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JOURNAL BEARINGS SYSTEM OF SHAFTS WITH ROLLING START-UP AID

UKŁAD ŁOŻYSK POPRZECZNYCH WAŁÓW Z TOCZNYM WSPOMAGANIEM ROZRUCHU

Summary: The article describes a radial journal bearing adapted to, e.g. high-speed rotating machinery, and a special radial-thrust bearing used for the bearing system of vertical shafts of water and wind power plants of the proconsumer type. In both of the described designs, the start-up and run-out of the slide bearings are supported by the rolling bearings that are activated by the shaft reaching the assumed rotational speed.

Keywords: rolling bearings, radial bearing, water power plants, wind power plants

Streszczenie: W artykule opisano łożysko poprzeczne przystosowane m.in. szybkoobrotowych maszyn wirujących oraz specjalne łożysko promieniowo-oporowe stosowane w systemie łożyskowania wałów pionowych elektrowni wodnych i wiatrowych typu prokonsumenckiego. W obu opisanych konstrukcjach rozruch i wybieg łożysk ślizgowych wspomagany jest przez łożyska toczne, które uruchamiane są poprzez osiągnięcie przez wał założonej prędkości obrotowej.

Słowa kluczowe: łożyska toczne, łożysko promieniowe, elektrownie wodne, elektrownie wiatrowe

Introduction

In the high-speed shaft bearings arrangement, there are a number of difficulties when frequent starts and run out under full load take place. The problem is then in choosing the type of bearing.

In the range of high and very high rotational speeds, slide bearings work well when the conditions for full hydrodynamic lubrication are provided [2, 3]. Occurrence of frequent starts and stops under load causes problems with mixed friction conditions and greater frictional wear; then the conditions for liquid lubrication are not met. This may lead to bearing seizure symptoms, leading to premature failure of the bearing, and even a fire hazard

In many cases, a significant increase in the starting resistances of the tribological system of slide bearings is very undesirable particularly, when there is a lack of lubricant in the area between the journal and the bearing sleeve. This requires the use of excess power of the drive motors due to starts. Also, when the machine runs down under load, unfavourable phenomena occur in the slide bearings that can lead to their destruction; the viscosity of the lubricant is significantly lowered. In the situation of their immediate start-up, the tribological conditions in the bearings become particularly critical.

At the Department of Mining Mechanization and Robotization of the Silesian University of Technology, a number of bearing arrangements have been developed, the main feature of which is the use of supporting the start-up and run-out of slide bearings by additional rolling bearing, which is automatically switched off. When the bearing reaches the assumed rotational speed, the automatic changeover system is turned on again, when the slide bearing overruns exposed to constant heavy load [15, 16, 17].

The article describes a radial journal bearing adapted to, e.g. high-speed rotating machinery, and a special radial-thrust bearing used for the bearing system of vertical shafts of water and wind power plants of the proconsumer type.

In both of the described designs, the start-up and run-out of the slide bearings are supported by the rolling bearings that are activated by the shaft reaching the assumed rotational speed.

Bearing of the vertical shaft of the proconsumer power plant with the use of a sliding bearing with a rolling start and run-out aid

For the needs of proconsumer wind energy, in which turbine rotors with a vertical axis are used, it is necessary to efficiently support the vertical shafts. The shafts are subjected to considerable constant loads resulting from the sum of the rotor weights,

the shaft itself of considerable length and weight, and all elements mounted on the shaft.

The nature of the proconsumer wind power plant operation requires frequent start-ups and stoppages of the systems, making the operation of the bearing systems difficult. Considerations of environmental protection require high, low-noise bearing running, because these systems most often operate in the immediate vicinity of users' premises. Similar conditions and requirements occur in the case of bearing arrangements of small water power plants, which most often use Pelton or related rotors with a vertical axis of rotation [17, 18].

The concept of shaft bearing arrangements for such applications is illustrated in Fig. 1. The following subassemblies can be distinguished in the bearing assembly: A - main slide bearing with hydrodynamically lubricated ball journal to carry full load in the range of higher rotational speeds, B - rolling bearing supporting start-up and run-out, C - automatic load switching system between A and B bearings depending on the rotational speed, D - bearing pre-adjustment system, E - stabilizing the transverse position of the shaft, auxiliary plain bearing. All components operate with the vertical shaft of the engine room that is made of a section of thick-walled pipe in the raw condition, i.e. without the need to perform machining operations on it, which significantly simplifies the construction of the engine room and significantly reduces costs. The elements fixed on the tubular shaft, including the turbine rotor and power generator drive components, are mounted in place by means of series-produced snap rings. Such connections enable the transmission of significant torques and longitudinal forces in a backlash-free way with easy adjustment of the position of the elements in relation to the shaft.

On the shaft 1, the spherical journal bearing 3 and the load switching support sleeve 4 are mounted with the use of clamping rings. The spherical pin 3 cooperates with the sleeve (support) 5 when immersed in the lubricating liquid 6 closed in the lubricating space 6 and enclosed in a sheet metal housing 7 (fixed in relation to the base of the plain bearing 8 by hard solder). The rolling bearing 9 aided in starting and run-out of the bearing assembly rests on a spherical support 10 embedded in the ring 11; the position in relation to the base 12 is controlled by a fine threaded connection with the gasket 26.

When the bearing arrangement is at a standstill, the full thrust load Q is transferred by the supporting rolling bearing 9 and the sliding sleeve 14, that is supported by a compression spring 13 embedded in the support sleeve 4.

In such a situation, the starting of the bearing system takes place with very reduced starting resistances only of the rolling bearing, as there is a

predetermined initial clearance in the slide bearing.

When the rotational speed increases after such a facilitated start-up, the automatic load switching system starts to operate from the auxiliary rolling bearing 9 to the main slide bearing, in which the conditions for full hydrodynamic lubrication have already occurred. Smooth switching of the load takes place as a result of the action of increasing centrifugal force acting on inertial weights 16 closed in housings 15. The housings 15 are engaged by means of thread connection with the control levers 20 mounted on the axles 18. The control levers 20, preferably in the number of 3, evenly seated in the recesses of the supporting sleeve 4, generate the lift of the sliding sleeve 14 upwards, as a result of which the bearing load is gradually released 9. When the load is completely removed, the bearing stops and the full radial thrust load, Q is transferred by the main plain bearing thanks to its spherical shape; there is no transverse loads generated by the wind pressure to the turbine rotor of the power plant.

During run-out when the speed is gradually reduced, the au-

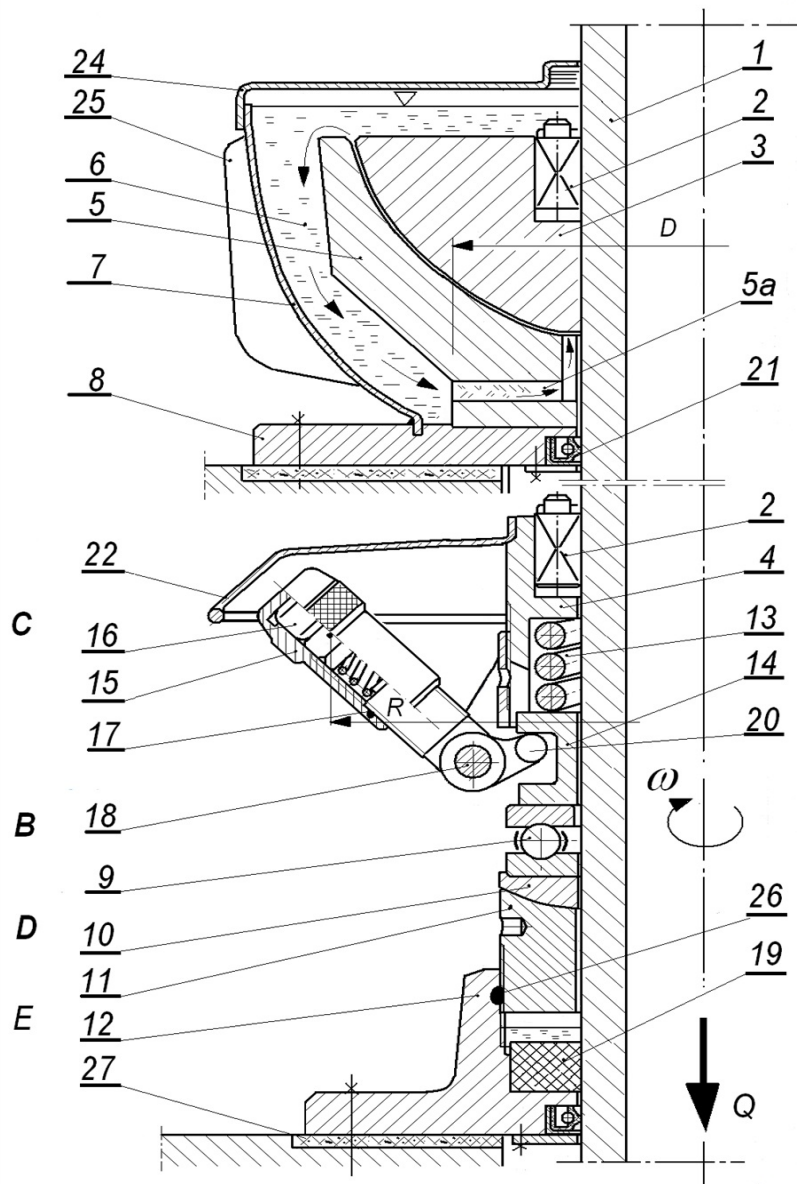


Fig. 1. Plain bearing arrangement with rolling start and run-out assistance

automatic load changeover operates in the opposite direction. The plain bearing is then smoothly relieved with the load being transferred to the supporting rolling bearing, which is gradually engaged by the sliding sleeve 14. In the final phase of run-out, only the rolling bearing operates until it stops. After stopping, the system is fully ready for start-up, even immediately. The described start-up and run-down process shows that the main plain bearing operates only under full liquid lubrication conditions and is protected against harmful tribological start-up processes, especially when running out under full load.

The automatic load switching system allows a wide range of speed control at which the load is switched. It is obtained initially by selecting the number and mass of inertial weights and more precisely by turning the fittings 15, as a result of which the radius R of the rotating of the mass S of the weights 16 changes. The weights 16, depending on the needs can be made of materials of different density, e.g. of lead or copper.

Turning the sleeve 11 performs the initial adjustment of the plain bearing clearance. The fine thread of the sleeve 11 enables a very precise adjustment of the bearing clearance.

During the operation of the plain bearing, intensive circulation of the lubricant occurs, as illustrated by the arrows in Fig. 1. The lubrication efficiency of the spherical pin is increased by spiral or radial grooves made on its sliding surface. These grooves additionally have appropriately formed wedge cuts, facilitating the formation of many unit-lubricating wedges. In addition to increasing the lubrication efficiency, these grooves act as the blades of a centrifugal vortex pump and intensify the circulation of the lubricant. This ensures the efficient dissipation of the heat generated in the slide bearing; the heat is absorbed by the sheet metal casing 7 and discharged to the environment by convection and radiation assisted by cooling ribs 25.

In this situation, the natural cooling of the bearing is fully sufficient. After cooling, the lubricant returns to the entrance through the openings 5a, which is favoured by the suction effect of the lubricating grooves in the rotating journal.

The described bearing of the wind turbine shaft is characterized by low starting resistance, and enables the power plant to operate at a significantly reduced wind speed. A special feature of the system is a very long service life, resulting from the operation of the main plain bearing only under conditions of full hydrodynamic lubrication. There is practically no wear and the supporting rolling bearing works for short periods of time and is at rest for the rest of the time.

A particularly advantageous feature in proconsumer applications is the high low-noise running of the bearings. A rolling bearing operates at a reduced rotational speed for a relatively short time, while an oil-lubricated plain bearing is, by its nature, practically noiseless. The nature of the operation of the slide bearing allows the use of a lubricant with a much lower viscosity, which additionally serves to improve energy efficiency, thanks to the reduction of heat generation as a result of the movement of the lubricating liquid.

It is possible to use a water emulsion and even water for lubrication. This is favoured by a large bearing surface and a large di-

ameter D of the cooperation zone, hence high sliding speeds. The resulting reduced average contact pressures, high sliding speeds, and in particular the nature of the operation of the slide bearing allow for the compensation of low viscosity of the emulsion or the water itself.

The use of water as a lubricant makes the bearing completely immune to fire hazards.

The described features are particularly desirable when used for bearing the shafts of a proconsumer-type wind or water power plant. The bearing can operate in sub-zero temperatures.

The shape of the container 7 for the lubricating liquid protects it against frost damage, and the possible ice layer between the pin and the pan does not significantly change the starting resistance when the water freezes (see ice skates), moreover, it quickly melts during operation.

Radial plain bearings with rolling start and run-out assistance

Radial plain bearing with liquid lubrication, adapted as the bearing of the shaft of a high-speed rotating machine, is shown in Fig. 2. Due to the nature of the work associated with frequent starts, it was desirable to use rolling start and run-out support.

With the journal mounted at the end of shaft 1 2 cooperates the sleeve with a sliding bushing 3. The sleeve 2 is fixed by the tilt with edge support in the tubular housing 4 and is fixed longitudinally with Seger rings 16.

Covers 15 and 17 with appropriate rotary seals 18 close the lubrication space of the plain bearing. A frame 5 with a fixed journal 5a is attached to a special cover 15, on which a rolling needle bearing 6 is mounted, supported longitudinally with Seger rings 7 and 8. Four clamps are periodically frictionally coupled to the roller bearing 6 segments 9 with a sliding fit in the holes made in the recess of the shaft end 1 (see section A-A - fig. 2).

When the stop of the system, the segment clamps 9 are pressed against the outer ring of the rolling bearing 6 by means of springs 10, the preload of which is regulated by screw plugs 11 with fine thread.

By correspondingly tightening /loosening the three set screws 14 at the loosened screw connections 20, the fixed pin 5a is also displaced transversely so that, via the rolling bearing 6, segment clamps 9, springs 10 and plugs 11, the pin 5a takes a position as close as possible coaxial to the shaft 1. Then the journal of bearing is raised above the sliding surface of the sleeve 3 by an amount corresponding to half the clearance in the plain bearing.

The plain bearing is then fully relieved and the rolling bearing carries the full load.

In practice, a sign of this may be the occurrence of only a slight shaft rotation resistance resulting from the resistance to movement of the rolling bearing itself. This adjustment is the best-done before filling the slide bearings with lubricant.

After reaching the aforementioned position of the journal 5a in relation to the shaft 1 axis, the threaded connection 20 must be tightened firmly in order to fix the permanent positions of both pins through the friction insert 13. This operation is performed

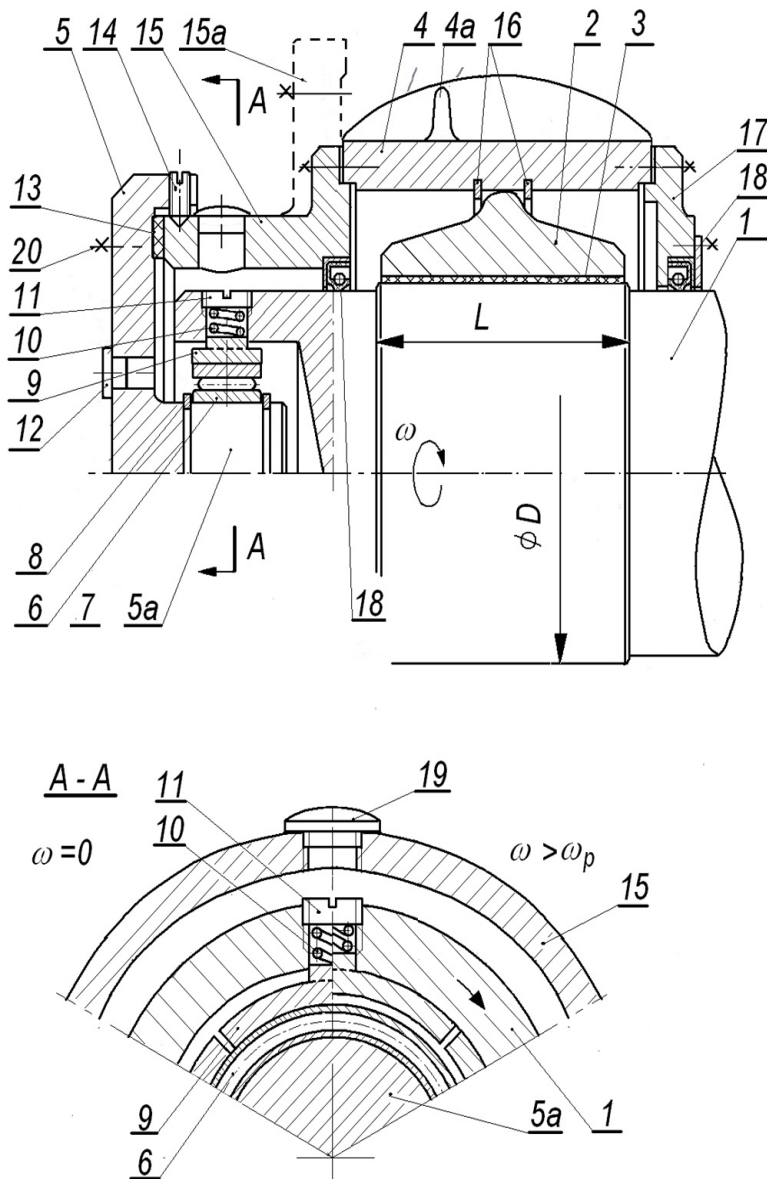


Fig. 2. Axial cross-section of journal bearing with the rolling aided start-up and run-out

once, whereby the space of the slide bearing should be filled with the lubricating liquid up to the level of the bearing shell 3 with an appropriate reserve.

Such adjustment causes, that, the star of the bearing takes place with significantly reduced resistance to movement, only the rolling bearing, because the slide bearing is completely relieved.

After the easier start-up, as the rotational speed of the shaft increases, the centrifugal force acting on the segment clamps causes additional deflection of the springs 10; the rolling bearing is smoothly relieved, and the relief is successively transferred to the slide bearing, in which a sufficiently high sliding speed has already occurred to enable the hydrodynamic lubrication effect. During the transitional period, both bearings operate with a smoothly changing proportion of the load distribution. When the supporting rolling bearing is unloaded, it stops. This can be easily checked through a transparent sight-glass 12. On the A-A section

(Fig. 2), the left side shows the position of the segment clamps at rest and in the first phase of the start-up, the right side shows the position of the segment clamps after full start-up, when the angular speed ω is regulated by switching speed ω_p . With full movement, the segment clamps rest against the inner surface of the shaft recess, which eliminates the possibility of generating vibrations caused by imbalance.

During coast-down, when the rotational speed of the automatic changeover system decreases, the loads act automatically in the opposite direction. As a result, the run-out to a stop is only carried out with the load on the supporting rolling bearing. The required switching speed is determined by simultaneously tightening/loosening the plugs 11 after loosening the plugs 19. As the lubricant in the slide bearing does not provide hydrodynamic lubrication at start-up, it becomes possible to use agents with a much lower viscosity, e.g. water, as a lubricant in the bearing and oil-water emulsions. This is to reduce heat generation and to take advantage of natural cooling. The heat dissipation to the environment is facilitated by the ribbing 4a around the entire circumference of the tubular body 4, especially in its lower part, filled with lubricant. To facilitate heat dissipation in this part of the fuselage, its suspension can be used with the use of a reinforced collar 15.

In addition to all the previously described advantages such as long service life, ease of starting, increased quiet running and improved energy efficiency, the bearing also has a very important feature in many applications. Appropriate regulation allows for obtaining the stability of the axis position of the entire bearing system in the full range of rotational speeds, which is particularly desirable in many rotating

machines. This allows for the reduction of clearances in the vane system of rotating machines in relation to the position of the fixed steering systems. This increases the energy efficiency of a range of rotating machinery, including gas turbines and high-speed rotor gas compressors.

Summary

Hybrid plain bearings with speed-activated rolling start and run-out aid can overcome the difficulties that arise in the case of the bearings of shafts operating under constant load and exposed to frequent starts and stops.

The article presents two selected concepts of bearing arrangements that can be adapted to various applications in mechanical engineering.

Plain bearings equipped with an automatic system of load

switching to supporting rolling bearings during starting and run-out are characterized by increased service life, reduced starting resistance and increased overall energy efficiency. They allow the use of lubricants of much lower viscosity, including oil-water and water emulsions, and are especially intended for high-speed mechanical systems as well as systems with high variability of rotational speeds in operation. The use of bearings of the described structure allows achieving many technical and economic effects, including ecological values and increased safety of use.

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