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(54) **High pressure turbine elastic clearance control system and method**

(57) A system and method for achieving clearance control for a high-pressure turbine by means of casing mechanical deflection. An active clearance control system is provided to act on a blade (14) that rotates near a shroud (16). The shroud (16) is attached to a case (24) at a shroud supporting location, or shroud hanger (22). A clearance (18) is required between a tip of the blade (14) and the shroud (16). The blade (14) tip and shroud (16) are surrounded with an elastic case (24). This case (24) can deflect radially in response not only to thermal expansion, but also to a difference in pressures acting on the inner and outer diameters of the case (24).

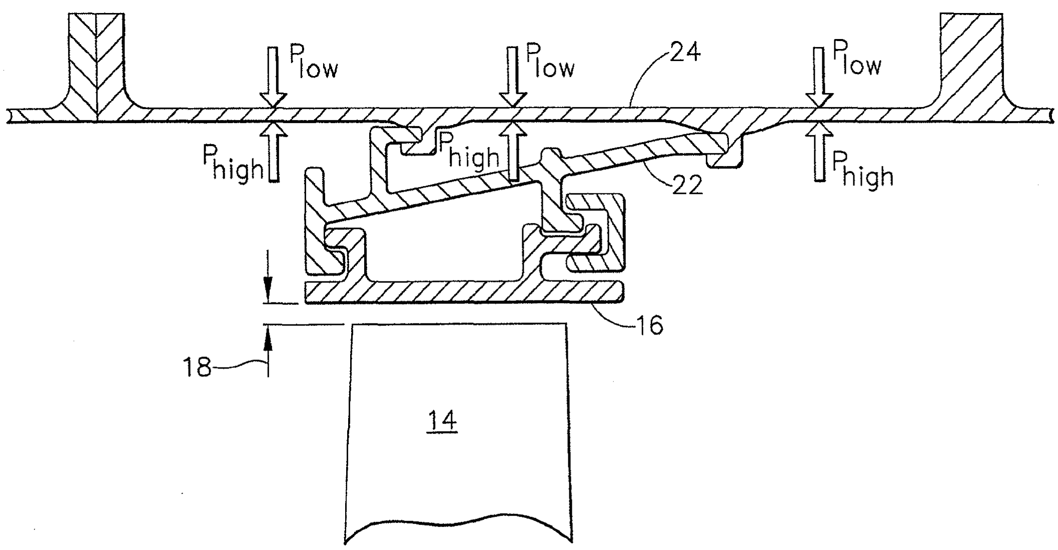

FIG. 3

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Description

[0001] The present invention relates to the active clearance control system of a high-pressure turbine and, more particularly, to casing mechanical deflection for the high-pressure turbine.

[0002] The active clearance control system (ACC) of a high-pressure turbine (HPT) has two basic functions. The first is to maintain tight blade-shroud clearances during transient operation, to minimize exhaust gas temperature (EGT). The second is to close the tip clearances during steady-state operation to increase turbine efficiency and reduce fuel burn.

[0003] For both types of designs, i.e., single and dual stage, the case will shrink or grow, depending on the air-cooling temperature and the effect on the temperature of the case. Changing the case temperature will result in a clearance change. The thermal part of the clearance system is a slow response deflection approximately 30-60 seconds.

[0004] State of the art active clearance control systems account for disk elastic deflection and blade thermal growth from idle conditions to take off by having a large clearance at idle. Such a system requires a large change in temperature at steady state conditions to reduce clearance to a minimum level. However, the desired case temperature change can be beyond system capabilities. In addition, it is difficult for the state of the art system to respond in time to overcome any rotor elastic stretch due to an instantaneous acceleration or re-acceleration (reburst) resulting in airfoil to shroud contact or rub.

[0005] It would be desirable to provide an improved active clearance control system and method for a high-pressure turbine that overcomes problems in the existing art.

[0006] In accordance with the invention a system and method are proposed wherein casing elastic deflection is used to improve active clearance control of a high-pressure turbine.

[0007] Accordingly, the present invention provides a system and method for achieving clearance control for a high-pressure turbine by means of casing mechanical deflection. An active clearance control system is provided to act on a blade that rotates near a shroud. The shroud is attached to a case at a shroud supporting location, or shroud hanger. A clearance is required between a tip of the blade and the shroud. The blade tip and shroud are surrounded with an elastic case. This case can deflect radially in response not only to thermal expansion, but also to a difference in pressures acting on the inner and outer diameters of the case.

[0008] The invention will now be described in greater detail, by way of example, with reference to the drawings, in which:-

Fig. 1 is a schematic illustration of a single stage active clearance control system of the type that may employ the casing mechanical deflection technique of the present invention;

Fig. 2 is a schematic illustration of a dual stage active clearance control system of the type that may employ the casing mechanical deflection technique of the present invention;

Fig. 3 illustrates the thin case active clearance control according to the present invention;

Fig. 4 is a diagram that shows the relation between pressure and rotor speed for idle to cruise conditions;

Fig. 5 is a diagram comparing the radial deflection of the rotor and stator for a state of the art system and for the system applying the present invention; and

Fig. 6 illustrates an alternative embodiment of the thin case active clearance control according to the present invention.

[0009] Modern gas turbine engine control systems typically require an active clearance control system for maintaining blade-shroud clearances and tip clearances during operation. For a single and dual stage HPT, illustrated in Figs. 1 and 2, respectively, the appropriate clearance 18 between the blade 14 and the shroud 16 is achieved by controlling the case 10 temperature. For a single stage high-pressure turbine type, the case is heated and cooled by air coming from compressor mid stage 12 and discharge pressure source. Moreover, for a dual stage high-pressure turbine type, the first stage turbine case is controlled by compressor discharge pressure air. The second stage is controlled by compressor inter-stage bleed air. At appropriate times, the case is cooled by fan air in order to reduce case ring 25 temperatures.

[0010] In Figs. 1 and 2, the blade 14 and blade tip rotate as a result of the hot air flowing through the turbine. The shroud 16 is a piece of metal that defines the distances, or clearances, between the blade 14 tip and the shroud 16 itself. The purpose of the active clearance control system is to minimize-clearance 18. The larger the clearance, the less efficient the turbine will be. The shroud 16 is attached to the case of the ACC by a hanger 22. Case growth causes the shroud 16 to move radially. In the existing art, the case 10 grows only by thermal expansion. With the present invention, the case will deflect due to thermal expansion and pressure acting on the outer and inner diameter of the case.

[0011] The present invention proposes a system and method for improving an existing high-pressure turbine active clearance control system by modifying the turbine case, as illustrated in Fig. 3. In accordance with the present invention, the elastic case 24 will be a continuous 360-degree shell flexible enough to deflect radially due to the difference between the pressures P_{low} acting on the outer diameter of the case 24 and P_{high} acting on the inner diameter of the case 24. The case 24 flexibility will be achieved by making the case average thickness in the locations supporting the hangers thin, so that the casing elastic deflection is increased from the prior art design. Although the specific thickness can vary, in the prior art the thickness of the casing at the location where the shroud supports are attached to the casing will be substantially thicker than that proposed by the present invention, with the prior art configuration therefore having negligible casing deflection. In a preferred embodiment of the present invention, the thickness will be thinner than the current design by eliminating the case rings 25, typically, by way of example only, on the order of approximately 0.1 inches to 0.2 inches, or otherwise significantly thinner than the 1 to 2 inch thickness of existing casings. It will be obvious to those skilled in the art, however, that the thickness can vary beyond the thickness of a preferred embodiment, still being thinner than the existing art provides for, without departing from the scope of the invention. As with existing systems, the shrouds 16 will be attached to the case 24 by shroud hangers 22. The shroud and the case will be made of a high temperature alloy.

[0012] With the application of the present invention, the blade 14 to shroud 16 clearance 18 will change when the case 24 deflects radially due to pressure. The blade tip to shroud clearance will depend on the magnitude of the pressure acting on the case. The pressure acting on the case depends on the engine operating condition. Referring now to Fig. 4 the relationship between pressure and speed is shown. The present invention takes advantage of this pressure and speed, resulting in the illustration of Fig. 5. In Fig. 4, the pressure is at a minimum when the engine is at idle conditions, in region 26. It will reach a maximum during high power at low altitude, in region 28. At cruise conditions, in region 30, when the engine is at high altitudes, the pressure will decrease (~30% change) while the speed remains almost constant (~10% change). According to this relationship between pressure and speed, illustrated in Fig. 4, the clearance will increase when the engine goes from idle to take off conditions. This pressure to speed relationship will allow the system to compensate for some disk elastic stretch and blade thermal expansion without the necessity of having large clearance at idle. Moreover, at high altitudes the pressure acting on the case will decrease, causing the case to shrink while the rotor speed change is small, thus maintaining high elastic stretch. This will result in smaller clearance at cruise relative to clearances required by current state of the art systems.

[0013] The present invention takes advantage of the relationship between pressure and speed. Fig. 5 illustrates the stator and rotor deflection when the elastic case of the present invention is applied to a single or dual stage high pressure turbine. The elasticity of the case is indicated by dotted line 32 in Fig. 5. The prior art stator response is shown by line 34, indicating the thermal expansion. The rotor response for both the invention and the prior art is shown by line 36, indicating disk elastic stretch and blade thermal expansion during periods of idle, acceleration and cruise. The present invention will provide a protection against airfoil to shroud contact due to instantaneous acceleration (reburst). The pressure will increase at nearly the same rate as the rotor speed during an instantaneous acceleration allowing the case to deflect to avoid airfoil to shroud contact (rubs).

[0014] Referring now to Fig. 6, an alternative embodiment for the thin case active clearance control can be applied by modifying the case elastic deflection to account for airfoil tip loss over operation time. The alternative embodiment comprises a band 38 attached to the case outer diameter. The band is preferably comprised of any suitable high temperature alloy or coating. The band thickness will be sized depending on the amount of airfoil material loss. The band will cause the case elastic deflection to be less by the same amount of airfoil material loss.

Claims

1. A method of controlling clearance in a gas turbine engine, comprising the steps of:

   providing an active clearance control system acting on at least one blade (14) that rotates near at least one shroud (16), the at least one shroud (16) having an associated shroud hanger (22), wherein a clearance (18) is required between a tip of the at least one blade (14) and the at least one shroud (16); and
   surrounding the blade (14) tip and shroud (16) with an elastic case (24), wherein the case (24) can deflect radially in response to thermal expansion and a difference in pressures acting on inner and outer diameters of the case (24).

2. A method as claimed in claim 1 further comprising the step of attaching a band (38) to the case (24) outer diameter to account for blade (14) tip loss during operation.

3. A method as claimed in claim 1 or 2 wherein the step of providing an active clearance control system further comprises the step of providing a single stage active clearance control system.

4. A method as claimed in claim 1 or 2 wherein the step of providing an active clearance control system further comprises the step of providing a dual stage active clearance control system.

5. A method as claimed in any preceding claim wherein the step of surrounding the blade (14) tip and shroud (16) with an elastic case (24) further comprises the step of providing an elastic case (24) having elastic deflection during engine operation.

6. A system for controlling clearance in a gas turbine engine, comprising:

an active clearance control system to act on at least one blade (14) that rotates near at least one shroud (16), the at least one shroud (16) having an associated shroud hanger (22), wherein a clearance (18) is required between a tip of the at least one blade (14) and the at least one shroud (16); and

an elastic case (24) to surround the blade (14) tip and shroud (16), wherein the case (24) can deflect radially in response to a difference in pressures acting on inner and outer diameters of the case (24).

7. A system as claimed in claim 6 further comprising a band (38) attached to the case (24) outer diameter to account for blade (14) tip loss during operation.

8. A system as claimed in claim 6 or 7 wherein the active clearance control system comprises a single stage active clearance control system.

9. A system as claimed in claim 6 or 7 wherein the active clearance control system comprises a dual stage active clearance control system.

10. A system as claimed in any preceding claim wherein the elastic case (24) comprises an elastic case (24) having elastic deflection during engine operation.

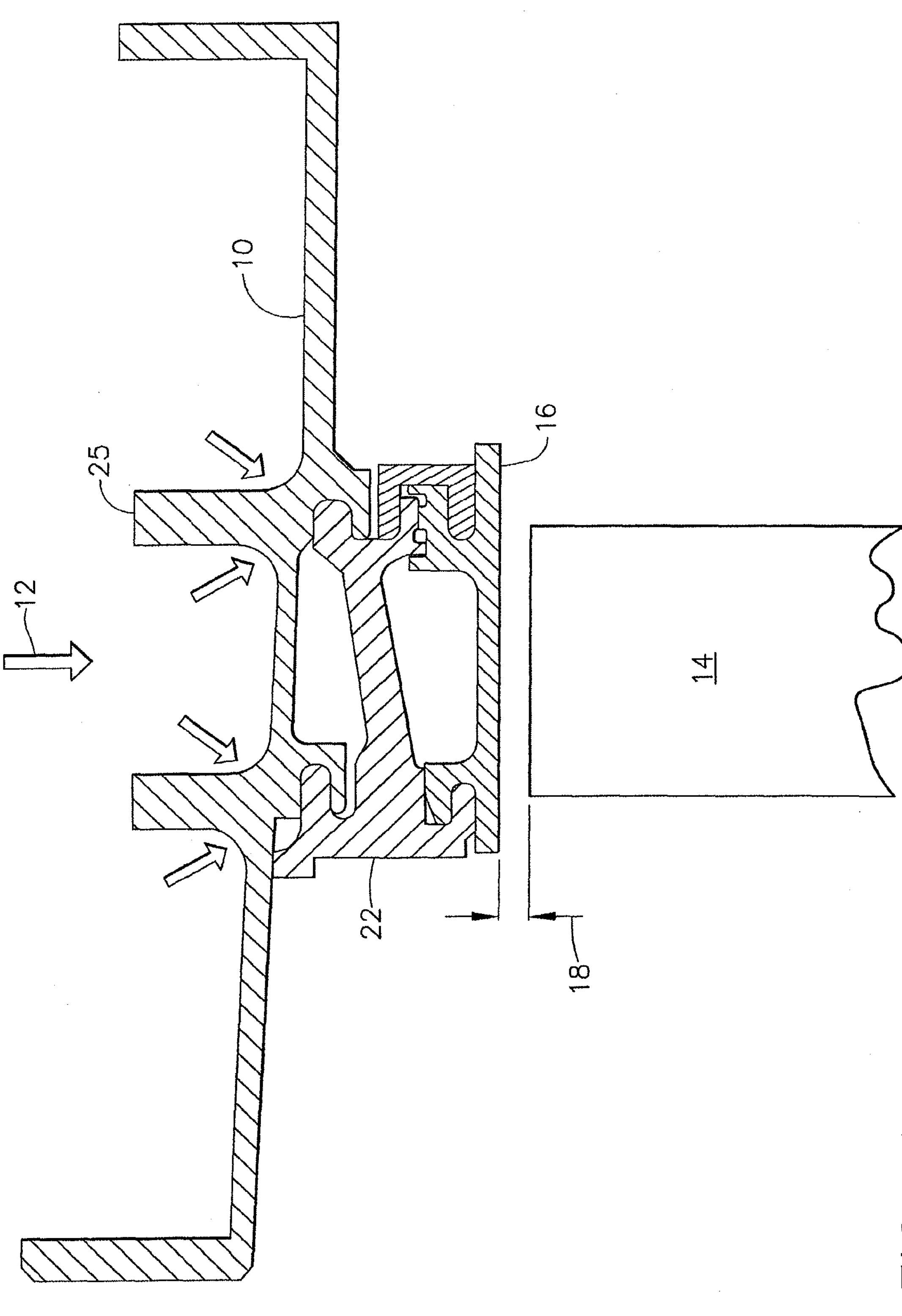

FIG. 1 (PRIOR ART)

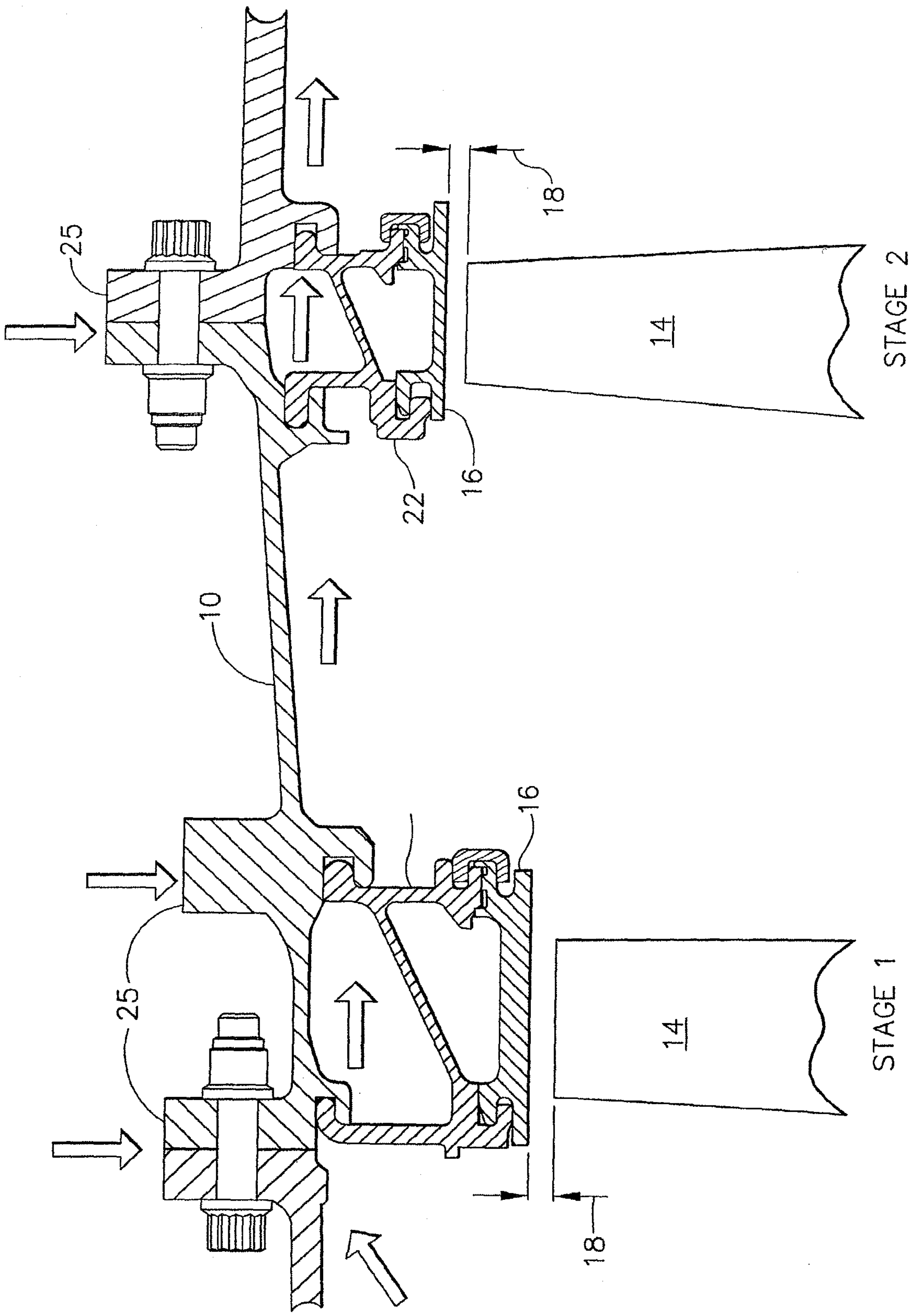

FIG. 2 (PRIOR ART)

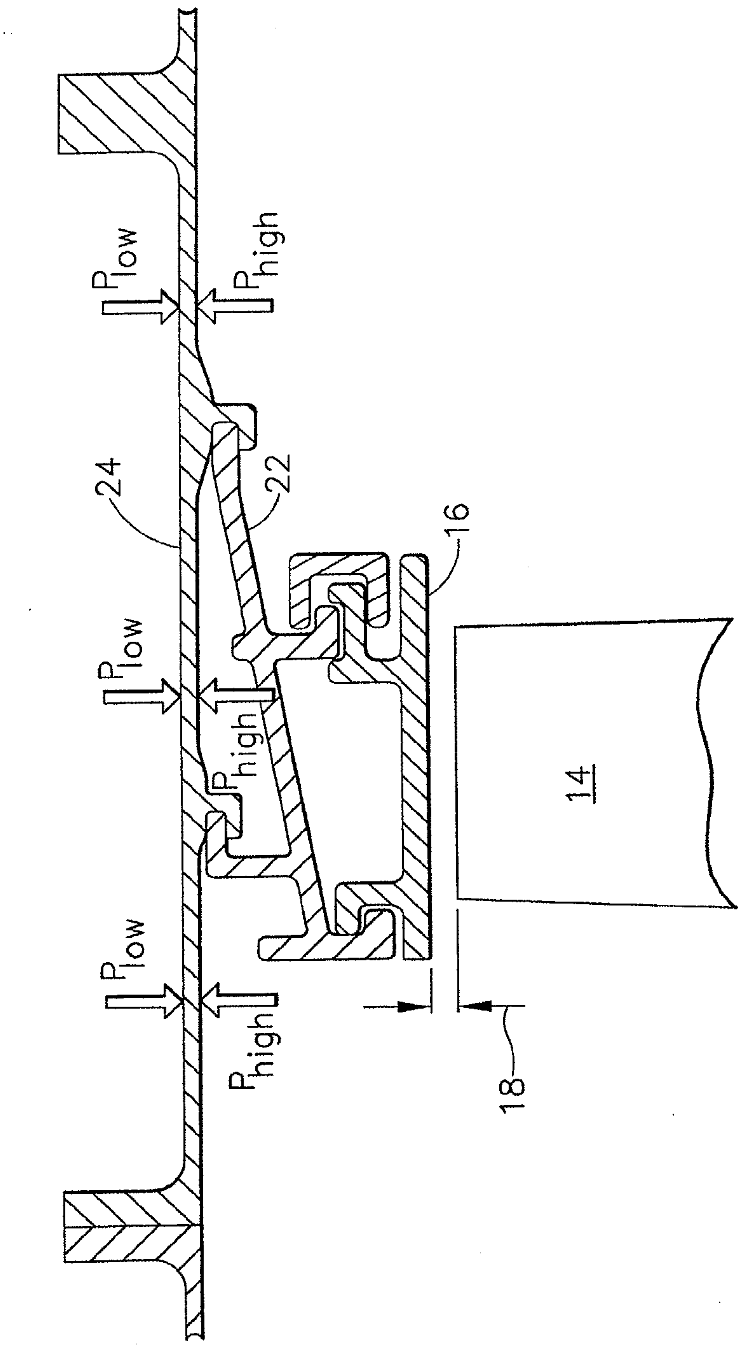

FIG. 3

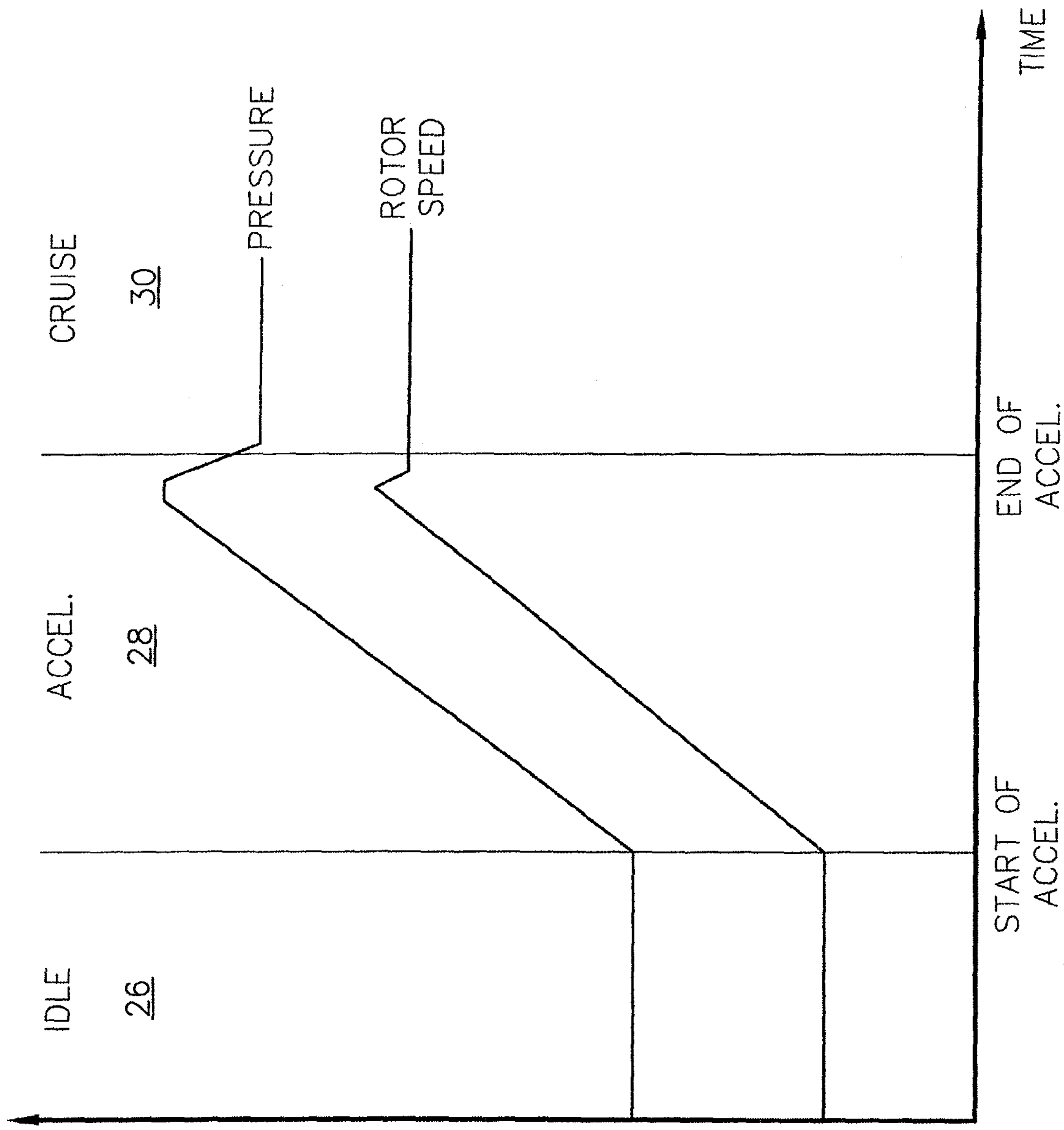

FIG. 4 (PRIOR ART)

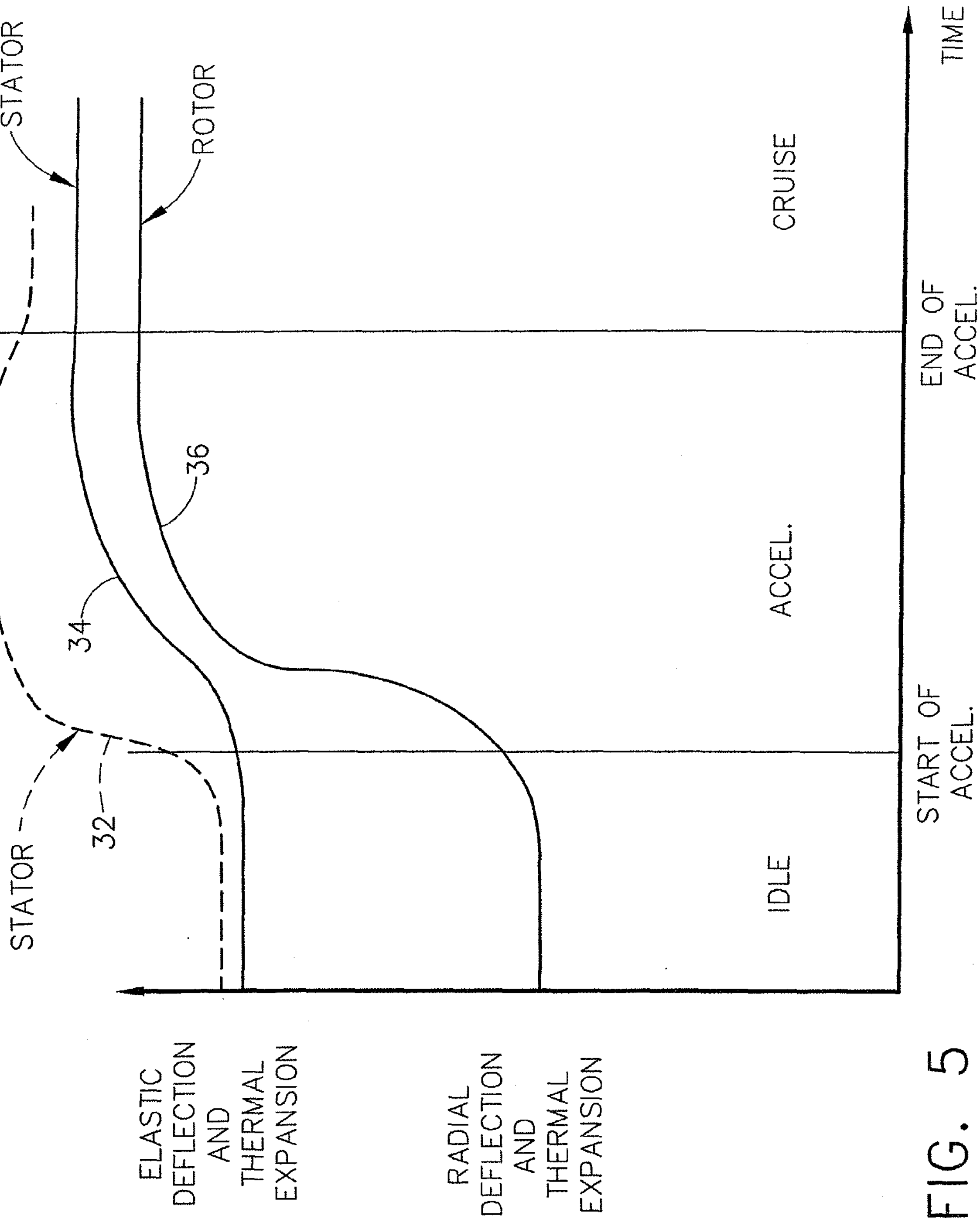
STATOR
ROTOR
TIME
CRUISE
END OF ACCEL.
36
ACCEL.
34
START OF ACCEL.
STATOR
32
IDLE
ELASTIC DEFLECTION AND THERMAL EXPANSION
RADIAL DEFLECTION AND THERMAL EXPANSION

FIG. 5

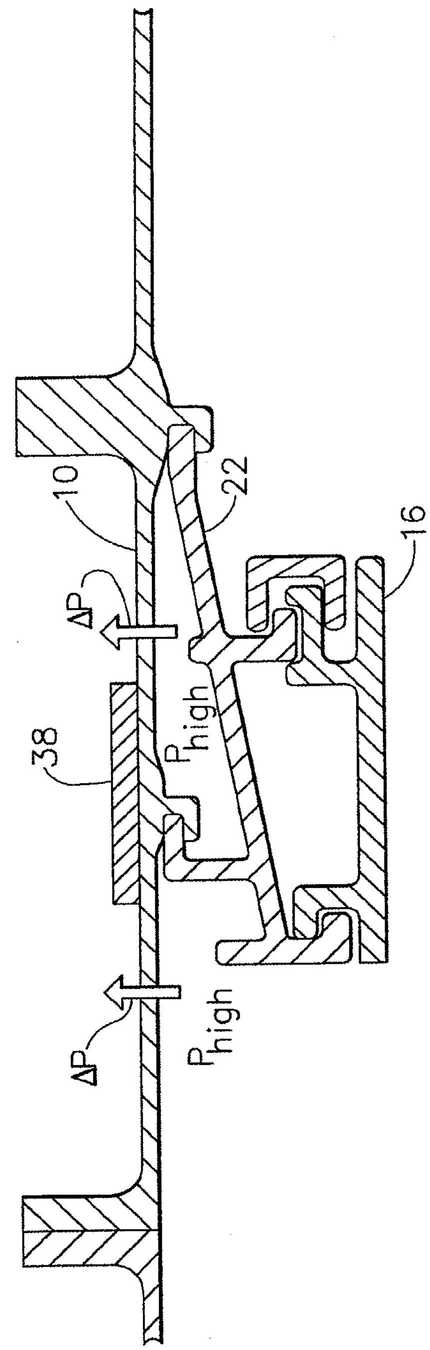

FIG. 6

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EUROPEAN SEARCH REPORT

Application Number
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Place of search	Date of completion of the search	Examiner
MUNICH	26 July 2004	Koch, R

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X : particularly relevant if taken alone
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