Application of Precision Acoustic Positioning In Dam Inspection

Abstract

New technology developed by SonicWorks, Inc., of Portsmouth, Rhode Island, allows for significant improvement in efficiency, accuracy, and detail in underwater inspection of dams, weirs, and similar structures. Utilizing a combination of precision acoustic positioning technology and flexible equipment arrangement, the SonicWorks Dam Inspection System is rapidly deployable from a mobile unit, requires minimal manpower for operation, and provides the inspection team with centimeter-accurate positioning of the inspection ROV or diver, and the capability of generating three-dimensional CAD drawings of the inspected surface. The system employs a variety of benchmarking capabilities making it compatible with all conventional survey technologies from traditional civil engineering to modern GPS-based systems.

The Problem

Large concrete dam structures require much more rigorous inspection than smaller structures. Whereas the inspection of small earthen dams or small dams of concrete, masonry, stone, or other construction is and can be limited to visual verification of structural integrity, large concrete dams present the problems of depth and poor visibility below the waterline, making visual inspection inadequate to properly assess the integrity of that portion of the structure.

Operational inspections of large dams, done more frequently than engineering inspections, typically require the use of divers to visually inspect the subsurface upstream face of the dam. This approach has several limitations, including placing the divers at risk of injury (high currents near the admissions spillway) and unsuitability of the divers as dam inspection technicians (may miss critical details that an engineer would notice).

Remotely Operated Underwater Vehicles (ROVs) have been employed to photograph or videotape the upstream faces of dams, but this approach, also, has practical limitations. The most serious of these limitations is the inability to precisely track the position of the ROV underwater. Having a photograph or video of a damaged portion of the dam may be useful, but not knowing where the defect was located makes planning for and returning to the site for remediation difficult.

The SonicWorks™ Solution

The SonicWorks™ APNS™ is a new, long baseline, acoustic positioning system which, utilizing a combination of frequency hopping, digital signal processing, and power control technologies, attains a position resolution of ±1 cm, and produces repeatable, accurate measurements of any sized solid dam. The Windows™-based Dam package consists of a control computer, five acoustic smart transceivers (stations), and an ROV

pinger module or diver cursor. The system includes mission management software to record the inspection process and produce comprehensive reports. Optional equipment is available to generate CAD as-built from the inspection process that can be overlaid with inspection annotations, video and still imagery.

Two stations are deployed upstream from the dam face, two on the dam face below any thermocline zone and the last transceiver centered above the other two and above the thermocline (see Figure 1). The system is designed to be deployed from a small rib boat and supported from a vehicle or trailer on the surface.

The SonicWorks™ APNS™ first performs an auto calibration routine wherein the system establishes a reference plane defined by the stations, then normalizes that plane to real-world geodetic coordinates, or to any other benchmark location defined by the situation. The first of the five stations, Transceiver A, (one of the two located on or near the bottom away from the face of the dam) corresponds to position 0,0,0 (in XYZ coordinates) of the reference plane. This transceiver, along with the four others, forms an "acoustic net" within which the ROV or diver/s can be tracked precisely. The ROV is then flown in a raster pattern along the face of the dam, between the two stations positioned on the face of the dam below the thermocline. The SonicWorks™ APNS™ automatically correlates the relative position of the ROV with its absolute position defined by the applicable benchmark. Photographs (or laser scans) can then be taken at precisely located intervals, then readily reassembled to form a mosaic picture of the underwater structure. Machine vision and laser range/targeting equipment can be integrated to produce the precise surface mapping required in spalling assessment.

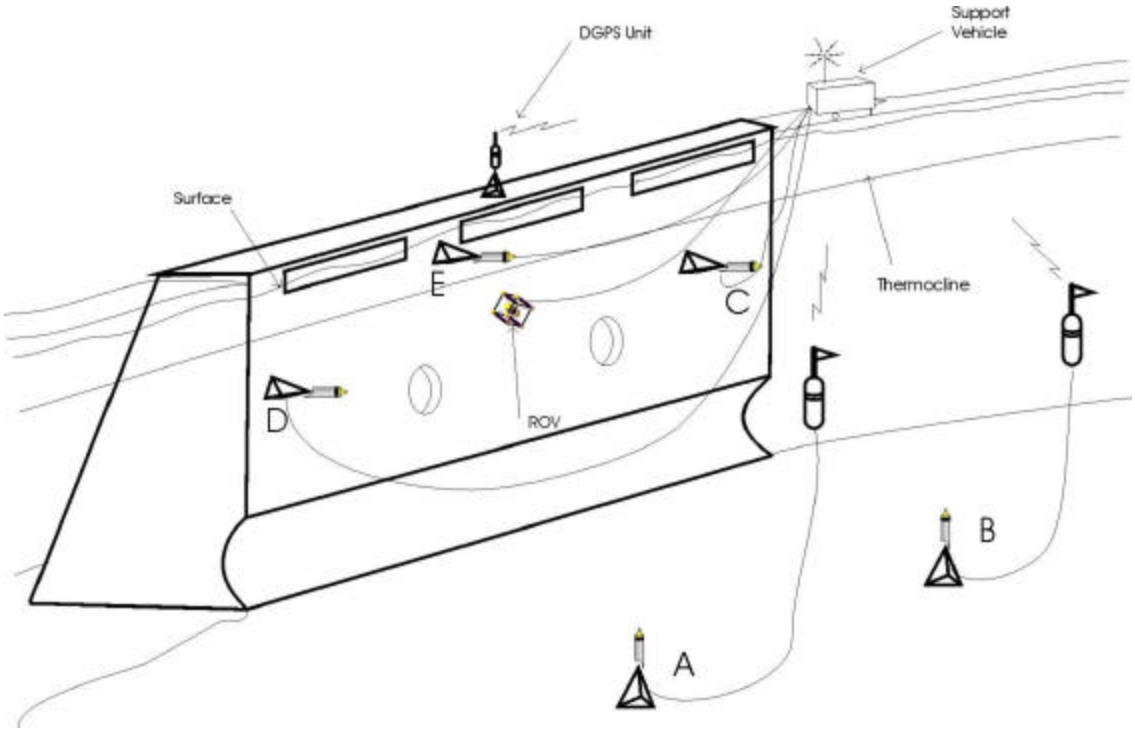

Figure 1.

Transceiver E shown in Figure 1 is positioned on the dam face below the waterline and above the thermocline (the region neat the surface below which the temperature of the water decreases rapidly). This transceiver allows the positioning system to compensate for the refraction of acoustic signals caused by the change in water temperature.

Deployment of the outboard network stations (A and B in Figure 1) is accomplished from a rib boat or other small craft. They are tethered to surface floats that transmit the position data to the control station. The remaining stations (C and D in Figure 1) are suspended from the dam face below the thermocline. The network deployment is designed to produce line of sight view with the vehicle locating pingers.

Two benchmarking options are available; the first requires the outboard transceiver buoys to be referenced to geodetic coordinates by conventional civil engineering techniques. This is accomplished with a laser transit system and direct entry of the positions of the two outboard marker buoys. The marker buoys automatically translate their position to the acoustic network referencing the system. Each time the system is moved along a large dam the outboard buoy positions must be reshot.

The second is precision Kinematic GPS based and totally automated. DGPS receivers are located in both outboard buoys while a third unit is placed on the top of the dam in a fixed location. The system uses the arrayed GPS receivers to form a precision (± 1 centimeter) network on the surface which is automatically translated to the net coordinates below the water. When repositioning along the face of a large dam, the outboard components are moved to provide line of sight to the new inspection area and the translation to geodetic coordinates is handled automatically.

What does this mean for the dam operator and inspection team? It means quick and easy setup, and rapid completion of detailed inspection of the entire dam surface below the water. Lengthy physical calibration procedures are eliminated, saving time. The ability of the system to calibrate itself and automatically correlate to the geodetic coordinate system, along with precision on the centimeter level (rather than within meters) plus other capabilities such as tracking, annotation, and CAD format output, mean ultra-precise mapping of the dam, the ability to return to any location of interest easily, and more efficient follow-up for areas in need of remediation.

Inspection vehicles

SonicWorks™ APNS™ is designed to support automated inspection by ROV. The RCS (Robotic Control System) can be applied to many off-the-shelf ROVs to produce a true robotic solution to inspection and intervention. The RCS includes the ability to program the surface scan process insuring complete and accurate coverage. A scanning contour feature provides a consistent vehicle hold off insuring consistent field of view and automated remote measurement of features. For more advanced inspection and intervention requirements the SonicWorks "Bee" has been designed to operate in demanding environments, up to 6 knots of current. The vehicle was designed to work

with the APNS and is an unlimited degree of freedom underwater robot. The vehicle uses an articulated thrust system to control vehicle attitude which may be positioned to follow any contour. The “Bee” provides the platform stability to operate water jetting equipment for dam face cleaning prior to inspection or repairs of spalling or grouting operations.

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