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APPARATUS FOR ASCERTAINING AND REGULATING DEFORMATION OF THE HOUSING AND ROTOR ELEMENTS OF AN ELASTIC FLUID TURBOMACHINE

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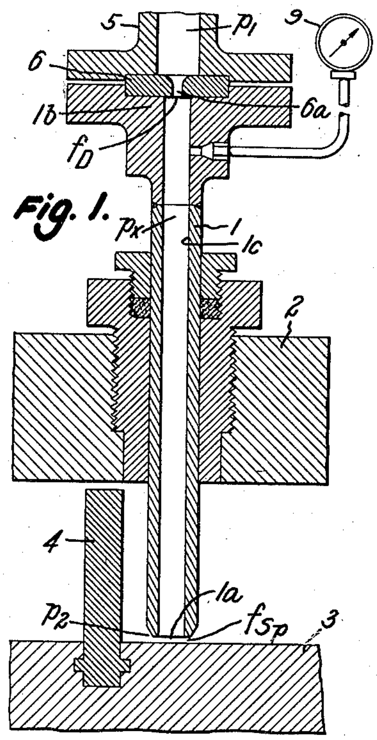

Fig. 1.

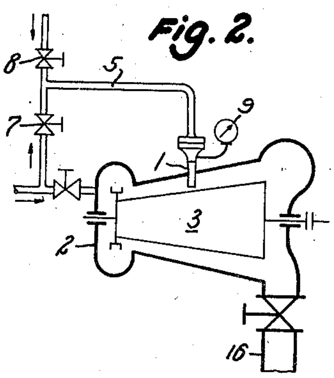

Fig. 2.

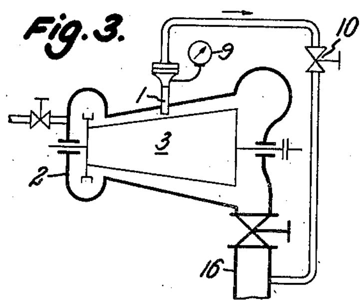

Fig. 3.

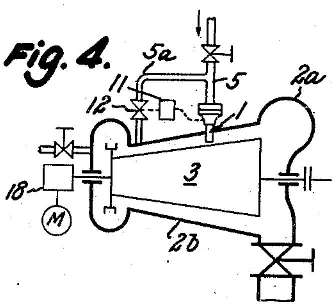

Fig. 4.

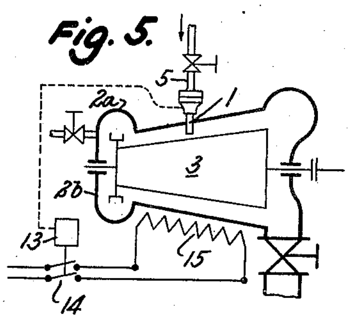

Fig. 5.

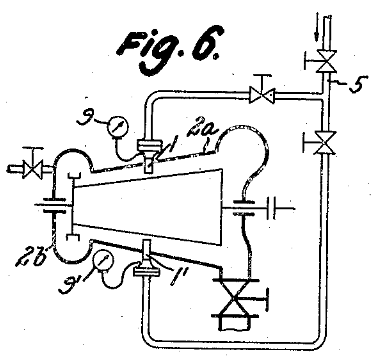

Fig. 6.

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APPARATUS FOR ASCERTAINING AND REGULATING DEFORMATION OF THE HOUSING AND ROTOR ELEMENTS OF AN ELASTIC FLUID TURBOMACHINE

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3 Claims. (Cl. 60—1)

1

The present invention relates to an improved apparatus for ascertaining and regulating deformation of the housing and rotor elements of an elastic fluid turbo-machine caused by unequal heat distribution with a view of maintaining minimum but accurate clearance between stationary and running parts of the machine.

The maintenance of the smallest possible radial clearance is of decisive importance for a good efficiency in all turbines, in particular turbines with relatively small volumes of steam. The smallest possible radial clearance of packings and blades is determined in all turbine models more or less empirically, without it being always possible to avoid with certainty a radial brushing between housing and rotor unless uneconomically large clearances are to be used. The brushing of blades and packings is often caused in that when starting the cold machine, during load variations, and when stopping, rotor and housing do not expand in radial and axial direction (depending on the model) with the same constant, so that enlargements or dangerous reductions of the radial clearances may occur temporarily on the entire periphery. Also it is to be assumed and sometimes to be inferred from observed brushing traces that, for example, the housings of axial turbines with horizontal partial flange do not remain sufficiently round when starting and during operation, whereby local brushing may be caused. Another very important cause of brushing is that after a turbine has been disconnected from its source of driving gaseous fluid, the temperature is not uniformly distributed between the under and upper parts due to stagnation or very low rate of flow of the driving fluid, the values being much higher in the upper part than in the lower part. This causes the housing and the stationary rotor to curve convexly toward the top, so that upon restarting, the blades or packings brush in the lower part and the rotor runs unsteadily. In the rotor this curvature can be equalized by shaft-rotating devices, but the housing remains curved, so that a brushing in the lower part is nevertheless frequently observed.

It is known that for the equalization of the temperature, either the lower part of the housing is more strongly insulated or, when standing still, the lower part of the housing is heated additionally, or that the steam or gas contained in the stationary turbine is circulated by special devices, for example fans. The main difficulty in maintaining and controlling the smallest possible radial clearance consists in that an accurate measurement of possible housing deformations in operation and when standing still with an accuracy of often less than 0.1 mm.,

2

which is necessary in consideration of the small permissible radial clearances, is very difficult. It is known also how to control blade clearance during operation by special feeler pins or feeler levers which are installed in the housing and are brought to the rotor, whenever a measurement is taken, until a slight brushing is perceptible. Particularly in turbines with high temperatures and high pressures this method is practically no longer applicable and moreover has the disadvantage that continuous control is not possible with it, especially since the feeler pins easily wear off if frequent measurements are taken.

To avoid all these difficulties, according to the method of the present invention, to ascertain and regulate deformation of the housing and rotor of turbo-machines caused by unequal heat distribution, there is conveyed to such a machine a current of a gaseous fluid which may be a vaporized liquid such as steam or a normally gaseous substance such as air in such a way that deformation of the housing and rotor causes a pressure variation in the gas fluid which can be used to indicate or regulate the deformation. It is also advantageous to use the pressure variation in the current of the gaseous fluid during operation or when the turbo-machine is disconnected from its source of driving fluid in order automatically to influence the deformation of the housing and of the rotor measured at the measuring point in such sense as will maintain the radial blade clearance at a desired normal value.

A device, likewise constituting the subject of the present invention, for carrying out the method according to the invention is characterized by a measuring tube which is connected in the current of the gaseous fluid and which is installed in the housing of the turbo-machine opposite a revolving surface of the rotor in such a way that one end constituting the mouth is spaced at a small distance from and confronts the revolving surface, its other end being provided with a throttle orifice whose cross section is approximately of the same size as the mean cross section of the gap between the mouth of the measuring tube confronting the rotor and the revolving surface of the rotor, in such a way that the pressure variation caused in the measuring tube by the deformation of the housing and rotor can be used to indicate or respectively to regulate the deformation.

The pressure variation caused in the measuring tube by the deformation of the housing and/or rotor can advantageously be used also to actuate a heating device for the lower part of the machine housing. Also, in turbo-machines equipped with shaft-rotating devices, when the machine is disconnected from its source of driving fluid and the shaft-rotating device is running, the pressure variation caused in the measuring tube by the deformation of the housing may actuate a valve, whereby a gaseous fluid of suitable temperature is conveyed to the interior of the turbo-machine in such a way that the amount thereof regulates the deformation of the housing. Also, under the same conditions as just described, a gaseous fluid of suitable temperature, whose quantity, automatically influenced by the measuring tube and the housing deformation, regulates the housing deformation, may be conveyed to the interior of the machine through the measuring tube itself. Finally, the arrangement may be made in such a way that in the upper as well as in the lower part of the housing a measuring tube for each is installed, which tubes can be used jointly for a differential measurement as well as separately for a measurement of the upper and lower blade clearances.

In the accompanying drawing which illustrates one practical construction of a device by which the method can be performed and various applications thereof for regulating deformation:

Fig. 1 is a view in vertical section of the measuring device as installed on a turbo-machine,

Fig. 2 is a schematic view which illustrates an application of the measuring device shown in Fig. 1 wherein a gaseous fluid such as fresh steam under pressure or alternatively compressed air are utilized to ascertain and indicate deformation in the machine;

Fig. 3 shows an arrangement similar to Fig. 2 but wherein the pressure measuring device is connected to a stage of lower pressure;

Fig. 4 illustrates schematically an application of the measuring device to regulation of the curvature of the housing when the turbo-machine is disconnected from its source of hot driving gaseous fluid, by controlling its temperature, the medium used for temperature control being a heated gaseous fluid;

Fig. 5 shows an embodiment similar to Fig. 4 wherein the heating medium is an electric type heater element; and

Fig. 6 shows another schematic arrangement employing two measuring devices for ascertaining deformation of the machine at diametrally opposite points on the rotor in the upper and lower parts of the housing.

With reference now to the drawing, and Fig. 1 in particular, a cylindrical measuring tube 1 having a bore 1c of uniform diameter is introduced from the exterior into the housing 2 of a turbo-machine, for example between a series of guide blades or in other suitable interstices, so that its lower end or mouth 1a facing the rotor 3 approaches radially a suitable cylindrical surface of the latter, for example the drum surface or the covering bands of a series of moving blades 4. The tube mouth 1a confronts the periphery of the rotor and is spaced from the same by a distance of about 0.5 mm. to 1.0 mm.

Through a gas line 5 connected to the upper end 1b of the tube a gaseous fluid such as air or fresh steam is introduced under constant pressure and flows into the tube through an orifice 6a in nozzle plate 6, the cross section f_D of orifice 6a being preferably substantially equal to the mean cross section f_{SP} of the gap existing between the tube mouth 1a and the periphery of the rotor 3. That is, area f_{SP} is equal to the circumference of the bore of the tube mouth 1a multiplied by the mean distance from the mouth

to the rotor surface. At a given pressure p_1, at the gas line 5 side of nozzle 6 and a known pressure p_2 in the respective turbine stage where the tube is located, the back pressure p_x in the tube 1 between the lower end or mouth 1a and nozzle 6 is wholly dependent upon the radial clearance between housing and rotor. In the range in which the pressure ratio at the tube mouth 1a is overcritical, pressure p_x is independent of the stage pressure p_2, so that here the accuracy of measurement is especially great and the measurement especially simple. A manometer 9 connected into the pressure chamber portion of tube 1 intermediate nozzle 6 and the lower end 1a measures the pressure p_x in this chamber portion of the tube and since such pressure varies with the distance between tube end 1a and the face of rotor 3, the scale on the manometer can be calibrated to indicate radial clearance between housing and rotor.

In accordance with Fig. 2, the same fresh steam as is used for driving the turbine can be conveyed to tube 1 through valve 7, or alternatively, some other vaporous or gaseous substance for example air under constant pressure can be led into tube 1 through valve 8, the two valves 7 and 8 being of course so arranged in the gas supply lines 5 that steam or air can be admitted to the latter in an alternative manner. The arrangement of tube 1 in the turbine is the same as shown in Fig. 1. Manometer 9, or any other like indicating or recording device which may be employed in lieu thereof, will accordingly indicate every variation in pressure in tube 1 and hence every variation in radial clearance between the lower end 1a of tube 1 and the surface of rotor 3.

Fig. 3 illustrates a slightly different embodiment. In Fig. 2, pressure p_1 of the gaseous fluid at the gas inlet side of nozzle 6 is higher than the stage pressure p_2 existing in the turbine where tube 1 is located. In Fig. 3 however, supply line 5 leading to tube 1 is connected to a stage of constant pressure lower than pressure p_2, which for example is constituted by a connection to a condenser 16 through valve 10. With the arrangement of Fig. 3, the measured pressure p_x within tube 1 will be somewhat dependent upon the respective stage pressure p_2 of the turbine, but in certain cases, this arrangement may be advantageous.

If it is desired to automatically regulate the curvature of the upper part 2a of the turbine housing when the turbine is disconnected from its source of driving gaseous fluid, an arrangement as shown in Fig. 4 may be utilized. Here the gas supply line 5 to tube 1 contains a branch line 5a leading to the interior of the upper part 2a of the turbine housing. A valve 12 in the branch line 5a is controlled automatically in accordance with the variation in pressure p_x in tube 1 over a pressure responsive regulator 11 to convey into the upper housing part 2a when the machine is so disconnected, more or less of a gaseous heating medium such as steam at a suitable temperature which functions to influence the temperature distribution inside of the housing. If, for example, in a turbine stage which during operation has a temperature of about 400° C., steam of about 250° C. is introduced into the upper part 2a of the housing through supply line 5a after disconnecting the turbine, and with the rotor shaft rotating device 18 running. The hotter steam stagnating in the upper housing half 2a is first cooled. If such cooling is insufficient so that the upper housing part 2a continues to curve convexly toward the top, the gap between tube end 1a and the surface of rotor 3 is enlarged thereby increasing the quantity of cooling steam. Conversely, the quantity of cooling steam will be automatically decreased when the upper housing part 2a returns to the flat position or even curves concavely. This method is especially suitable for pre-connected turbines which are to be stopped for example only at night for a few hours. In these it will be advisable to close the waste steam valve and to convey steam to the measuring device 1 from the waste steam line beyond this valve, which for example is provided from another still running pre-connected turbine with steam of about 250 to 270 deg. C. The steam admitted through the measuring device then escapes under a corresponding pressure from the stuffing boxes of the turbine. This method enables an immediate restarting of the pre-connected turbine after a stoppage of any desired length and with a minimum of energy losses and cost of operation. In the Fig. 4 arrangement it will also be noted that the gaseous fluid used for heating the upper part 2a of the housing also serves as the pressure fluid admitted to the interior of tube 1 for measuring purposes.

Fig. 5 shows still another arrangement for regulating the state of curvature of the turbine housing with the turbine disconnected from its source of driving fluid and the shaft rotating device running. Here an electrical heating unit 15 associated in heat transverse relation with the lower part 2b of the turbine housing is controlled by a regulator 13 responsive in accordance with the change in pressure p_x within the pressure chamber of measuring tube 1. Regulator 13 actuates a switch 14 connected in the electric power supply line to heater 15 and the arrangement is such that heater 15 is connected whenever the measured pressure p_x exceeds a preselected value and is disconnected whenever pressure p_x falls below such value. The pressure fluid used in measurement of the pressure enters tube 1 through supply line 5 as before.

In the arrangement illustrated in Fig. 6, not only is a measuring unit 1 disposed in the upper half 2a of the turbine housing as in all the other embodiments but a second such unit 1' is also used, the latter being diametrally opposite the measuring unit 1 in the lower half 2b of the turbine housing. Measuring units 1 and 1' may be used independently, as shown, with the readings being taken on manometers 9 and 9', respectively or may be utilized together in such manner that the resultant regulatory action is made dependent upon the pressure differential between the two units.

In conclusion, it will now be apparent that the method and associated apparatus which has been described enables one to maintain continuous control over the radial clearance between rotating and stationary parts at various points in the turbine while the turbine is operating and also to indicate or record such clearances if desired. The invention also makes it possible to regulate clearances when the turbine is disconnected from its source of driving fluid at least as long as the machine remains under steam for possible re-use after having been disconnected. The novel system of measurement, namely that of pressure variation also is obviously superior to those employing feeler pins for there are no parts subject to wear action due to contact with the rotating member. The cross section f_{SP} of the gap at the lower end 1a of the measuring tube can be read at any time on a measuring device, for example a manometer. Finally, the invention is most suitable as a solution for one of the most difficult problems encountered in operation of the most modern of high-pressure, preconnected steam turbine plants, namely that of keeping the turbines in readiness for immediate restarting after having been shut down, during a period of reduced load or for any other reason.

Moreover, while the invention has been illustrated as applied to the measurement of radial clearances in a turbine, the principles of the invention are obviously equally applicable to the measurement and regulation of axial clearances especially in impulse turbines.

Having now disclosed my invention and described and illustrated a representative mode by which the same may be put into practice, I claim:

1. The combination with a turbo-machine of apparatus for measuring and regulating deformation of the housing and rotor elements of said turbo-machine caused by unequal heat distribution, said apparatus comprising a tube secured to said housing and extending therefrom in the direction of the rotor surface with the mouth of said tube disposed closely to and confronting the rotor surface, a throttling orifice disposed in said tube to establish a pressure chamber therein between said orifice and tube mouth, a valve controlled inlet on said housing for admitting hot gaseous driving fluid to the interior thereof for driving said rotor during normal operation of said turbo-machine when delivering power, an auxiliary motor coupled to said rotor for rotating the latter when the hot driving fluid is cut off at said inlet, means for admitting a portion of said hot driving fluid into the pressure chamber in said tube for flow through the tube mouth against the surface of said rotor, the fluid pressure variation in said chamber being proportional to the variation in distance between the tube mouth and rotor surface, means for heating said housing, and means responsive to the variations in pressure in said chamber for regulating said heating means and thereby also the deformation of said housing when said auxiliary motor is rotating said rotor and the hot driving fluid is cut off.

2. Apparatus for measuring and regulating deformation of a turbo-machine as defined in claim 1 wherein the means for heating said housing is comprised of a valve controlled auxiliary inlet to the interior of said housing at the upper portion thereof through which heated gaseous fluid is passed to the upper interior portion of the housing, and operation of the valve controlling said auxiliary inlet is regulated by the pressure variations in said chamber.

3. Apparatus for measuring and regulating deformation of a turbo-machine as defined in claim 1 wherein the means for heating said housing is comprised of a heater unit in heat transfer relation with the lower part of said housing.

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