United States Patent [19]

Sljusarev et al.

[11] **3,841,788**

[45] **Oct. 15, 1974**

[54] **DEVICE FOR TURNING THE STATOR VANES OF TURBO-MACHINES**

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[22] Filed: **Nov. 9, 1972**

[21] Appl. No.: **305,184**

[52] **U.S. Cl.** **415/147,** 415/160

[51] **Int. Cl.** **F01d 17/14**

[58] **Field of Search** 415/147, 149, 160, 163, 415/150, 151

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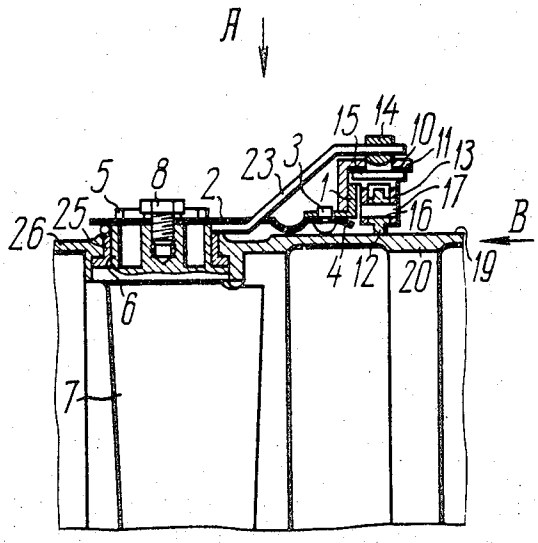
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[57] **ABSTRACT**

A device comprises a synchronizing ring which is installed with a possibility for turning with simultaneous axial displacement along the housing of a turbo-machine. This synchronizing ring is pivotally connected to levers and given a means for limiting its displacement in a plane perpendicular to its axis. Each lever is pivotally connected with one end to the synchronizing ring, whereas with the other end is rigidly secured to the journal of the vane. The means limiting the displacement of the synchronizing ring comprises rollers. Each roller is kinematically linked with the synchronizing ring and installed in the latter ring with a possibility for turning around the axis directed along the radius of the ring and passing approximately through the axis of the roller, each roller cooperating with the housing of a turbo-machine.

4 Claims, 9 Drawing Figures



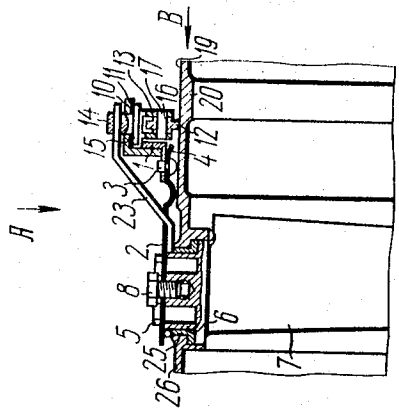


FIG. 1

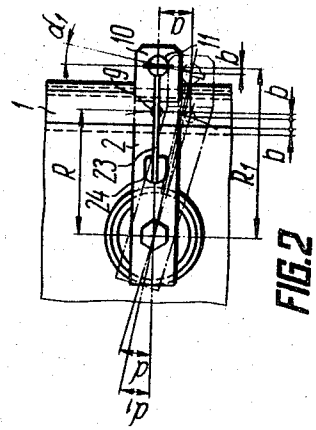


FIG. 2

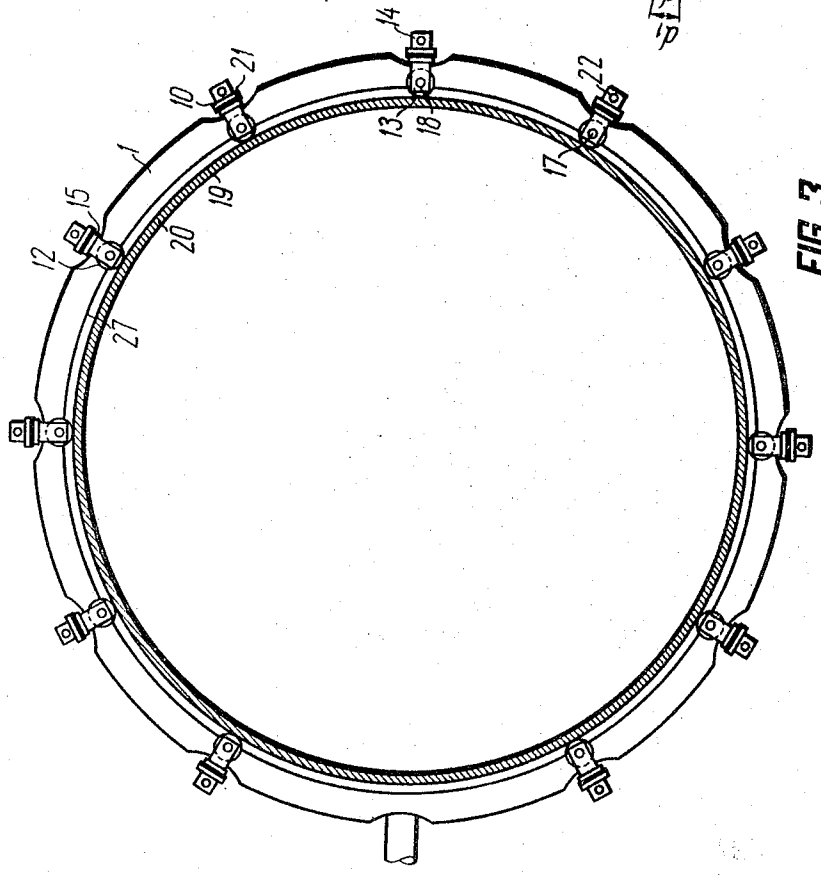


FIG. 3

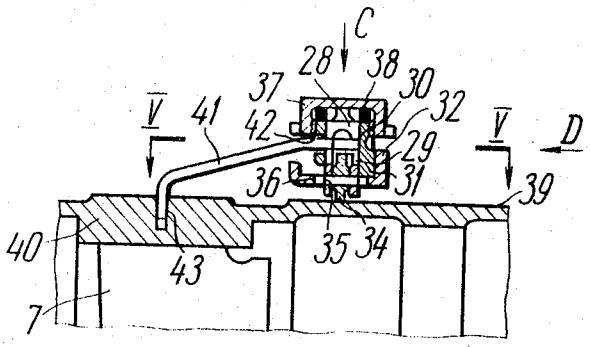


FIG. 4

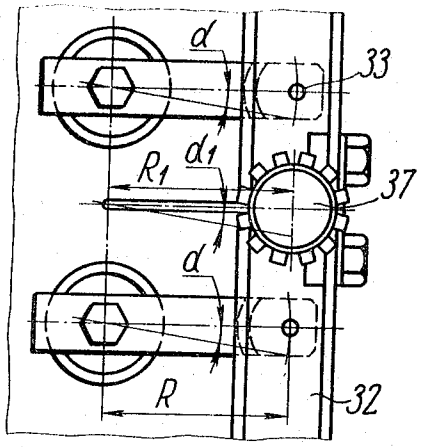


FIG. 6

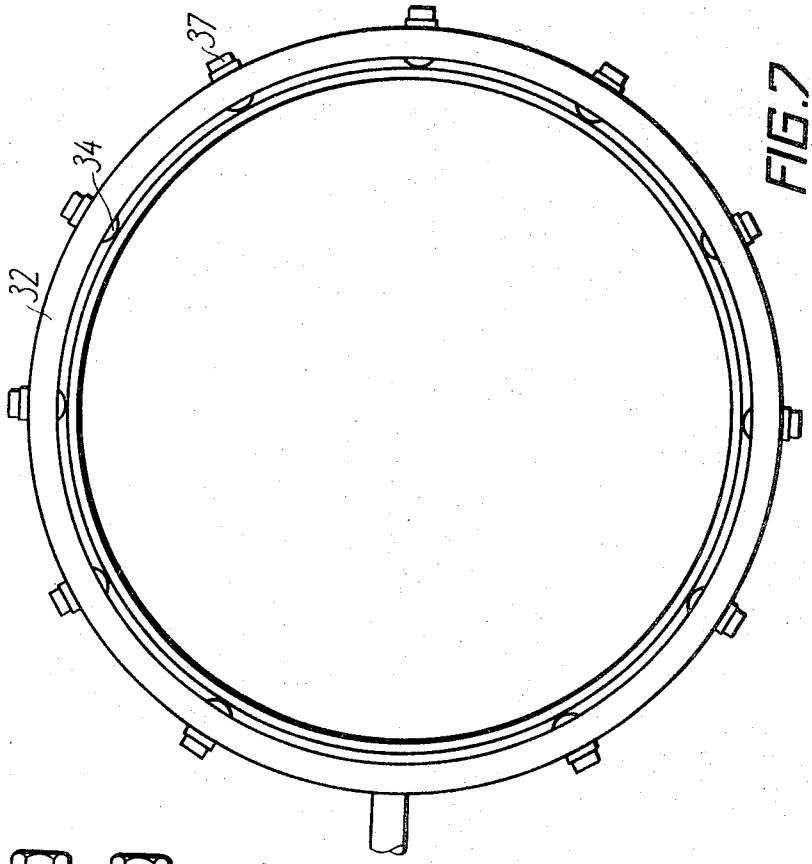


FIG. 7

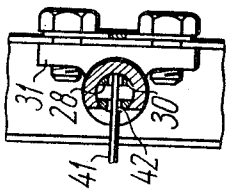


FIG. 5

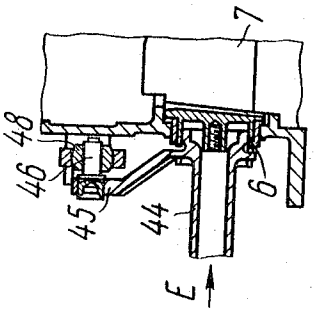


FIG. 8

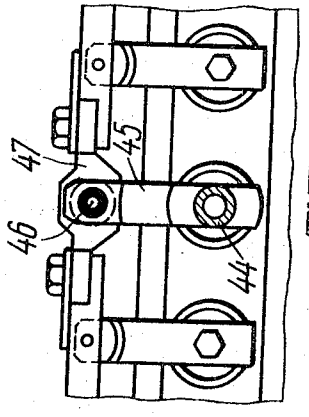


FIG. 9

DEVICE FOR TURNING THE STATOR VANES OF TURBO-MACHINES

The present invention relates generally to the turbo-machinery and, more particularly, to the devices for turning the stator vanes of turbo-machines.

The invention may be most successfully employed in axial-flow compressors of gas-turbine engines.

There are known devices for turning the stator vanes. A device comprises a synchronizing ring pivotally connected to levers. The pivotted connection of the synchronizing ring to each lever is made by means of a pivot fixed to one end of the lever. The pivot is radially directed in relation to the synchronizing ring. With its other end the lever is rigidly secured to the root of the vane with no possibility for relative turning. The synchronizing ring is installed around the periphery of the compressor housing and rests on rollers which are mounted in another ring rigidly secured to the housing. Beside that, the synchronizing ring is restricted in axial displacement by the shoulders of that another ring. The synchronizing ring has axial slots accurately disposed along the circumference and widening toward the end to face the vanes. The pivots are housed in these slots.

During operation of the device the synchronizing ring is turned around its axis by means of a servomotor which is pivotally connected to the synchronizing ring. During turning, the synchronizing ring runs on the rollers along the ring which is rigidly secured to the housing.

In this action, the levers are turned due the thrust exerted by the walls of the axial slots in the ring to ensure turning of the vanes. In the above example, the synchronizing ring is only turned around its axis with no axial displacement, while the levers connected to the vane turning axles are moved in a plane perpendicular to a plane of turning the synchronizing ring, therefore at the place where the lever is linked to the synchronizing ring the pivot is shifted along the slot with simultaneous turning therein through the sliding contact between the slot and the pivot within the height of the latter.

On the other hand, as the pivot of the lever is moving retaining all the time the initial position iof its axis while the axis of the slot turns, during operation of the given device a change occurs in an angle between the pivot axis and the slot axis. However, the synchronizing ring is of a definite thickness and the position of the pivot at an angle to the axis of the slot requires the latter to be widened which is provided for in this device and has been mentioned above. The same position of the pivot at an angle to the axis of the slot leads to a situation when the contact of the pivot with the walls of the slot in every position, except one when the axes of the pivot and of the slot coincide, is effected only at one point along the edge of the slot.

One disadvantage of the described device is that with the point contact between the pivot and the slot, high specific pressures are generated at the place of contact, which leads to a high bearing stress.

Another disadvantage is that during operation of the device the point of contact is moving within the length of the slot and the height of the pivot and also around the circumference of the latter which in combination with high specific pressures leads to an increased wear. This makes operation of the device less reliable.

One more disadvantage of the above described invention is that the axial slots considerably reduce the durability of the synchronizing ring, which therefore requires a substantial increase in the cross-section of this ring. This materially increases the weight of the given device.

Next disadvantage of the above device is associated with difficult technology of making the slots variable in width and exactly disposed along the circumference. Reduced accuracy in positioning the slots along the circumference of the synchronizing ring causes different angling of the vanes, which tells negatively on the operation of a turbo-machine.

On the other hand, the geometry of the slot itself should be exactly maintained because any deviation from this requirement would lead to an enlarged clearance in the slot-to-pivot connection which in its turn would cause work hardening. Difficult technology involved in making the slots adds to the cost of the entire device.

Also known in the art is a device for turning the stator vanes. This device comprises a synchronizing ring which is pivotally connected to levers. Each lever is rigidly secured to the vane. Here, the synchronizing ring is positioned around the turbo-machine housing and has no contact with said housing or with any other part rigidly secured to the housing, i.e. it is given a guaranteed clearance over any surface of the housing or other part fixedly connected to said housing. The synchronizing ring has radial holes with bolts housed therein. By means of these bolts the balls of the spherical joints are fixed to the outer surface of the synchronizing ring.

Each lever with its one end is rigidly connected to the vane journal, whereas with its other end provided with a bushing with an inner sphere encompassing said ball it is pivotally connected to the synchronizing ring. Thus, the synchronizing ring is located around the compressor housing through a certain clearance and connected to the housing only through the agency of the levers and vanes.

In operation of the above-described device for turning the stator vanes, the synchronizing ring when forced by the action of a servomotor performs a complex motion: turning around the axis with simultaneous axial displacement. Herewith, the balls fixed to the ring come to act on the bushings installed in the levers and turn the latter and the vanes as as well. As the spherical joint allows no possibility for the bushing to displace in relation to the synchronizing ring in the direction along the radius, the levers in this case are deformed to the required value within the elastic limits and to this aim the latter levers are made resilient.

Due to the fact that a clearance is provided between the synchronizing ring and the housing and the ring is effected by the actuating effort which can be represented as a couple of forces including a force passing through the axis of the ring and approximately in a plane perpendicular to the axis of the ring and hence the connection of the ring to the housing is effected through the agency of the resilient levers, the synchronizing ring when forced by said effort is displaced in a plane mentioned. This displacement of ring entails different turning angle of the vanes. These vanes which are located at diametrically opposed points as to the direction of the actuating effort, will turn strictly to the required angle, but out of those vanes positioned at diametrically opposed points perpendicular to the direc-

tion of the actuating effort some vanes will turn to an insufficient angle corresponding to the displacement of the ring, while the other will turn this angle more. The remaining vanes according to their location in relation to those mentioned will be given a less or larger angle of turning.

A disadvantage of this invention is associated with impossibility of turning all the vanes through one and the same angle, which impairs the parameters of a turbo-machine.

A widely known method for remedying this disadvantage is the application of two or more synchronously operated actuators for transmitting the actuating effort to the synchronizing ring, which actuators are equidistantly spaced along the circumference of the ring and due to their cooperation prevent the occurance of a force passing through the axis of the ring. In this case there occurs no different angle of turning the vanes located at various points, the parameters of a turbo-machine are not impaired, however the synchronously operated actuators by themselves are sophisticated units with feed-back system, which highly complicates the device and raises the cost of its production.

Apart from that, the application of synchronously operated actuators is associated with a considerable increase in the weight of the device.

It is an object of the present invention to improve the operation of a turbo-machine.

It is another object of the present invention to provide a device more reliable and durable in operation.

It is one more object of the present invention to make the production of the device easier and to reduce the cost thereof.

It is yet another object of the present invention to reduce the weight of the device.

These and other objects are achieved due to the provision of a device for turning stator vanes of a turbo-machine, comprising a synchronizing ring installed with a possibility for turning with simultaneous axial displacement along the housing of a turbo-machine, said ring connected to the levers with each of them rigidly secured to a vane, according to the invention, the synchronizing ring is provided with a means for limiting its displacement in a plane perpendicular to its axis.

It is expedient that the means limiting the displacement of the synchronizing ring is made in the form of rollers and includes kinematic links for connection to the synchronizing ring, said rollers are installed in the above synchronizing ring with a possibility for turning around an axis directed along the radius of said ring and passing approximately through the axis of said roller, whereas the latter cooperates with the housing of a turbo-machine.

It is desirable that kinematic links are made as yokes each of them housing a single roller; journals of said yokes pivotally installed in the synchronizing ring; a carrier for turning the roller and cooperating with said roller.

It is recommended that the carrier pivotally connected with its one end to the journal of the yoke, whereas with its other end it is linked with the vane turning axle.

It is in the spirit of the invention that the carrier with its one end is pivotally connected to the journal of the yoke, whereas with its other end it is pivotally joined to the housing of a turbo-machine, while the pivoted joint is located in a plane passing through the vane turning axes.

A device embodied as described makes its production easier, increases reliability and longevity and improves operation of a turbo-machine due to the effect of turning all the vanes through one and same angle. This is achieved due to the fact that the synchronizing ring during its compound motion is adapted to run on the rollers over the housing of a turbo-machine. The rollers are adapted to limit the displacement of the ring in a plane perpendicular to the axis of rotation thereof. Therefore, all points of the ring circumscribe strictly equidistant trajectories in space. Since the ends of the levers are pivotally connected to the synchronizing ring the axes of joints would describe the same equidistant trajectories and consequently all the levers would deflect through one and the same angle and turn the vanes connected thereto through the same angle.

The above embodiment of a device provides for a lighter weight of the latter as against the above described devices.

Other objects and advantages will become more fully apparent in the hereinafter given description of the actual embodiments with reference had to the accompanying drawings, in which:

FIG. **1** is a longitudinal sectional view of a device for turning stator vanes of a turbo-machine, according to the invention;

FIG. **2** is a view along arrow A in FIG. **1**;

FIG. **3** is a view along arrow B in FIG. **1**;

FIG. **4** is a longitudinal sectional view of another embodiment of a device for turning stator vanes of a turbo-machine, according to the invention;

FIG. **5** is a sectional view across V—V in FIG. **4**;

FIG. **6** is a view along arrow C in FIG. **4**;

FIG. **7** is a view along arrow D in FIG. **4**;

FIG. **8** is a longitudinal sectional view of an actuator adapted to displace the synchronizing ring; and

FIG. **9** is a view along arrow E in FIG. **8**.

Reffering now to FIG. **1**, a device for turning stator vanes of a turbo-machine comprises a synchronizing ring **1** performing a compound motion: turning around its axis and simultaneous displacement along said axis. A lever **2** is pivotally connected to the synchronizing ring **1** by means of a pivot **3** secured to the end **4** of the lever **2**. The end **4** is made spherical. The other end of the lever **2** is placed in slot **5** of a journal **6** of a vane **7** and rigidly secured to said journal by a screw **8**. The synchronizing ring **1** has holes **9** (FIGS. **1, 2**), with each hole housing a pivot **3** (FIG. **1**) of the lever **2**, and brackets **10** each rigidly connected to the ring.

Each bracket **10** has a hole **11** directed along the radius of the synchronizing ring **1** (FIG. **3**). Rollers **12**, each kinematically linked with the synchronizing ring **1**, are installed on the latter individually by means of a yoke **13** provided with a journal **14**, a shoulder **15** and a slot **16** (FIG. **1**). The roller **12** is housed in a slot **16** on a pin **17** which is inserted in a hole **18** (FIG. **3**) of a yoke **13**. The journal **14** of the yoke **13** is accommodated in a hole **11** (FIG. **1**) of the bracket **10**.

The rollers **12** rest on the surface **19** of the housing **20** of a compressor. An adjusting shim **21** (FIG. **3**) is placed between the bracket **10** and the shoulder **15** of the yoke **13** to ensure contact between the roller **12** and the surface **19**.

The journal **14** of the yoke **13** has a hole **22** housing one end of a carrier **23** (FIG. **1**), while the other end

of the carrier 23 made as a ring is slipped upon the journal 6 of the vane 7. Beside that, the carrier 23 is inserted through an opening 24 (FIG. 2) in the lever 2. The carrier 23 is locked against displacement along the axis of the journal 6 (FIG. 1) of the vane 7 at one end by means of the lever 2 and at the other by a bushing 25 which is pressed into a hole 26 in the housing 20 and serves as a bearing for the journal 6 of the vane 7.

The spherical end 4 of the lever 2 is pressed to the surface 27 (FIG. 3) of the synchronizing ring 1.

The lever 2 (FIG. 1) is made elastic and having maximum rigidity in the plane of its rotation, therefore it remains pressed with its end 4 against the surface 27 (FIG. 3) of the synchronizing ring 1 at any position occupied during operation, because due to the effort exerted by the surface 27 it deforms within the elastic limits in a direction toward the centre of the synchronizing ring 1.

In operation of the device, for turning the vanes 7 of the stator the synchronizing ring 1 when forced by a servomotor (not shown in the drawings) performs a compound motion: turning around its axis and simultaneous axial displacement.

The ring 1 is displaced in the circumferential direction by value *a* (FIG. 2) and axially by value *b*. Herewith, as the synchronizing ring 1 is nowhere able to get closer to the housing 20 (FIG. 1) (this is prevented by the rollers 12) the ring moves without deviating from a plane perpendicular to its axis and, it follows that all points of the ring 1 circumscribe strictly equidistant trajectories in space. Due to the fact, that the end 4 of each lever 2 is pivotally connected to the synchronizing ring 1, the axis of each pivot 3 circumscribes the same path; as a result each lever 2 deviates through one and the same angle α (FIG. 2) and by this turns the vane 7 (FIG. 1) connected thereto through the same angle α.

α — is deviation angle of the lever 2.

Owing to the fact that the journal 14 of each yoke 13 is displaced together with the corresponding bracket 10 and the synchronizing ring 11 in the circumferential direction by value *a* (FIG. 2) and axially by value *b*, the journal 14 due to the carrier 23 (FIG. 1) while moving remains constantly directed with the axis of the hole 11 toward the turning axis of the vane 7. Thus, the yoke 13 turns together with the roller 12.

R_1 (FIG. 2) — a beeline from the turning axis of the vane 7 (FIG. 1) to the axis of the journal 13 of the yoke 13.

R — a distance from the turning axis of the vane 7 (FIG. 1) to the axis of the pivot 3.

Distance R_1 from the axis of the vane 7 (FIG. 1) to the axis of the corresponding yoke 13 is longer than distance R from the axis of the vane 7 to the axis of the pivot 3 (FIG. 1) hence, the angle for turning each yoke 13 with the roller 12 is found to be somewhat less than angle α.

However, at small values of α and insignificant differences between R and R_1 the difference between α and α_1 can be neglected. In other words, when the synchronizing ring 1 is in motion each roller 12 (FIG. 1) turns with insignificant deviations following the trajectory of the ring 1 in motion and runs along the surface 19 of the housing 20 practically with no slip whatsoever.

The synchronizing ring 1 moving, and the levers 2 turning the pivots 3 are turning in the holes 9. At this time, the pivot 3 contacts the hole 9 through the surface.

The specific pressure at the contact place is thus reduced which consequently brings stress reductions in the contacting parts to add to reliability and longevity of the device.

The lever 2 is constantly pressed against the surface 27 of the synchronizing ring 1 by its end 4, whence the relative displacement of the pivot 3 and the hole 9 in the synchronizing ring is reduced to the minimum, only to turning, to reduce wear of this pair.

The lever 2 is made elastic with maximum rigidity only in a plane of its turning, therefore due to twisting deformation within the elasticity limits the pivot 3 is able to occupy an angular position which is dictated by the hole 9.

At this time, elastic resistance to twisting the lever 2 when turning the synchronizing ring 1 gives the effect of taking out clearances between the pivot 3 and the hole 9 and by this obviates a possibility for cold hardening, which also improves reliability and durability of the device.

Provision of the holes 9 in the synchronizing ring 1 allows its cross section to be reduced as compared with the above described devices, which cuts the weight of the novel device. Moreover, the holes and the pivots 3 require no complicated production technology to make, thus the device is simple and inexpensive to produce.

To completely exclude any difference between the turning angle of the levers 2 and the rollers 14 it is expedient to embody a device for turning the stator vanes in accordance with an embodiment illustrated in FIGS. 4, 5, 6.

In contrast to the first described embodiment, the rollers 12 (FIG. 1) with yokes 13 are displaced and positioned on the synchronizing ring 1 between holes 9 in which the pivots 3 of the levers 2 are located. Also somewhat changed is the method of taking out the clearances between the rollers and the surface of the housing. This method is given here only as a more convenient one with respect to the assembly of the device in question but in no way altering the nature of the latter.

A journal 28 (FIG. 4) of each yoke 29 is installed in a hole 30 of each bracket 31 rigidly secured to the synchronizing ring 32. The axis of each hole 30 is found in a common plane with the axes of holes 33 which play a role similar to that of the holes 9 (FIG. 2) in the first described embodiment. Each yoke 29 with the roller 34 mounted on a pin 35 is inserted into the hole 30 through an opening 36 made in the synchronizing ring 32. The journal 28 rests against the bottom of the nut 37 of the bracket 31. Position of the nut 37 in the direction along the axis of the hole 30 is determined by the thickness of an adjusting shim 38 which is selected with the aim to ensure a guaranteed contact between the rollers 34 and the surface 39 of the compressor housing 40. This version of performing adjustments in the position of the roller 34 is somewhat easier to embody from the technological point of view as against that in the first described embodiment. A carrier 41 with its one end enters a hole 42 (FIG. 5) in the journal 28, while with its other end it comes into a hole 43 (FIG. 4) in the housing 40, which latter hole is located in a common plane with turning axes of the vanes 7.

In the second embodiment the levers **2** are connected to the vanes **7** the same as has been described for the first embodiment.

The principle of operation as to the second embodiment is fully the same as has been described above.

In this embodiment of a device for turning the stator vanes **7** angles α_1 (FIG. **6**) of turning the yoke **28** are equal to angle α of turning the vanes **7,** because radii R and R_1 are equal.

For displacing the synchronizing ring **1** (FIG. **1**) and **32** (FIGS. **4, 7**) it is expedient to employ an actuator consisting of a driving shaft **44** (FIG. **8**) which is mounted in the journal **6** (FIG. **1**) of the vane **7.** The shaft **44** (FIG. **8**) is given a lever **45.** Rigidly secured to the lever **45** is a pivot **46.** Either synchronizing ring **1** (FIG. **1**) or **32** (FIG. **4**) is split and connected by a strip **47** (FIG. **9**). The strip **47** mounts a ball joint **48** (FIG. **8**) whose hole houses the pivot **46.**

By the action of a servomotor (not shown in the drawings) the shaft **44** is turned and through the agency of the lever **45** and the pivot **46** moves the synchronizing ring **1** (FIG. **1**) and **32** (FIG. **4**).

An actuator embodied as described is small in size and light in weight.

What we claim is:

1. A device for turning the stator vanes of a guiding apparatus for a turbo-machine, comprising: a housing for said turbo-machine; a synchronizing ring adapted to be turned about the axis of said turbo-machine and simultaneously move along said axis; a plurality of levers, each said lever being pivotably connected at one end thereof with said synchronizing ring and at the other end thereof being rigidly connected with the vanes of said guiding apparatus; means mounted on said synchronizing ring for limiting the displacement of the latter in a plane extending normal to the axis of said turbo-machine, said means being formed of a plurality of rollers; kinematic links being each connected at one end thereof with respectively each of said rollers and at the other end thereof being each connected to said ring, said links including pivotable means allowing said roller to turn in response to interaction thereof with said housing about an axis directed along the radius of said ring and passing approximately through the axis of said roller, and a carrier for turning said roller being adapted to cooperate with said roller.

2. A device as claimed in claim **1,** said pivotable means comprising: a yoke engaging said carrier and having at one end a journal which is pivoted in said synchronizing ring and at the other end a slot accomodating said roller so as to be arranged in its plane of symmetry passing through the axis of said journal.

3. A device as claimed in claim **2,** said carrier being pivotably connected at one end thereof with the journal of said yoke and at the other thereof being pivotably connected with a turning axis of said vanes.

4. A device as claimed in claim **1,** said carrier being pivotably connected at one end with said journal, said journal having an axis lying in a plane passing through the axis of pivots connecting said levers with said synchronizing ring, and at the other end being pivotably connected with said housing for said turbo-machine, the last-mentioned pivotable connection being located in a plane passing through the turning axes of said vanes.

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