ANALYSIS OF HYDROPOWER PLANTS OPERATING EFFICIENTLY IN LOW-PRESSURE WATERCOURSES

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ABSTRACT:

This paper focuses on the analysis of hydropower plants operating efficiently in low-pressure watercourses. The study examines the challenges and opportunities associated with harnessing energy from watercourses with relatively low flow rates and pressure. It reviews different technologies and strategies employed to optimize energy production in such conditions, including the use of small-scale turbines, low-head systems, and advanced control mechanisms. The paper highlights case studies of successful low-pressure hydropower installations and discusses the environmental and economic benefits of utilizing these underused water resources. Furthermore, it provides insights into the technical modifications and design improvements that can enhance the efficiency of hydropower plants in low-pressure environments.

Introduction. Today, in order to meet the demand for electricity, there is a need for an environmentally friendly and reliable renewable energy source, with hydropower playing a key role. In hydropower, a hydro turbine occupies a special place in converting the mechanical energy of flowing water into electrical energy. It is well known that the efficiency of hydraulic turbines largely depends on the performance of their impellers. Hydro turbines are classified into active, reactive, Archimedes screws, and water wheels [1].

Figure 1 presents a graph showing the application areas of various types of turbines, which should be considered when aiming to improve the output power and economic performance of hydropower under very low pressure conditions. It can be seen from the graph that water wheels are widely used for efficient operation in low-flow water sources such as rivers and irrigation channels [2].

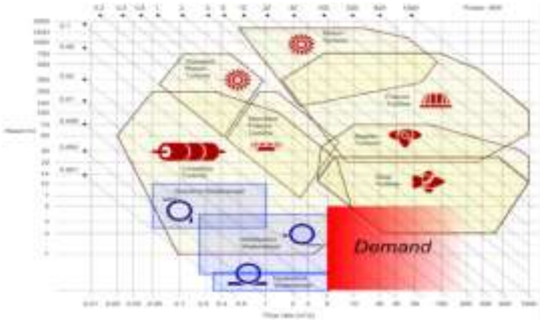

Fig. 1. Application area of various types of turbines

Let's analyze research on water wheels that have been developed and operated both globally and in our republic.

Figure 2 shows an experimental study of a micro hydropower plant with a vertical axis adapted to pumping units. In this case, the outer diameter of the turbine is 0.3 m, the number of blades is 6, the angle of installation of the blades is 55°, the diameter of the guide device is 1 m, the number of guide surfaces is 16. As a result of practical tests, a micro hydropower station with a vertical axis with a capacity of 3 kW was developed with low-pressure watercourses with a water flow pressure of 1m and a water flow rate of 0.25 m3/s, and the production of 19500 kW of electricity per year was achieved. A patent for the invention of the Ministry of Justice of the Republic of Uzbekistan "Vertical axis hydroelectric device, IAP 07462, dated 08/17/2023" was obtained for the developed installation [3-5].

Fig. 2. - Experimental installation of a microelectric power plant with a vertical axis

In Fig.3. The developed micro hydropower plant with a floating base in the form of pontoons is presented, which serve to eliminate problems with changes in water level and at the same time as guides. The blades of the water wheel are mounted at an optimal angle of inclination to reduce the resistance at the outlet of the water. As a result, this design makes it possible to increase the efficiency of a hydropower plant by 1.5-2% when operating in low-pressure watercourses. The conditions for achieving the maximum efficiency of n=32% of a hydropower plant have been determined, according to which the water flow rate is Q=0.46 m3, the water flow rate is V=4 m/s, the optimal angle of inclination of the blades, which allows increasing the force interacting with the front of the blade and reducing the force preventing the movement of the water wheel and interacting with the reverse side of the blade is β=30° [6].

Fig. 3. Conducting an experiment of a developed micro hydropower plant

Lashofer et al. studied a hydraulic turbine of the Archimedes screw type, which rotates around an axis inclined at an angle of 22°–35° to the horizontal and has been used as a hydraulic turbine over the past two decades (Fig. 4). The diameter of Archimedes screws ranges from 0.6 to 4 m, with pressure drops from 1.2 to 8 m and water flows from 0.3 to 8.0 m^3/s. According to the analysis, the rotation speed of Archimedes screws can reach 20–80 rpm, with an installed power of 3–300 kW and an efficiency of 70–90% [7].

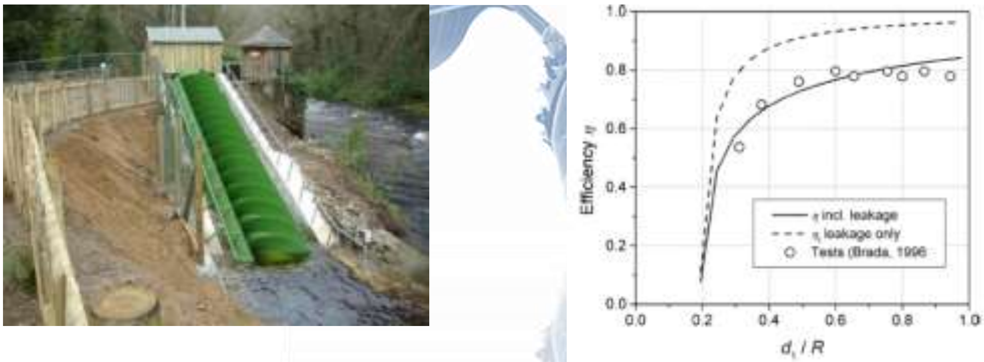

Fig. 4. (a) External view and (b) Energy characteristics of Archimedes screws

Turnock et al., in their research, developed a microhydroelectric power plant with a floating base designed to operate in low-current watercourses [8]. The efficiency of this design (Fig. 5) remains unchanged despite variations in water level due to the use of a floating base.

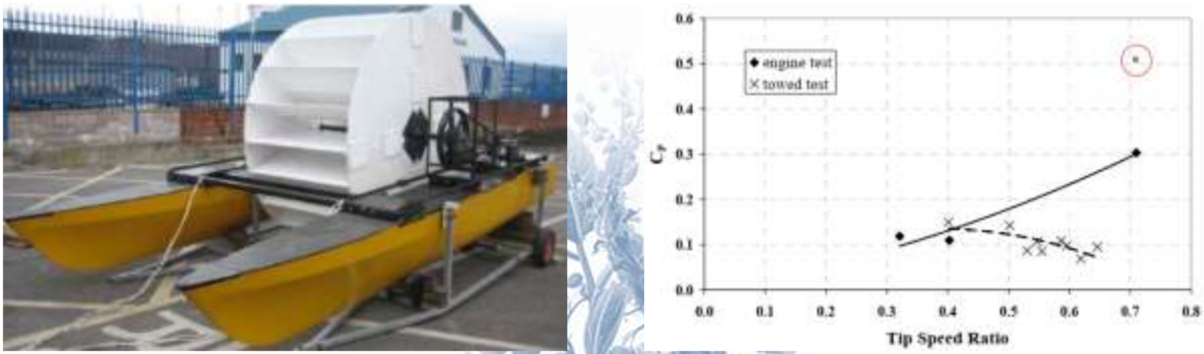

Fig. 5. (a) External view and (b) Graph of the dependence of the water utilization coefficient and the speed coefficient of the floating hydropower system with a water wheel developed by S.R. Turnock.

J. R. Gandhi et al., in their study, presented a hydropower plant (Fig. 6) featuring a water wheel mounted on a floating base and equipped with a slow-speed generator designed for efficient operation in low-pressure watercourses [9].

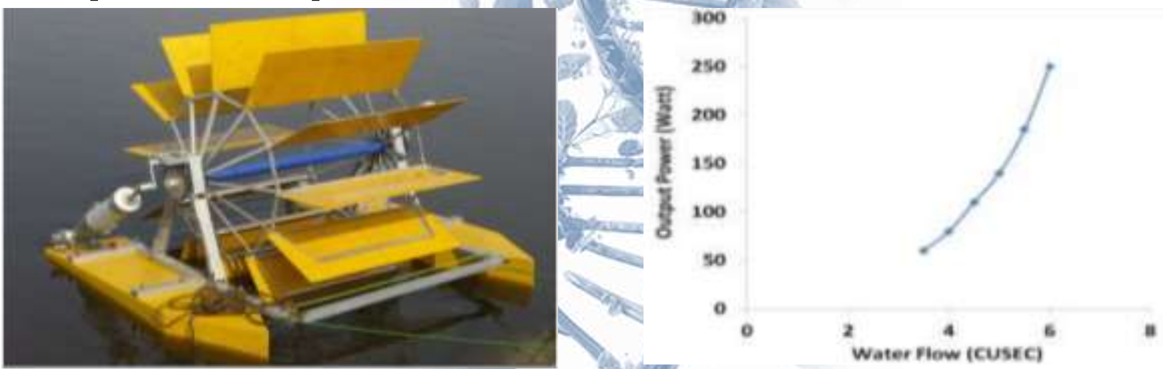

Fig. 6. Design of the micro hydropower plant developed by J.R. Gandhi.

Conclusion. A theoretical study found that water wheels with a floating base are widely used for the efficient operation of hydropower plants in low-pressure watercourses with a water flow rate of 1–4 m/s. In contrast, Archimedes screws have several disadvantages related to tilt and drop. Despite the efficient operation of the aforementioned water wheels in low-pressure watercourses, these hydropower plants still have disadvantages requiring improvements in the straight shape of the blades, as a result of which it is possible to achieve an increase in the efficiency of these plants by reducing the drag coefficient.

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