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[33] **Germany**

[31] **P 17 73 500.1**

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[54] **APPARATUS FOR TESTING THE VANE ANCHORAGE OF TURBINE VANES**
6 Claims, 4 Drawing Figs.

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 73/92, 73/100

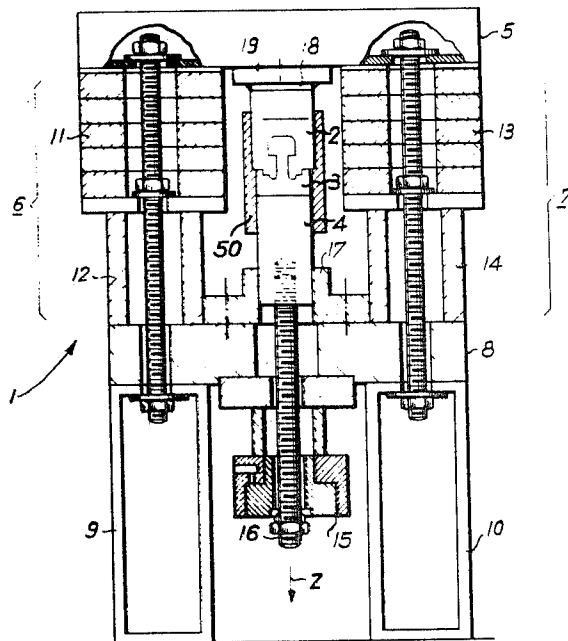
[51] Int. Cl..... G01n 3/08,
 G01n 3/28, G01n 3/24

[50] Field of Search..... 73/464,
 71.1, 95, 67, 100, 93, 90, 91, 92, 101, 102, 97

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ABSTRACT: Testing apparatus for determining tightness, deformations and weak points of the vane anchorage of a turbine vane. The apparatus operates by applying forces to a vane, which includes a vane base, attached in the normal fashion to a simulated portion of a turbine rotor. A force in a direction corresponding to the radial direction in a turbine rotor and hence to the direction of centrifugal force in a rotating rotor is applied by attaching the vane and rotor portion to respective first and second yokes separated by resilient elements and drawing the vane and rotor portions apart. A force in a direction corresponding to the axial and/or tangential directions of a turbine rotor and hence the direction of the forces of the driving fluid which act on the vanes during operation of a turbine is applied by an additional device while the vane and rotor portions are held in the yokes.



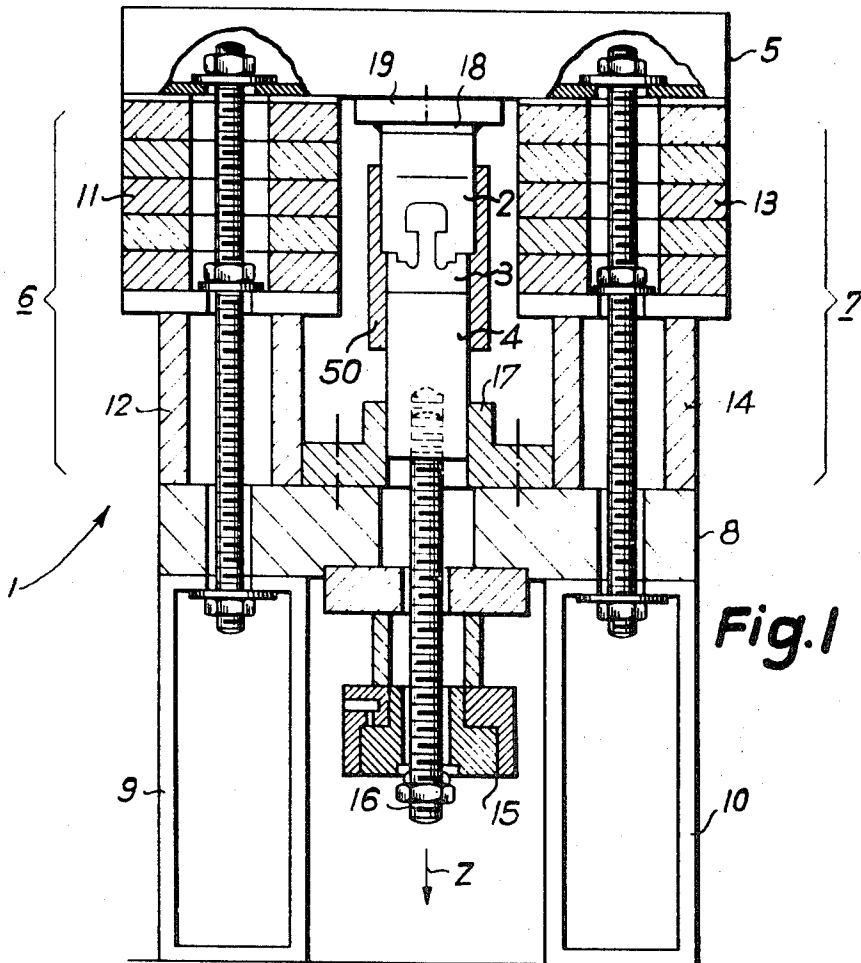


Fig. 1

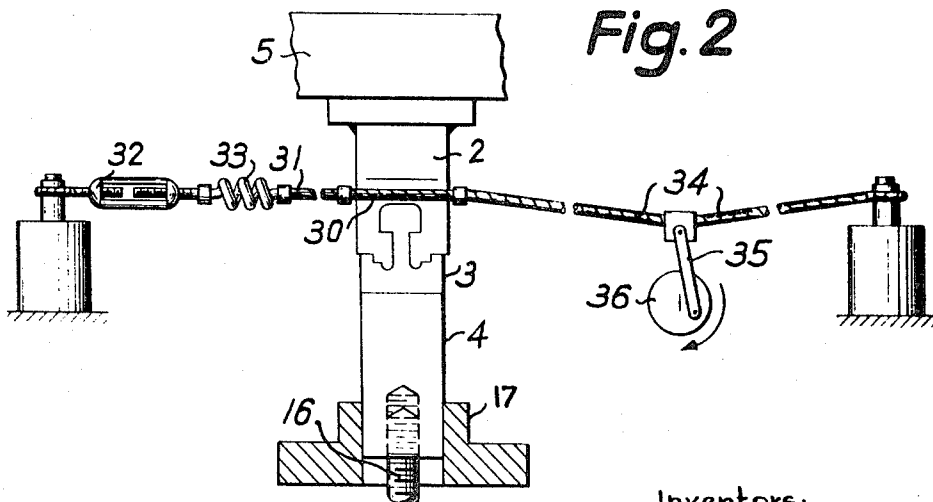


Fig. 2

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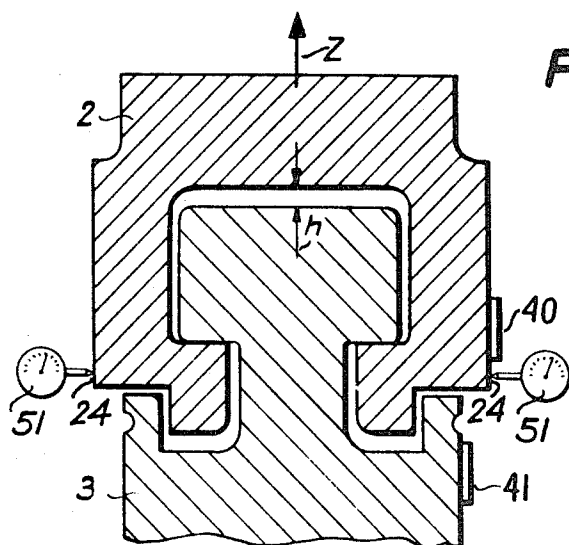


Fig. 3

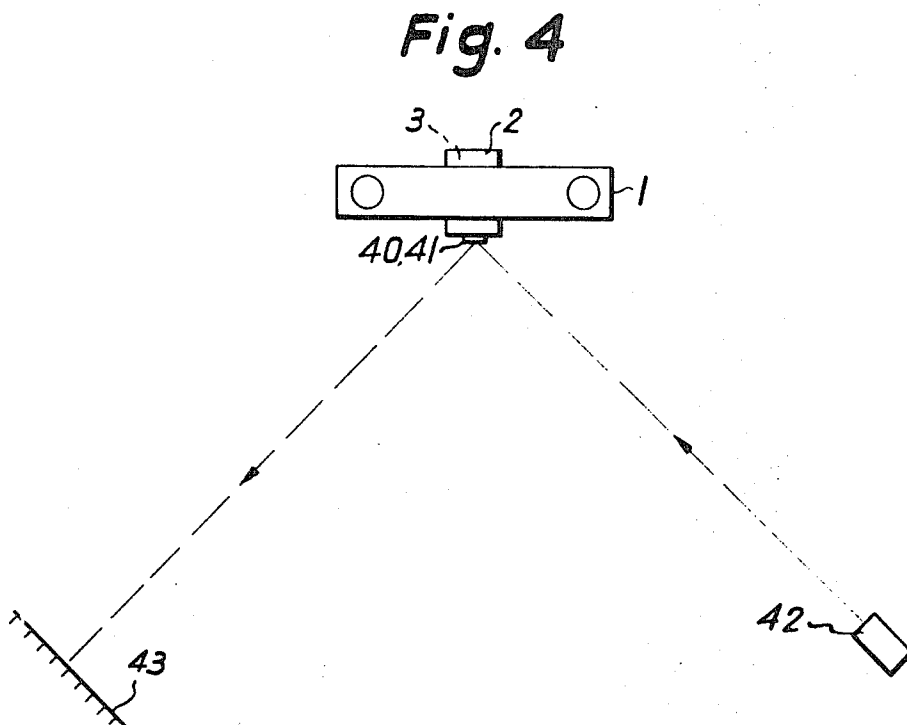


Fig. 4

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APPARATUS FOR TESTING THE VANE ANCHORAGE OF TURBINE VANES

BACKGROUND OF THE INVENTION

The present invention relates to a testing device for determining tightness, deformations (warping) and weak points of the vane anchorage of turbine vanes.

When constructing large turbines, such as steam turbines, it is necessary to design the turbine vanes or blades so that when attached or anchored to the turbine rotor and placed under the stresses of operation they will not be subject to failure, e.g., by cracking at their base where the greatest stresses appear. In order to avoid this type of damage in completed turbines, it is desirable to provide apparatus which is capable of simulating the various stresses that act on turbine blades during normal operation to permit an experimental verification of the stresses determined by theoretical calculation.

SUMMARY OF THE INVENTION

An object of the present invention, therefore, is to provide suitable apparatus which simulates the centrifugal and fluid (e.g., steam) forces which act, in practice, upon the vane anchorage of turbine vanes. More particularly, it is an object of the present invention to provide a device which permits the determination of the elastic deformations in the base of a turbine vane; detection of any tilting or slippage of a turbine vane; as well as the location of the weak points of a turbine vane at which possible permanent deformations, cracks or breaks may occur through an overstress during operation of a turbine.

This object, as well as other objects which will become apparent in the discussion that follows is achieved, according to the present invention, by simulating both a portion of a turbine rotor and a turbine vane having a vane base attached to the rotor portion: by providing means for applying a force to the simulated rotor and vane in a direction corresponding to the radial direction of a rotor and hence to the direction of centrifugal force which acts in a rotating rotor and by providing means for applying a force to the vane in at least one direction transverse to the direction corresponding to that of centrifugal force. This second force is thus applied in a direction corresponding to the axial and/or tangential directions of a rotor and hence to the direction of the forces of the driving fluid which act on a vane during operation of the turbine.

According to a preferred embodiment of the present invention the simulated rotor portion is attached to a first yoke, the vane is attached to a second yoke and the two yokes are supported in a spaced-apart relationship by means of suitable resilient elements. The means for applying the force corresponding to the centrifugal force is realized by a device for attaching the second yoke to the simulated rotor portion.

According to another preferred embodiment of the present invention, the means which apply the force to the vane to simulate the force of a driving fluid (e.g., steam) include means for periodically varying this force.

According to a further embodiment of the present invention means are provided to heat the joint between the simulated rotor portion and the vane.

Finally, it is practical if means are provided to detect the relative motion between the base of the vane and the rotor portion and to measure the deformations in the joint between the vane and the rotor portion as the various loading forces are applied. In the preferred embodiment of the present invention the motion-detecting device is realized by a light-optical measuring instrument while the deformations can be measured by devices such as dial gauges.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a cross-sectional view through a portion of the testing apparatus according to a preferred embodiment of the present invention.

FIG. 2 is an elevational, and partly schematic illustration of apparatus for simulating the application of the forces of a driving fluid in the testing apparatus of FIG. 1.

FIG. 3 is an enlarged cross-sectional view of a portion of the apparatus of FIG. 1 showing a joint comprising the straddling base of a turbine vane and an impeller hub of a turbine rotor.

FIG. 4 is a schematic illustration of a light-optical measuring device which may be used in the apparatus of FIG. 1.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The preferred embodiments of the present invention will now be described in connection with FIGS. 1-4 of the drawing. The testing apparatus illustrated in FIG. 1 comprises an adjustable frame 1 constructed to hold a turbine vane 2 together with a rotor segment 3 and a shaft or shank 4. The frame 1 includes two yokes 5 and 8 which are mounted on support columns 9 and 10. The turbine vane 2 is fastened in the central portion of the frame 1 on the yoke 5 which has a U-shaped profile. The yokes 5 and 8 are spaced apart by braces 6 and 7 consisting of resilient elements 11 and 13 and supporting sleeves 12 and 14, respectively.

A hydraulic stretching or pulling device 15 is arranged on the yoke 8 and provided with a pull rod 16 which has one end attached to the shaft 4 of the rotor segment 3. The shaft 4 is guided in a sleeve 17 fastened to the yoke 8. The shaft 4 is therefore supported by the pulling device 15, which, in turn, abuts against the yoke 8.

In order to brace the vane 2 with respect to the rotor segment 3, the top plate 18 of the vane 2 is welded to a plate 19 that is bolted to the yoke 5.

The yoke 5 is braced with respect to the yoke 8 by the resilient elements 11 and 13. These resilient elements may, for example, consist of laminations of metal and rubber. The purpose of the resilient elements is to allow the yoke 5, and thus the vane 2, sufficient freedom of movement in the horizontal direction; that is, in the direction corresponding to the tangential and/or axial direction of the assumed rotor.

The pulling device 15, which is supplied with a hydraulic fluid under pressure, operates to apply a static force to the turbine vane anchor: i.e., a force which corresponds to the centrifugal force acting on a rotating rotor. The magnitude of this force can be adjusted and measured by controlling and measuring the hydraulic pressure. In addition, this vertically acting force can be measured by means of the spring deflection of the resilient elements 11 and 13.

In order to simulate the operating conditions of a turbine, the joint between the vane 2 and the rotor segment 3 is preferably heated, by a heating device 50, to the temperatures reached during operation.

FIG. 2 schematically illustrates a preferred embodiment of apparatus, according to the present invention, for applying forces to the vane 2 which correspond to the forces of a vane-driving fluid; that is, for example, the forces applied to the vanes of a turbine by steam. This force-applying apparatus includes a loop 30 of wire rope arranged to surround the vane blade, a length of wire rope 31, a tension-controlling device 32 and a spring 33. By tensioning the wire rope 31 with the device 32 a prescribed force can be applied to the turbine blade 2 in the horizontal direction. Depending upon the position of the blade 2 with respect to the yoke 5, the force can be exerted in a direction corresponding to the axial and/or tangential directions as defined by the assumed rotor. A force in the axial direction effects a bending in the "maximum direction" and possibly causes the blade to tilt. A force applied in the tangential direction effects a bending in the "minimum direction" and possibly causes the vane 2 to slide on the rotor segment 3. The maximum directions, referred to above, should be understood to mean the directions of maximum and minimum bending of the vane 2.

In order to simulate the actual operation of a turbine with the turbine vanes subjected to oscillating fluid forces, a further wire rope 34 can also be attached to the loop 30 and tensioned by a connecting rod 35 connected to a rotating disc 36. This

wire rope 34 can therefore be moved back and forth at a frequency, for example, of 3 Hz. Since the forces of a driving fluid such as steam result in impulses on turbine vanes in the axial direction, first in the direction of the emerging steam and then in the opposite direction, the vane 2 can also be tensioned in the identical manner in the opposite direction by the wire rope 31.

The movement of the base of the vane with respect to the rotor segment 3 during the application, to the vane 2, of the horizontal loading forces is measured by viewing the change in the angular position between two suitable external surfaces on the rotor segment and the base of the vane. This angular change is determined by a light-optical device which employs mirrors 40 and 41 arranged on the external surfaces of the elements 2 and 3 as shown in FIG. 3.

FIG. 4 schematically illustrates the construction of this light-optical measuring device. In addition to the mirrors 40 and 41, the device is provided with a light source 42 and a measuring screen 43 having a suitable scale. The mirrors 40 and 41 reflect a light beam from the light source 42 to the screen 43. The forces acting on the vane 2 produce small movements within the vane anchorage which result in a displacement of the light marks on the screen 43. A properly rigid coupling between the base of the vane and the rotor segment leads to identical movements in the reflected light beams. A relative motion between the vane base and the rotor segment results in a change in the distance between the light marks on the screen. If the relative movements remain within the elastic limits of the vane and rotor, this change will be small. However, if the vane 2 tilts or slides with respect to the rotor segment 3, there will be a considerable change in the distance between the marks.

During operation of a turbine a centrifugal force acts on the turbine vanes causing the supporting shoulders at the base of the vanes to press against the corresponding shoulders of the rotor segment. This condition may be simulated by the apparatus according to the present invention to test the quality of the vane anchorage.

When a centrifugal force or simulated centrifugal force is applied between vane and rotor (the latter by the pulling device 15), elastic deformations occur in the base of the vane and in the rotor segment, as shown in FIG. 3, causing an increase in the distance h between the upper surface of the rotor segment and the lower surface of the main body of the vane. This change in the distance h can be measured, in dependence upon the applied force Z , by suitable measuring elements such as dial gauges. This distance change should be measured both at the belly and at the backside of the vane to detect any settling as well as any increases in distance caused by an elastic elongation of the vane.

Measuring elements such as dial gauges 51 can also be applied at the points 24 in the middle of the vane 2 to measure the spread at the base of the vane in relation to the applied force Z . This measurement makes it possible to determine when one or both of the sides of the vane base come in contact with the retaining catches of the rotor segment 3. By removal of the retaining catches it is also possible to determine the spread at the base of the vane for all values of applied force.

The principal component of the forces applied by the driving fluid (e.g., steam) acts in the circumferential direction of the assumed rotor. By tensioning the wire rope in this direction, it is possible, with the apparatus according to the present invention to determine that tangential force which causes the vane to slide, given various values of the pulling force Z . Use of the optical measuring device illustrated in FIG.

4 to detect a change in the relative positions of the sides of the base of the vane and the intersecting plane of the rotor segment, make it possible to determine elastic flexure at the base of the vane in dependence upon the force applied in the tangential direction.

The vane-driving fluid also exerts forces, or rather force impulses, on a vane in the axial direction of the assumed rotor. By rotating the vane on its mount by 90°, the wire rope can be employed to simulate these axially directed forces to investigate their effects.

In particular, it is possible to investigate the bending or tilting movements of the vane which are executed at the vane base. If the tension of the wire rope is varied, it is possible to determine the angular variations in the position of the external surfaces of the vane base and the rotor segment in dependence upon the pulling force Z . Information concerning the seating of the vane in its mount can be obtained by varying the pulling force Z . Finally, the existence of vane-tilting movements can be determined by varying both the wire rope tension and the pulling force Z .

We claim:

1. Testing apparatus for determining tightness, deformations and weak points of the vane anchorage of turbine vanes comprising, in combination:

- a. means simulating a portion of a turbine rotor;
- b. vane means, comprising at least a portion of a turbine vane and a vane base, attached to said rotor portion;
- c. a first yoke;
- d. a second yoke connected to said first yoke;
- e. resilient element means for resiliently supporting said first yoke with respect to said second yoke, said first and second yokes and said resilient means forming a frame for supporting said vane means;
- f. first means for attaching said first yoke to said vane means;
- g. second means for attaching said second yoke to said simulated rotor portion, said second means including means for applying a force to said simulated rotor portion corresponding to the radial direction of a rotor and hence to the direction of the centrifugal force in a rotating rotor; and
- h. means for applying a force directly to said vane means in at least one direction transverse to the force applied by said second attaching means corresponding to the axial and/or tangential directions of a rotor and hence to the direction of the forces of a driving fluid which act on a vane during operation of a turbine.

2. The apparatus defined in claim 1, wherein said means for applying a force to said vane means in said transverse direction includes means for periodically varying the force.

3. The apparatus defined in claim 2, further comprising means for heating the joint between said simulated rotor portion and said vane means.

4. The apparatus defined in claim 3, further comprising light-optical measuring means for measuring relative motion between said vane base and said simulated rotor portion during the application of forces to said vane means and said simulated rotor portion.

5. The apparatus defined in claim 4, further comprising measuring means for measuring deformations in said vane means and said simulated rotor portion during the application of forces to said vane means and said simulated rotor portion.

6. The apparatus defined in claim 1, wherein said radial force applying means is a hydraulic device.

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,603,143 Dated September 7th, 1971

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It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

In the heading of the patent, line 5, change "June 26, 1969" to --May 26, 1969--.

Signed and sealed this 23rd day of May 1972.

(SEAL)
Attest:

EDWARD M. FLETCHER, JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents