portion 53 of the outer endwall 22, and the other end is inserted in a slot 54 of the casing 12. In case of thermal expansion of the dividing plate 52, this plate 52 slides in the slot 54, maintaining sealing between the other end portion of the dividing plate 52 and the casing 12. Said end portion 53 is chosen at a region corresponding to a guide vane end portion adjacent to the turbine blade 16. The cooling fluid supplied from an opening 55 flows from the upstream compartment 50 to the downstream compartment 51 through an orifice 56 in the dividing plate 52. The pressure in the upstream compartment 50 can be the same pressure as the gas pressure at the guide vane 21. The size of the orifice 56 is chosen so that the pressure reduced thereby is the same pressure as that of the gas passing at the turbine blade 16. The cooling fluid can flow out through small gap between projections 23a, 23b and support rings 28, 29. This embodiment can serve to allow the clearance to be set even smaller without the negative influence on the shrouds 27.

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1 1. A turbine comprising a casing (12) in which are disposed a turbine rotor assembly (10) and a guide vane assembly (11) upstream of the turbine rotor assembly (10), said turbine rotor assembly (10) being fixed to a turbine rotor (14) and being provided with a plurality of turbine blades (16), said guide van assembly (11) comprising a plurality of guide vane segments (17) which are provided with a plurality of guide vanes (21), and there being shrouds (27) spaced from turbine blade tips (26) so that the clearance between said shrouds (27) and turbine blade tips (26) can be controlled, c h a r a c t e r i z e d i n t h a t said shrouds (27) are mounted to a body (17) stationary in the rotating direction of said turbine rotor (14) and movable freely in a radial direction under expansion thereof, and which can be expanded radially from the centre of said turbine rotor (14) substantially in the same manner as said turbine blades (16).

2. A turbine according to claim 1, wherein said body (17) comprises said guide vane segment (17) of which inside part is fixed to a stationary member (18, 20) disposed inside said guide vane segment (17).

3. A turbine according to claim 2, wherein said stationary member comprises a stationary part (18) of a bearing (15) to rotatably support said turbine rotor (14) and an annular member (20) provided between said stationary part (18) of the bearing (15) and said guide vane segments (17).

4. A turbine according to claim 2 or claim 3, wherein said casing (12) is provided with guide means (28, 29) to guide said guide vane segments (17) radially under thermal expansion of said guide vane segments (17).

5. A turbine according to anyone of claims 2 to 4, wherein said guide vane segments (17) each is provided with an outer endwall (22) and an inner endwall (24) respectively so that high temperature fluid can flow therebetween, and said outer endwall (22) extends downstream so as to face said turbine blade tip (26) whereby said extended portion of said outer endwall can be used as said shroud (27).

6. A turbine according to claim 5, wherein a sealed space (31) is formed by a pair of projections (23a, 23b) outward extending from said outer endwall (22) and a pair of support rings (28, 29) inward extending from said casing (12) so that said support rings (28, 29) and said projections (23a, 23b) can engage slidable.

7. A turbine according to claim 6, wherein there are provided compensating means to cancel bending of said shrouds (27) caused by pressure of said high temperature fluid and cooling fluid flowed in said space (31).

8. A turbine according to claim 7, wherein said compensating means comprise means for supplying said cooling fluid of almost the same pressure as that of said high temperature fluid.

9. A turbine according to claim 7, wherein in said space (31) there is provided a dividing member (52) with an orifice (56) of which one end portion is fixed to said outer endwall (22) and the other end portion is inserted slidably in a slot (54) formed in said casing (12), so as to provide an upstream compartment (50) and a downsteam compartment (51) thereby, and the size of said orifice (56) is chosen so that the pressure of said cooling fluid is reduced thereby and becomes about the same pressure as that of said high temperature fluid.

10. A turbine according to anyone of claims 2 to 9, wherein materials of said guide vane segments (17) and said turbine blades (16) are selected whose coefficient of liner expansion each is close.

Fig. 1

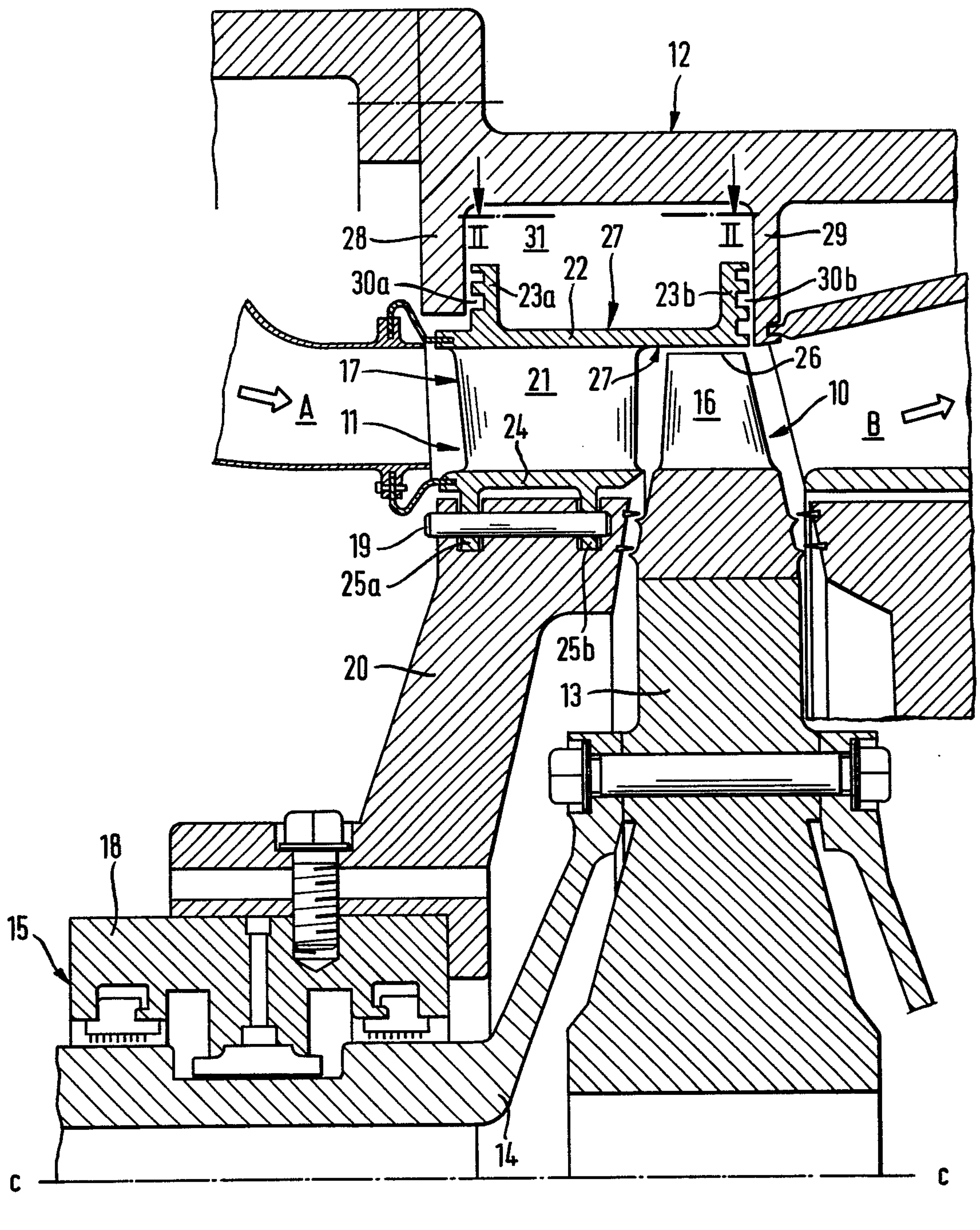
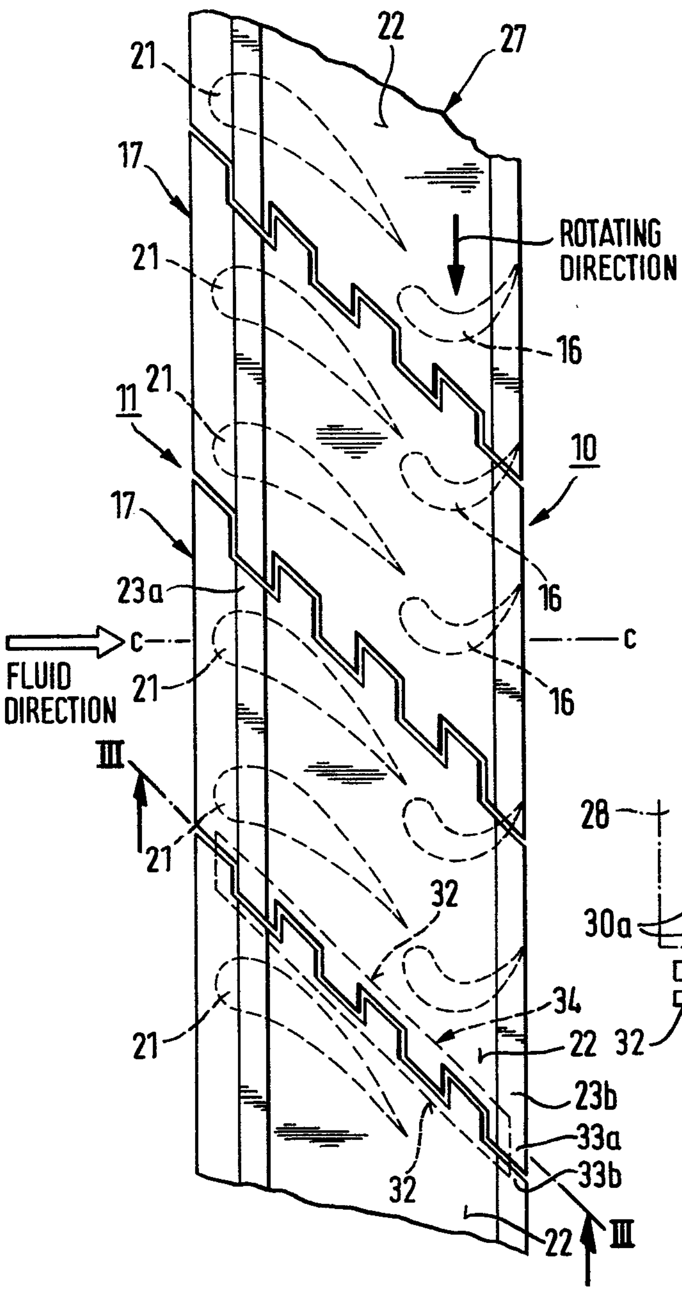
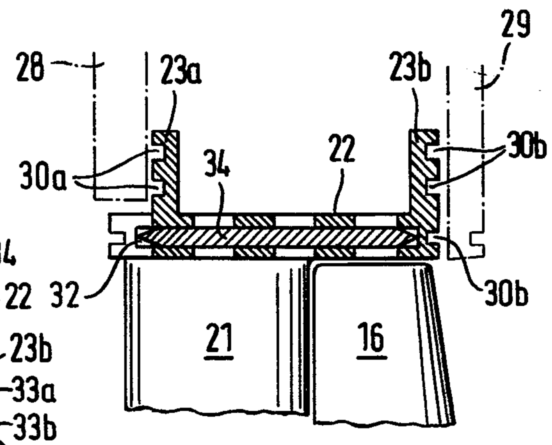

12
28
II
31
27
II
29
30a
23a
22
23b
30b
17
21
27
26
16
10
A
11
24
B
19
25a
25b
20
13
18
15
14
c
c

Fig. 2



22
27
21
17
ROTATING
DIRECTION
16
11
10
23a
c
FLUID
DIRECTION
III
32
34
23b
33a
33b

Fig. 3



28
23a
23b
29
30a
34
22
30b
32
21
16

Fig. 4

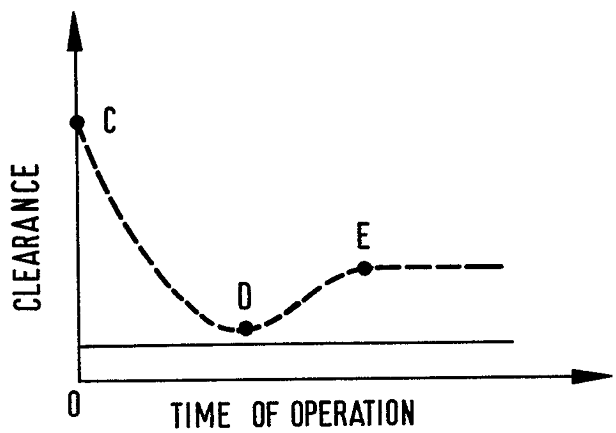
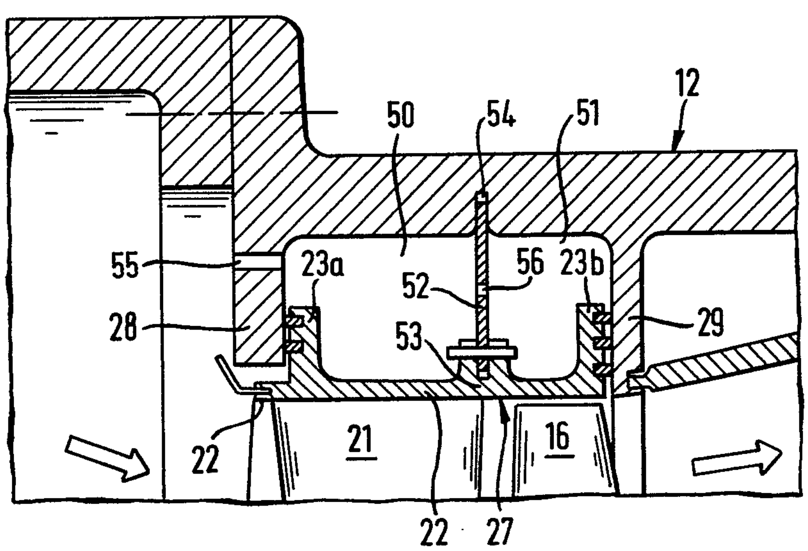

C
D
E
CLEARANCE
0
TIME OF OPERATION

Fig. 5


12
50
54
51
55
23a
56
23b
52
28
29
53
22
21
16
22
27