

¹ Katedra Materiałów Inżynierskich i Biomedycznych – RMT1,
 Wydział Mechaniczny Technologiczny, Politechnika Śląska,
 ul. Konarskiego 18a, 44-100 Gliwice, Polska

^{2*} Politechnika Łódzka
 Corresponding author: stanislaw.strzelecki@p.lodz.pl

THE CONCEPT OF A PROCONSUMER HYDRO POWER PLANT WITH A SPECIAL BEARING FOR THE MAIN SHAFT

KONCEPCJA PROSUMENCKIEJ SIŁOWNI WODNEJ ZE SPECJALNYM ŁOŻYSKOWANIEM WAŁU GŁÓWNEGO

Summary: This paper presents the idea of economical, proconsumer hydro power unit. The described hydro power unit allows the generating of electric energy for own needs. However, the overproduction of power can be supplied to the state energy system. The hydropower units of small output that use the local rivers and creeks should additionally support the operation of wind power units. The design of such units should consider such restriction as, among others, cyclic operation that is characterized by often starts and stops.

Proconsumer hydropower units have to assure a fast start, respective energy efficiency and a very high durability. These features can be obtained by means of proper design of the journal bearing of turbine main shaft. Hybrid bearing system connecting the journal bearing with the rolling bearing assures the decrease in the start power losses, good durability and reliability of proposed system of hydropower unit. Very important feature of this system is the application of the rolling bearing during the operation. Such bearing allows

the decrease in the start time and protects against an insufficient load capacity of lubricating oil film. It is possible to apply the emulsions oil-water as well as clean water as lubricant, too.

Keywords: substrates, proconsumer hydropower unit, combined rolling-journal bearing system

Streszczenie: Artykuł przedstawia koncepcję ekonomicznej, prosumenckiej siłowni wodnej. Omówiona energetykę prosumencka pozwala użytkownikom na wytwarzanie energii elektrycznej na własne potrzeby. Przewidziano możliwość przekazywania nadmiaru energii do krajowej sieci energetycznej.

Uzupełnieniem wiatrowej energetyki prosumenckiej może być wykorzystanie małych siłowni wodnych wykorzystujących lokalne zasoby rzek i strumieni. Konstrukcja siłowni wodnych dla indywidualnych potrzeb uwzględni szereg ograniczeń w tym okresową pracę charakteryzującą się częstymi rozruchami i zatrzymaniami.

Prosumenckie siłownie wodne muszą zapewniać szybki rozruch, odpowiednią sprawność energetyczną oraz wysoką niezawodność. Cechy te może zapewnić odpowiednie rozwiązanie łożyska ślizgowego wału głównego. Hybrydowy układ łożyskowania łączący łożyskowanie ślizgowe z tocznym zapewnia zmniejszenie oporów rozruchowych, trwałość i niezawodność proponowanego układu siłowni wodnej. Ważną cechą proponowanego rozwiązania konstrukcyjnego jest zastosowanie wspomagającego łożyska tocznego, które automatycznie włączane jest do pracy podczas wybiegu. Łożysko toczne zapewnia zmniejszenie czasu rozruchu i zabezpiecza przed pracą w warunkach niedostatecznej nośności filmu smarowego. Możliwe jest również zastosowanie emulsji olejowo-wodnych i czystej wody.

Słowa kluczowe: prosumencka energetyka wodna, łożyskowanie ślizgowo-toczne

Introduction

Proconsumer energy, where users themselves generate electricity for their own needs, and possibly sell excess energy to the general grid, in Polish conditions, may be based on the use of wind and water energy. Wind conditions in most of the country, except for the coastal zone and hills, conditions are limited, and there are often virtually windless periods [1]. In low winds, when the proconsumer wind turbines stop, the tall "windmills" are still able to work.

A supplement to proconsumer energy can be the use of small water power plants (units) using local resources of rivers and streams. Due to the lowland location, the available drops in local waters are generally small, and there are often water shortages. Hence, the design of hydroelectric power stations for the purposes of individual use must take into account a number of limitations. In particular, small hydropower units can operate

periodically intermittently, which forces frequent start-ups and shutdowns of the systems.

Design solutions of such hydro power units must ensure quick start-up with low starting resistances, good energy efficiency, and high reliability and facilitated ongoing service by the users themselves of energy obtained from a proconsumer installation. The costs of a hydropower unit for individual use, when the investors are direct users, are very important.

The concept of a small hydropower unit operating in conditions of frequent starts and shutdowns

Unlike industrial hydropower, special Kaplan or Francis type turbine rotors cannot be used in proconsumer installations due to the complexity of design and high production costs of rotors for individual conditions. This also applies to the water inlet and drainage channels.

Due to frequent start-ups, typical solutions for hydrodynamic bearing arrangements of shafts with oscillating segments cannot be used, mainly due to the complexity of their structure, high costs and start-up difficulties [2.5].

Under the described conditions, much simpler Pelton type turbine rotors can be used, as well as a specially developed sliding system of radial-axial bearing with liquid lubrication, in which the start-up and overrun are supported by a properly made rolling bearing. In the proposed design solution, it is possible to use many recycled elements, mainly motor vehicles and work machines. It is also necessary to use systems enabling the storage of generated electricity for periods of forced shutdowns of proconsumer hydropower units.

Schematic diagram of a hydropower unit for individual use is shown in Fig. 1.

A simple impeller of the Pelton type 1 is mounted by means of expansion rings on the vertical main shaft 2, suspended on a special transverse-longitudinal bearing 3 with liquid lubrication; the shaft guiding is ensured by a radial bearing 4 with a self-lubricating sleeve. At the upper end of the shaft, two gears, e.g. with toothed belts 5, are mounted to increase the rotational speed of the main shaft. The gears 5 drive generators 6, that can be obtained e.g. from vehicles recycling. The electric current generated by the generators supplies the consumers (e.g. lighting) and charges the accumulator batteries 8 through a typical voltage regulator 7.

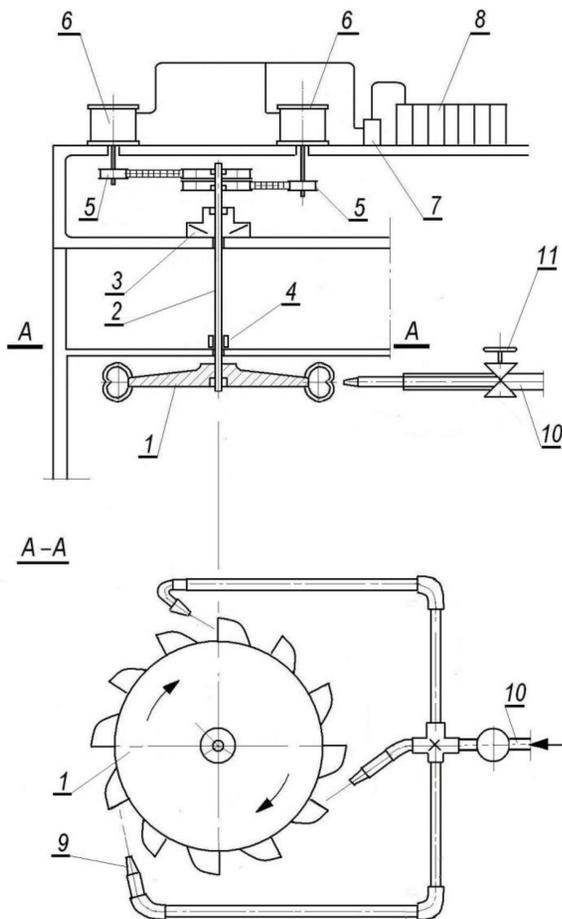


Fig. 1. Layout of the system of a proconsumer hydropower unit

The turbine rotor 1 is driven by water jets fed by evenly spaced nozzles 9 which are supplied from the central water pipeline 10 through the regulating valve 11. The nozzles 9 and the use of a double drive system of two generators cause that the main shaft is not exposed to significant transverse loads causing bending and transfers twisting moment, only. Suspending the shaft 2 on the bearing 3 as high as possible in a given localization situation eliminates the occurrence of compression longitudinal load in the shaft, which protects the shaft against buckling. The shaft can be made of a section of steel or duralumin pipe in normal manufacturing condition without the need for machining, if all rotating elements on the shaft are fixed with expansion rings (Fig. 2 – fixing the operating sleeve 3). The connections with the use of expanding rings can ensure efficient wedge-free connections, well transferring torque and longitudinal forces. They enable easy adjustment of the position of each of the joined elements along the shaft length, and facilitate the assembly of the gym system by the users themselves. Instead of a double drive system of generators, it is possible to use a toothed gear, e.g. planetary, with a coaxial input and output. The use of vehicle-type generators, in the event of the need to supply devices with mains voltage, requires the inclusion of a typical 12/24 V DC to 230 V AC mains voltage converter in the system.

Vehicle and machine accumulator batteries, which are used periodically by their nature, can be used as accumulators for storing the energy during the periods when the engine room is switched off. This applies, exemplary, to batteries for agricultural tractors and combine harvesters and others. These batteries left in vehicles and working machines require periodic recharging with electric current, especially in the period of the greatest energy deficit. Using them in the proposed energy storage plant will additionally increase their durability.

Wheels and gears with toothed belts used to drive generators may, like generators, come from recycling vehicles. This significantly facilitates the design of a proconsumer power unit and significantly reduces investment costs.

The water supply piping 10 from the upper reservoir can be made of conventional plumbing components.

The Pelton-type turbine rotor can be in the form of a disc on the circumference, which is mounted with evenly spaced blades in the form of dish-shaped elements pressed from sheet metal.

It is also possible to make the rotor disc, e.g. from tantalite with blades made of hard plastic and bolted connections to the disc, or in the form of a monolithic cast of Al-Mg alloy.

Axial and radial bearing of the main shaft in a small exposed water power plant for frequent start-up and shutdown periods

In the described proconsumer hydropower unit the particular role fulfils the special journal bearing with fluid lubrication. Additional roiling bearing, operating during the starts and slows down of the unit supports the start of this bearing; the design of this bearing presents Fig. 2.

The operating bush 3, by means of conical expansion rings 2, is mounted on the shaft 1 that is manufactured without offsets. The bush 3 is designed as the journal of the sliding axial radial bearing and it cooperates with the support 4 that is fully flooded in the lubricant 5 closed in the housing 6. On the supporting, non-movable bush 7 it is fixed the added rolling bearing 8; the coupling ring 9 rests on this bearing. In the rest state of bearing, the travelling bush 10 rests on the coupling ring 9 but travelling bush 10 is pressed by the set of deflected arm 12 that are fixed on the axes 13 (cross-section A-A, Fig. 3).

During the start up of unit, the full load of bearing 6 transmits the supporting rolling bearing 8. At the increase in the rotational speed of the system and the increase in centrifugal force the movable arms 12 act on the loading elements 12 and they cause the gradual deflection of springs 15. It causes that the load applied to the sliding bush 10 decreases and the rolling bearing 8 is freed gradually from the load. Hence, the journal bearing is smoothly loaded because the fluid lubrication conditions just occurred.

Both types of bearings operate during the transitional period. Gradually, the sliding sleeve 10 is lifted up by the tensioned spring 11, the ends of which are engaged in the recesses of the operating sleeve 3 and the sliding sleeve 10. The rolling bearing then comes to a complete standstill, and the full thrust load Q and possible transverse load V is transmitted by the plain bearing under liquid lubrication conditions. The transverse load is transferred due to the conical shape of the sliding surface at the β angle. In addition, this ensures lateral stabilization of the shaft 1 and a favourable extension of the lubricant flow path between the sliding surfaces of the sleeve 3 and the support 4. The lubricant flows from the center towards the outside due to the centrifugal force associated with the rotation of the operating sleeve 3 carrying with it the heat generated in the journal bearing. After cooling, the lubricant returns to the input side of the bearing, as illustrated by the arrows in Fig. 2.

The circulation of the lubricant is favoured by oblique holes 4a and the gravitational change in density due to the heat transferred from the cooled bed 4.

The described method of operation of the entire system causes that the starting resistances are significantly reduced thanks to the rolling bearing and the slide bearing is protected against operational conditions of the lack of fluid friction. When the hydropower unit is shut down, the bearing system continues to run in reverse order, so that there is never any direct friction between the components in the journal bearing. The level of rotational speed at which automatic switching of the operation of both types of bearings takes place is controlled by the mass of the weights 12a and the preload of the springs 15 by turning the threaded plugs 16. The moment of switching the operation of the bearings can be observed through the transparent sight-glass 17 after illumination with a strobe lamp. In practice, it is sufficient to be guided by the clearly audible change in noise generated by the rolling bearing in relation to the practically silent operation of the journal bearing with liquid lubrication. Lubricant filler 20 integrated with the vent and the level indicator completes the entire bearing system.

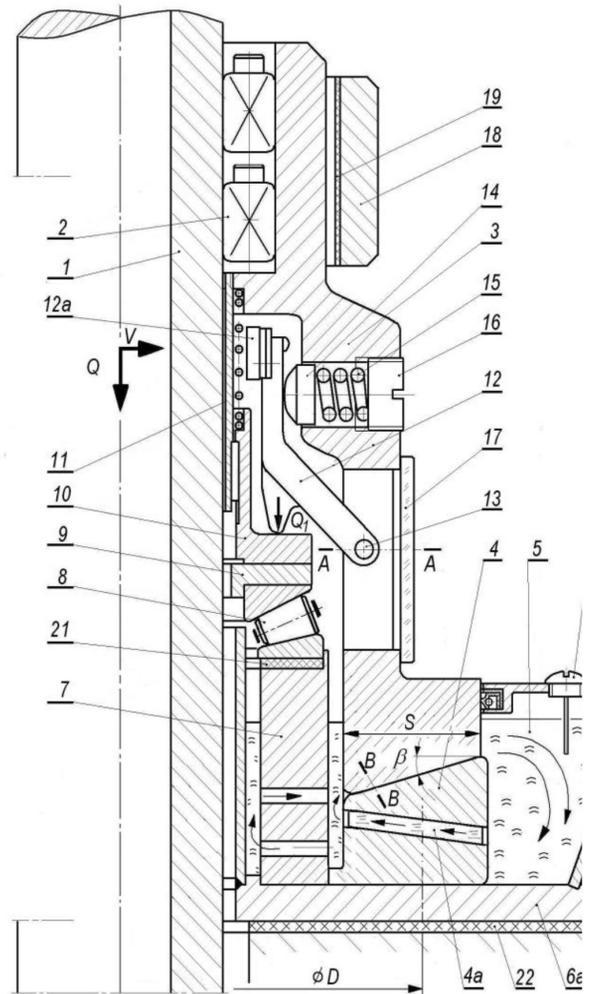


Fig. 2. Design of the axial-radial solution of main shaft of small hydropower unit

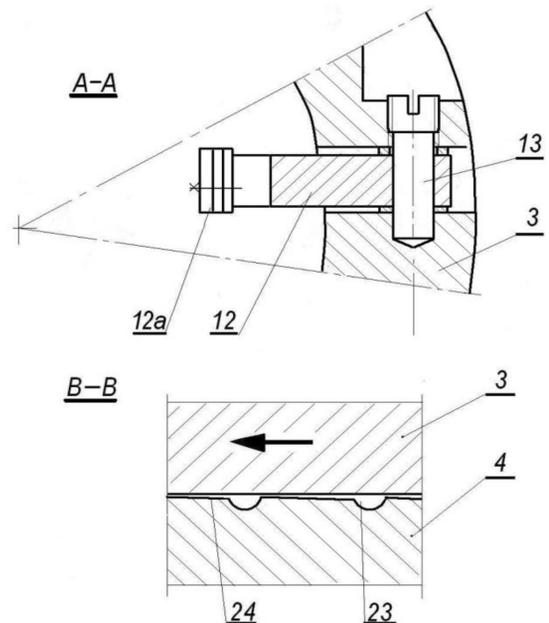


Fig. 3. Axial-radial bearing of the main shaft of small hydropower unit; (cross-section B-B, see Fig. 3)

If it is necessary to stop the bearing operation, a simple shoe brake 18 with a high-friction lining 19 can be used.

Vibration and noise reduction is ensured by polymer shims 21 and 22.

The bearing design allows for a larger bearing surface in the form of an increased width S and an average diameter D , which additionally increases the average speed of sliding in the journal bearing. Thanks to this, it is possible to use a lubricant of much lower viscosity for lubrication, the more so as it does not have to be selected due to the start-up [4]. This serves to reduce the resistance to the movement in the bearing and increasing the overall energy efficiency of the hydropower unit. Spiral grooves 23 and lubricating wedges 24 are made on the sliding surface, preferably a support, to increase the efficiency of lubricating film formation and cooling the friction zone (section B-B, Fig. 3).

The presented bearing of the main of shaft hydro power unit is characterized by a particularly high service life, as the supporting rolling bearing works for short periods of operation only at start-up and slow-down, while the journal bearing operates only under full hydrodynamic lubrication conditions, thus practically wear-free.

After the rotational speed control is performed, at which the operation of both types of bearings is switched, and the position of the water nozzles is determined, the current operation of the hydro power unit is limited to opening/closing the main water supply valve 11 from the upper reservoir of the power plant.

Summing up

The described concept of a proconsumer small hydropower unit is characterized by simple design and reduced investment costs thanks to the use of largely recycled components.

The design of a small hydropower unit can be implemented with a large participation of direct users of the generated electricity. The system enables to achieve high technical and economic effects in the form of network energy savings. It is especially designed for the applications where the availability of energy is limited. Hybrid bearing of the main shaft of the unit ensures easy start-up and high-energy efficiency with a particularly long service life.

References

- [1] Lubońska Z., Wind farms in the power system. WNT. W-wa. 2006. in Polish)
- [2] Wasilczuk M., Large-size Hydrodynamic Thrust Bearings. Scientific Publisher ITE. 2012. Radom.(in Polish)
- [3] Dąbrowski Z., Neyman A., Wasilczuk M., Axial Bearings - Contemporary operational problems. Machine Operation. Issues. Book 3 (139). 2004. in Polish)
- [4] Lawrowski Z., Plain bearings. Ed. Wrocław University of Science and Technology. 2001. Wrocław. (in Polish).

Article reviewed

Received: 06.03.2022 r./Accepted: 20.03.2022 r.

korozja kosztuje! *

***) straty korozyjne szacuje się na 3-6% PKB**



na życzenie wysyłamy bezpłatny
egzemplarz okazowy:
redakcja@ochronapredkorozja.pl

Czasopismo
„Ochrona przed Korozją”
– forum wymiany wiedzy
i doświadczeń na temat
ochrony materiałów
przed skutkami korozji

www.ochronapredkorozja.pl
www.sigma-not.pl