Rehabilitation of Trunnion Assemblies

The failure of a spillway gate in 1995 at Folsom Dam near Sacramento, California focused industry-wide attention on the potential for excessive coefficients of friction in trunnion assemblies. At Priest Rapids Dam on the Columbia River in Eastern Washington State, engineers inspected the dam’s spillway gates and found they had cracked thrust washers in the gates’ trunnion assemblies.

Owned and operated by Public Utility District #2 of Grant County, Priest Rapids Dam has 22 spillway gates that provide flood control and fish passage. Gates at the dam have performed reliably since the late 1950s when Merritt, Chapman, and Scott constructed the dam. The radial gates are 40 feet wide and 52.37 feet tall with a maximum rotating movement of 55 degrees. Each gate has two trunnion assemblies.

An investigation of the gate’s trunnion assemblies at the dam pointed to a materials problem. Laboratory analysis indicated that stress corrosion cracking of the washers’ bronze alloy material was ammonia-induced. The bottom line was a corrosion problem likely precipitated by bird droppings.

As a result of the findings, District engineers and consultants made further investigation of the thrust washers and decided to remove and rehabilitate the trunnion assemblies from each of the spillway gates at the dam. The rehabilitation would involve replacing the bronze-alloy-based thrust washers with thrust washers made of a corrosion-resistant composite material. Since the trunnion bearings also were bronze-alloy-based components, it was deemed prudent to use the opportunity to replace the bearings as well.

“Our objective was to rebuild the assemblies with materials that offered optimum strength and durability so we can minimize any potential for failure,” said George Thompson, the District’s project engineer.

The District is proceeding with the 4-1/2-year rehabilitation project and expects to complete the project in 2005. Working with its contractors and consultants, the District devised an engineering and project approach that addresses many technical challenges and may be a model for other facilities with physical and operational similarities.

Project Challenges

Several aspects of the project at Priest Rapids Dam made trunnion rehabilitation a rigorous undertaking. Overcoming the physical challenges and meeting the technical requirements demanded might, precision and innovation.

“The location of the trunnion assembly in the spillway gate makes the assembly difficult to access and remove,” according to Thompson. “We had to develop a gate positioning procedure to isolate the forces in the spillway gate and restrain them to allow for removal of the trunnion assemblies,” he explained.

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The process involves disconnecting the trunnion assembly from the gate arms, pushing the large gate, which weighs about 96 tons, upstream about 2 inches and then restraining the gate assembly in place until the trunnion was free. The trunnion is extracted by rotating it vertically and lifting it out with a crane. Later, to replace the trunnion, the gate is moved back in place using hydraulic jacks and a series of anchor pads, and the trunnion assembly is reconnected to the trunnion arms.

Another consideration for the project was the crane that would lift the trunnion assemblies from the spillway gates. The estimated weight of a trunnion assembly with rigging is ~7000 pounds (3175 Kilograms). The crane had to meet performance requirements, and its placement had to accommodate traffic that uses the roadway across the dam for access to the Wanapum Indian Village. Placing a mobile crane on the roadway would periodically restrict traffic, and the District wanted to avoid traffic restrictions.

For the trunnion rehabilitation project, the District contracted WHECO a Pasco, Washington-based company specializing in crane repairs, remanufacturing, component upgrades and structural repairs with engineering support. WHECO addressed the crane issues by designing and manufacturing a 5-ton capacity-rated, cantilever gantry crane tailored for the project at Priest Rapids dam. The 4-legged, radio-controlled gantry crane travels with “electric-over-hydraulic” power, rolling up and down the spillway on a set of rails that can be repositioned at each gate. The crane’s footprint is fitted to the dam structure, and the reach of the boom (~60 feet) extends from the top of the spillway to the gate’s trunnion. The crane’s design and capacity makes it a workhorse for the trunnion lifting requirements and for installing needed fixtures such as work platforms and pulling fixtures. Because the gantry crane operates off the roadway, its use provides uninterrupted access to traffic along the dam’s roadway.

The limited construction season was another constraint on the project. From April to October, the District spills water for fish passage as required by the state’s Department of Fish and Wildlife, National Marine Fisheries Service, and Washington Department of Ecology. Consequently, there are only six months during the year (i.e., October through March) when project activities, including annual gate maintenance, can take place at the dam.

Prototype Installation

The project began with a prototype phase to refine procedures for removing and reinstalling the trunnion assemblies at the dam and for disassembling and changing out components at the repair facility. WHECO completed the prototype project with a full rehabilitation of both trunnion assemblies at gate #5.

“We used the prototype project to test and refine the set of procedures developed by Stone & Webster,” said WHECO President Dave Wood. “The prototype provided learning and actual experience for developing efficiencies to meet the project’s tight

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timeline. As a result, we were able to refine highly efficient procedures for work at the dam, and we found ways to streamline repair approaches in collaboration with Orkot, the bearing manufacturer," said Wood.

Field Installation

WHECO extracts the trunnion from the dam's spillway gates according to contract requirements. The District requires that the Contractor work on one gate at a time and that the Contractor loosen or remove flange and web splice plate fasteners on only one trunnion assembly at a time.

Once extracted, the trunnion assemblies are transported to WHECO's repair shop for disassembly and component replacement. For this task, the assembly is placed in a 200-ton horizontal press, and the outer portion is warmed to 150°F. The 16-in-diameter pin is pushed out of the assembly, and the assembly is removed from the press. The bronze-graphite bushing is cut from the trunnion housing, and the housing is then sand blasted and painted with a Wasser three-coat paint system. WHECO technicians machine, grind and polish the stainless steel-cladded pin to a 16 micro inch or better finish. The precision polishing is essential for optimal fit, which allows the pin to rotate freely in the trunnion with minimal friction and wear.

The outside diameter of the pin is measured at eight locations, every 22.5 degrees, at each end of the pin. The inside diameter of the casting, in which the pin and bearing fit, is cleaned and measured at eight inner locations, every 22.5 degrees, at both ends. Those measurements are transmitted to the bearing manufacturer, Orkot Composites, which manufactures and machines the trunnion bearings and thrust washers at its factory in Eugene, Oregon.

Trunnion Bearings and Thrust Washers

The District requires the trunnion bearings and thrust washers to be designed for continuous normal loads, intermittent immersion in water, and suitable clearances between trunnion pins and bearing surfaces in ambient conditions from -20°F to 120°F.

The required normal size specifications for the replacement trunnion bearings is16-in. I.D., 18.25-in. O.D., 29-in. length. The project requires the bearings to support a 4,000 p.s.i. normal load and a 12,000 p.s.i. rated load. Specifications for the thrust washers are for a normal size of 24.25-in. O.D., 16.063-in. I.D., 0.75-in. thickness. The thrust washers require a 1,600 p.s.i. normal load and a 4,800 p.s.i. rated load. Material specified for the trunnion bearings and the thrust washers is a synthetic self-lubricating non-metallic Teflon® polyester composite.

The corrosion-resistant composite bearing material selected for the project is the Orkot® TXMM, which is a polyester fabric reinforced thermoset incorporating a Teflon® bearing surface and solid lubricants for a self-lubricating low friction bearing. The Orkot®

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TXMM material has a compressive strength of 43,500 p.s.i. and a yield of 13,200 p.s.i., which far exceeds contract requirements.

Orkot developed the material specifically for the Hydro industry. The Orkot® TXMM has excellent mechanical strength and wear resistance; it performs with virtually no swell in water and offers superior dimensional stability. In addition to spillway gates, the composite material is used for wicket gate bearings, linkage bearings, operating rings, fish screen bearings, trash rake bearings, and vertical pump shaft bearings.

During prototype construction, it was discovered the trunnion pin and trunnion bore measurements were not consistent at every trunnion. Thus, each casting and pin is individually measured after cleaning, machining, and polishing is complete. When Orkot receives the actual dimensions from WHECO, Orkot engineers run a calculation program to determine the correct size for bearing manufacture. Bearing interference, clearance, temperature and tolerances are taken into consideration. Each bearing is precision machined to match the exact sizes of a specific trunnion pin and trunnion bore. The thrust washers are sized to accommodate the expected difference in pin sizes between gates and are machined in advance of the delivery date.

Individual fitting of the bearing ensures clearances are uniform on all the gates and is a better technical approach than trying to make one size bearing fit all gates. However, the matched fitting takes time, and time is limited by the project’s schedule. The contract specifies that the bearings shall be delivered within seven calendar days after notification of the actual dimensions of the trunnion pin O.D. and the trunnion bore I.D.

“We conquered the challenging production schedule by manufacturing bearing blanks in advance of anticipated delivery dates,” explained Orkot Engineering Manager John Robinson. “When measurements come in, the blanks are ready for machining,” he explained. As a result, delivery runs between one to four calendar days following receipt of hardware dimensions.

When the newly manufactured components are delivered to WHECO, WHECO reassembles the new trunnion bearing using a freeze fit technique. The bearing is submersed in a liquid nitrogen bath for approximately 45 minutes to shrink the bearing through freezing. The frozen bearing is then placed in the casing and allowed to warm up; as it warms it expands for a precision press fit. Prior to inserting the pin, the I.D. of the bushing is lightly coated with a lithium-based grease to aid installation and the initial run. The completely reassembled trunnion with the new thrust washers and bearings is transported back to the dam and installed at the spillway gate.

Project Commentary

One of the factors that made for a smooth-running project is the spirit of cooperation among staff working for the District, WHECO and Orkot. Because of the short construction season, each party is working quickly, actually in less time than is stipulated by the contract, to fulfill task requirements.

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“When we are ready to extract or install a trunnion assembly at the dam, the District is allowed a period of 5 days to move the bulkhead, but they typically have it moved the next day,” says Wood. “At the same time, at WHECO, we hasten to get measurements to Orkot, and their turnaround on the bearing is very responsive, usually within a couple of days,” he says.

Thompson comments that, “By working together like this, the team is making the most of the time available to get the work done. It helps solve any problems that arise and keeps the project moving forward.”

He further credits project success to the engineers that developed a good procedure. Contributors include David Moore (Grant County PUD) and Jim Passage (Montgomery Watson Harza) who worked on the initial inspection and investigation, and Ray Ellis (Grant County PUD) and Rick Dulin (ECI) who developed trunnion bearing and thrust washer replacement procedures.

With completion of the public works project, Thompson anticipates no further problems with cracks in thrust washers at Priest Rapids Dam. “We began assessments in February 2002 to quantify and measure improvements that result from the rehabilitation of the trunnion assemblies,” said Thompson. “Overall, we expect the project will reduce trunnion friction, provide for optimum operation of the spillway gates and enhance reliability,” he stated.

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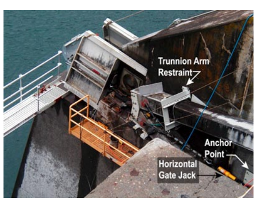
Photo and Captions

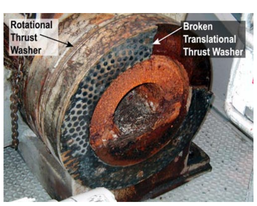
A gantry crane erected on the spillway at Priest Rapids Dam in Washington State (USA) is used to install rebuilt trunnion assemblies at each of the dam’s gates.
(file is gantry-crane.jpg)

The trunnion assemblies are loaded on a truck for transport to the repair shop.
(file is on-truck.jpg)

Broken thrust washer.
(file is broken-Washer.jpg)



Trunnion assembly position on the spillway gate.
(file is on-spillway.jpg)



Trunnion assembly before rehabilitation.
(file is before-rehab.jpb)

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