Development of Pump Turbine for Seawater Pumped-Storage Power Plant

Tetsuo Fujihara
Haruo Imano
Katsuhiro Oshima

ABSTRACT: Acquiring a pumped-storage power generation site utilizing river water recently faces several restrictions due to environmental assessment. On the other hand, there are many sites favorable for constructing a pumped-storage power plant utilizing seawater in Japan, which is surrounded by the sea. Seawater pumped-storage power plants have several advantages such as lower civil construction cost and lower power distribution cost due to their proximity to nuclear or steam turbine power plants. Seawater pump turbines are used under the condition where the corrosion environment is noticeably severe, rather than conventional river water pump turbines. In addition, pump turbines have many narrow spaces between parts and their major parts are embedded, so that it would be very difficult to apply proper corrosion prevention measures. This problem cannot be solved only by conventional corrosion-preventive engineering. The Agency of Natural Resources and Energy of the Ministry of International Trade and Industry entrusted Electric Power Development Co., Ltd. with the construction of the world's first seawater pumped-storage pilot plant in Kunigami Village in Okinawa Prefecture, Japan, to execute verification tests for five years after the completion of construction in March, 1999. This paper will deal with materials, structure, and corrosion-preventive engineering of the pump turbine for the seawater pumped-storage power plant.

INTRODUCTION

FOR the seawater pumped-storage power plant, the Agency of Natural Resources and Energy of the Ministry of International Trade and Industry entrusted Electric Power Development Co., Ltd. with the survey and development program "Verification tests and Investigation for seawater pumped-storage techniques," and starting in 1981 the research work was carried out for making the seawater pumped-storage practical.

In addition, the systematic verification test was conducted since 1984, to investigate the corrosion characteristics of metallic materials, effect of corrosion-preventive paint, cathodic protection, adhesion characteristic of marine organisms, and other problems under the simulated running conditions of the actual machine. The verification test was executed by using three model pump turbines which are made of the same materials as those of the actual machine and are geometrically similar, in the middle district of Okinawa Island.[1)]

We have recently designed and manufactured a pump turbine for the pilot plant based on the results of the above-mentioned test. Fig. 1 shows a bird's eye view of the pilot plant, whose plan and sectional view are shown in Figs. 2 and 3, respectively. This paper will present an outline of applied materials, paint, corrosion preventive method, and countermeasures for preventing the adhesion of marine organisms.

STRUCTURAL FEATURES OF PUMP TURBINE

Table 1 shows the specifications of the pump turbine for seawater pumped-storage, and Fig. 4 shows the sectional view of the pump turbine and appearance of the pump turbine shop assembly.

The pump turbine for seawater pumped-storage is constructed so that the runner can be taken out from below for easy disassembly and reassembly. The water passage surface is simplified to guard against crevice corrosion as much as possible. The corrosion preventive structure of individual parts is described below.

Main shaft sealing box

Ceramics has been applied to the sealing element. Water drain pipes are provided up to the drain pit to prevent water leakage on the head cover.

Wicket gate stem bearing assembly

The wicket gate stem packing was doubled to prevent seawater from entering into the bearing housing even if seawater should leak from the upstream

Fig. 1—Bird's-Eye View of Pilot Seawater Pumped-storage Power Plant, Okinawa Pref. in Japan.
The octagonal shape shows the upper dam. The sea is the lower reservoir. The outlet of the tailrace is surrounded by tetra-pods for protection from waves.

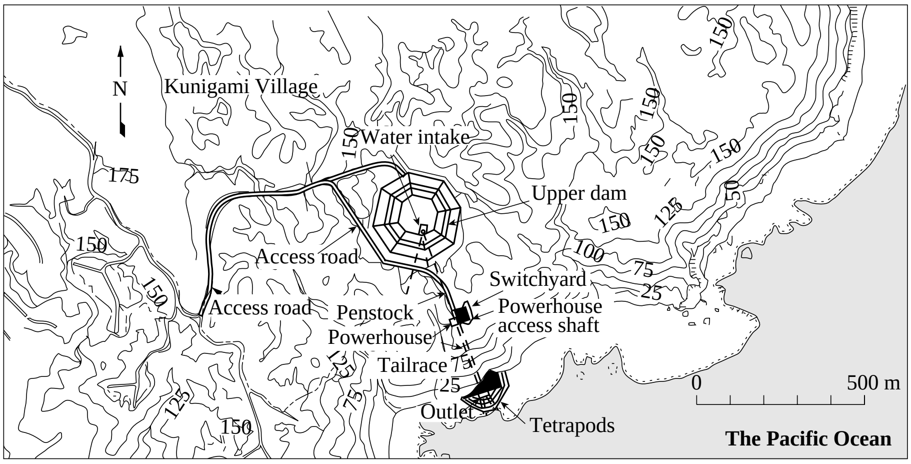


Fig. 2—Plan View of Seawater Pumped-storage Power Plant. The octagon-shaped upper dam is located 500 m away from seashore at the elevation of 150 m.

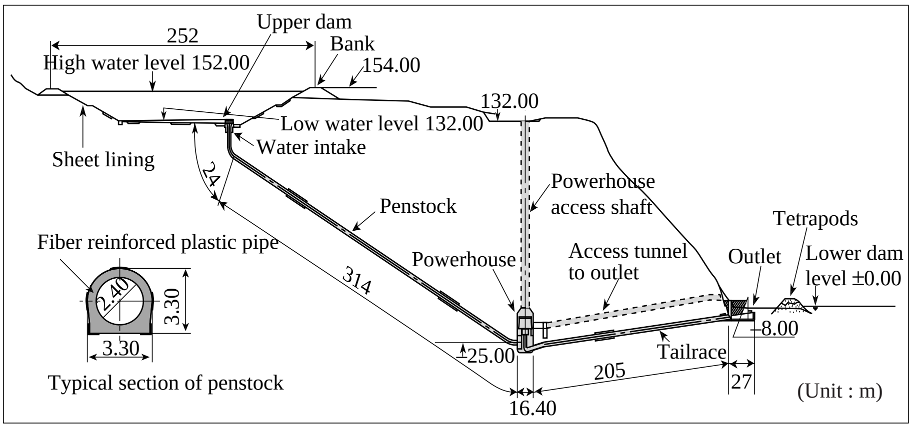


Fig. 3—Sectional View of Waterways. The underground powerhouse is situated 150 m below ground level.

side packing. The wicket gate stem bearing can be replaced without disassembling the head cover and the discharge ring.

Wicket gate seal packing

The wicket gates are generally furnished with seal packings at the top and bottom faces to guard against leakage water from the spiral case to the runner chamber. The seal packing is usually held by a separate packing gland. The rubber packing of the seawater pump turbine is, however, jointed to a stainless steel base by rubber moulding process as shown in Fig. 4 to reduce crevices. In addition, upper and lower facing plates are integrated into the head cover and the discharge ring to decrease crevice corrosion caused

TABLE 1. Specification of the Pump Turbine for Seawater Pumped-Storage

Turbine operation		Pump operation	
Max. output	31,400 kW	Max. input	31,800 kW
Max. net head	141 m	Dynamic head	160 m
Max. discharge	26 m^3/s	Discharge	20.2 m^3/s
Specific speed	178.2 m-kW	Specific speed	51.4 m-m^3/s
Rotating speed	450±6% r/min		

by the space between the two components, whereas they are tightened by a lot of bolts in the case of conventional pump turbines.

Main shaft and runner

The connection joint between the main shaft and runner is completely sealed by rubber gaskets so as to isolate seawater from the coupling bolts.

MATERIALS AND CORROSION PREVENTIVE METHOD

The materials and corrosion preventive method for parts of the pump turbine were selected by taking both the corrosion resistance of material and the economical evaluation into account. Mild carbon steel which is coated with paint is used for comparatively low-flow-velocity portions, while stainless steel is used for high-flow-velocity portions. In order to prevent corrosion due to paint damage and against crevice corrosion, cathodic protection is used. Since corrosion is accelerated as the flow velocity becomes higher, the cathodic protection is designed to be carried out by an external power source system in order to make the corrosion preventive current adjustable.

Spiral case and stay ring

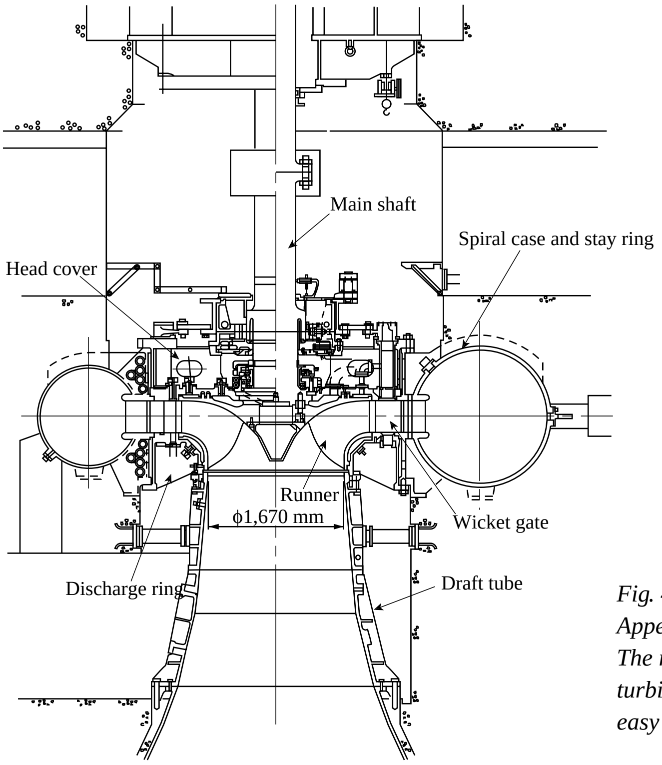
These components are made of rolled steel for welded structures (JIS-SM400A) and water passage surfaces are coated with vinyl-ester-type, extremely thick film paint with glass flakes.

Head cover and discharge ring

Water passage surfaces are made of austenitic stainless steel (JIS-SUS316L) with a low carbon content. Surfaces that do not become wet are made of rolled steel for welded structures (JIS-SM400A) to maintain low costs.

Wicket gate, runner and main shaft

The wicket gate and runner are made of austenitic stainless steel casting (JIS-SCS16A or equivalent) with a low carbon content plus nitrogen which is added to improve the corrosion resistance. The main shaft is provided with a slip ring to provide the corrosion



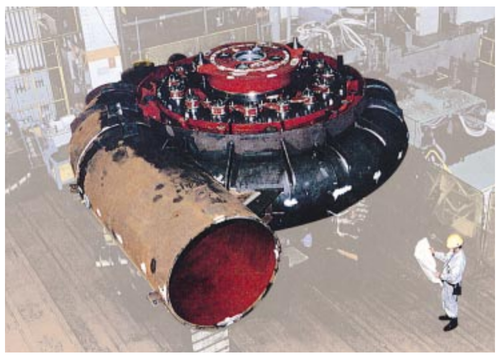


Fig. 4—Sectional View of Pump Turbine and Appearance of Pump Turbine During Shop Assembly.
The runner can be taken out from below, leaving pump turbine main parts and generator motor as they are, for easy maintenance work.

preventive current for cathodic protection. The main shaft is made of stainless steel forging for the pressure vessel (JIS-SUSF316N) containing nitrogen in austenitic group.

Draft tube

The upper part of the upper draft tube liner is made of austenitic stainless steel with a low carbon content (JIS-SUS316L), while the other parts are made of rolled steel for general structures (JIS-SS400) and coated with vinyl-ester-type, extremely thick film paint with glass flakes.

Main shaft sealing box

The seal is made of ceramics. Other parts are made of austenitic stainless steel with a low carbon content (JIS-SUS316L). Since the space between the main shaft and the sealing box is narrow, the sacrifice electrode system is adopted as a corrosion preventive measure.

PREVENTION OF THE ADHESION OF MARINE ORGANISMS

The barnacle is a typical example of marine organisms adhering to the pump turbine, pipings, valves, and auxiliary equipment. Barnacles adhere to substances when the flow velocity is less than approximately 5 m/s, and they adhere most easily when the flow velocity is 1 or 2 m/s. Since the adhesion of barnacles reduces the efficiency of pump turbines and causes clogging of piping and other failures, this problem must be carefully considered with relation to the components where the flow is apt to be stagnant, for example the draft tube, the spiral case, pipings, etc. Barnacles secrete a viscid substance from their body when adhering to the surface of an object. It is generally known that it is difficult for this substance to be fixed to surfaces which repel water. Accordingly, the portion in pump turbine components where the flow is apt to be stagnant should be coated with anti-pollution type dirt-prevention paint which can repel water.

CONCLUSIONS

This paper dealt with the structural features of the pump turbine for seawater pumped-storage, corrosion preventive measures, and measures for preventing the adhesion of marine organisms. When anti-corrosion engineering for seawater pump turbines is established, the limitations on location of pumped-storage power plants are remarkably relaxed, and an increase in the demand for pumped-storage power plants expected.

In closing the paper, authors extend their hearty thanks to the parties concerned in Electric Power Development Co., Ltd. for their guidance in developing the pump turbine for the seawater pumped-storage power plant.

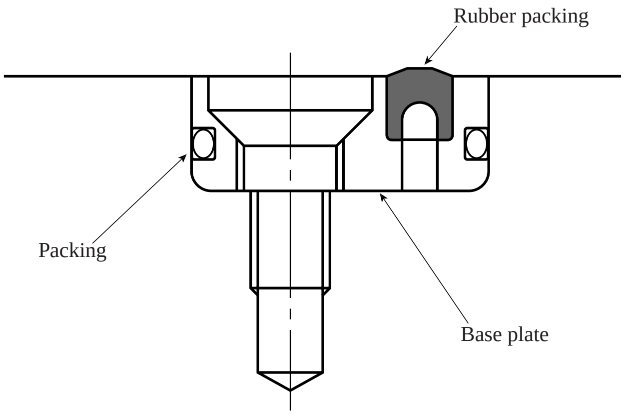


Fig. 5—Structure of Wicket Gate Seal Packing.
To prevent crevice corrosion, the rubber packing and the base plate are jointed together by rubber moulding process.

REFERENCE

(1) F. Osawa et al., “Research and Development of Reversible Pump-Turbine for Sea Water Pumped Storage (Part 1 Evaluation of corrosion resistance of material in sea water),” JSME-ASME International Conference on Power Engineering–93 (1993)

ABOUT THE AUTHORS

Tetsuo Fujihara
Joined Hitachi, Ltd. in 1970. Belongs to the Turbine Design Section at Hitachi Works. Currently working to design turbine plants.
E-mail: fujihara@cm.hitachi.hitachi.co.jp

Haruo Imano
Joined Hitachi, Ltd. in 1959. Belongs to the Hydraulic Machine Design Section at Hitachi Works. Currently working to design water turbines.

Katsuhiro Oshima
Joined Hitachi, Ltd. in 1979. Belongs to the Hydraulic Machine Design Section at Hitachi Works. Currently working to design water turbines. Member of the Japan Society of Mechanical Engineers.
E-mail: k_ooshima@cm.hitachi.hitachi.co.jp