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Ultrasonic Evaluation of Flood Gate Tendons

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ABSTRACT

Our water resources infrastructure is susceptible to aging degradation just like the rest of this country's infrastructure. A critical component of the water supply system is the flood gate that controls the outflow from dams. Long steel rods called tendons attach these radial gates to the concrete in the dam. The tendons are typically forty feet long and over one inch in diameter. Moisture may seep into the grout around the tendons and cause corrosion. Lawrence Livermore National Laboratory is working with the California Department of Water Resources to develop advanced ultrasonic techniques for nondestructively inspecting their tendons. A unique transducer was designed and fabricated to interrogate the entire tendon. A robust, portable unit was assembled that included a computer controlled data acquisition system and specialized data processing software to analyze the ultrasonic signals. This system was tested on laboratory specimens and is presently being fielded at two dam sites.

Keywords: ultrasonic, nondestructive evaluation, flood gate, tendon

1. INTRODUCTION

The steel tendons that are embedded in the concrete and hold the flood gates to the dam are susceptible to corrosion. When they fail the nut on the end comes off and the tendon no longer supports the pivot plate, see Figure 1. Fortunately there are many redundant tendons for each support plate. An ultrasonic technique was developed and implemented to assess the condition of the tendon a long its 40 foot length. The only access to the tendon is from the end above the nut, see Figure 2. The ultrasonic pulse-echo method insonifies the tendon from the end and senses signals returning from corrosion along the length of the tendon.

The portable ultrasonic instrumentation consists of:

- High energy (1 mJ) ultrasonic transducer with the capability for producing pulsed compressional waves over a round trip distance of greater than 80 feet within steel rods with various diameters,
- Waveform Digitizer,
- Laptop computer for controlling the data archiving and data reduction. The software is all commercially available and operates in a Microsoft Windows 95 environment,
- And a commercially made, ultrasonic pulser-receiver.

The transducer is driven by a factory modified pulser-receiver. The pulser-receiver was modified to operate with an increased energy output, reduced pulse repetition rate, and an expanded low frequency range. The ultrasonic echoes are viewed on the computer to identify the location of anchors at the far end of the tendons. The temporal histories are stored on a laptop computer where the waveforms may be examined and transformed into a corresponding spectral domain. With an external printer connected to the computer, hard copies of the waveforms are available. The computer may be connected to a local area network for transferring data. The computer is complemented with an IOmega JAZZ drive, PCMCIA ports, and a CD ROM drive. A block diagram of the instrumentation is shown in Figure 3.

2. ULTRASONIC TRANSDUCER

The design of the low frequency transducer required research into commercially available low frequency transducers and into the available literature on high power, pulsed transducers. Ultrasonic instrument manufacturers were questioned regarding the availability of pulser-receivers that could produce significant output energy to operate a low frequency transducer.

No suitable transducers were available for the inspection of long rods. Thus we engineered a unique, low frequency transducer for the tendon inspection. The transducer was designed to transmit a high energy pulse into and receive echoes from the tendons and anchors. The specialized transducer required the development of transducer support instrumentation that would generate high energy output pulses and digitally process and archive returning ultrasonic echoes from each tendon. An example of the temporal history for a calibration rod is shown in Figure 4.

The transducers are designed to produce an extensional wave with a 1 mJ output pulse at 30 kHz into a long tendon. The transducer impedance was matched to the tendon acoustic impedance with an acousto-mechanical matching transformer inserted between the transducer and the tendon. A specific transformer is required for various tendon diameters.

3. SUMMARY

Lawrence Livermore National Laboratory designed and constructed an ultrasonic inspection system for the California Department of Water Resources. The ultrasonic system has the capability of inspecting concrete-imbedded, post-stressed, steel rods. The rods may be 1 to 1.5 inches in diameter and have lengths to over 40 feet. Such geometry and physical restrictions as found with these steel tendons have never before been inspected with ultrasound. The closest inspection technique that has been done on long rods is a modal analysis that is limited to establishing a length without identifying surface conditions.

A specially designed, low frequency ultrasonic transducer has successfully identified concrete adhesion according to length of tendon, identified location of anchors, and possibly identified the location of corrosion damage along the length of the tendon. More work is required to integrate the physical properties of the tendons with the ultrasonic temporal histories from the tendons. This effort to integrate the known parameters of time, materials and space will require signal processing. This programming could be performed on a commercial software package, such as “ProMatLab”. Preliminary investigations in filtering the temporal data from the tendons would indicate that it may be possible to resolve tendon damage apart from the echoes from flexural nodes and anchors reflected from within the tendons.

The ultrasonic tendon inspection system is being fielded. The results provide information about the condition of the tendons and aid the California Department of Water Resources in maintaining the flood gates.

A) flood gate and tendons

B) damaged tendon.

Figure 1. Photographs of a flood gate showing the location of the tendons that attach the gate to the concrete structure.

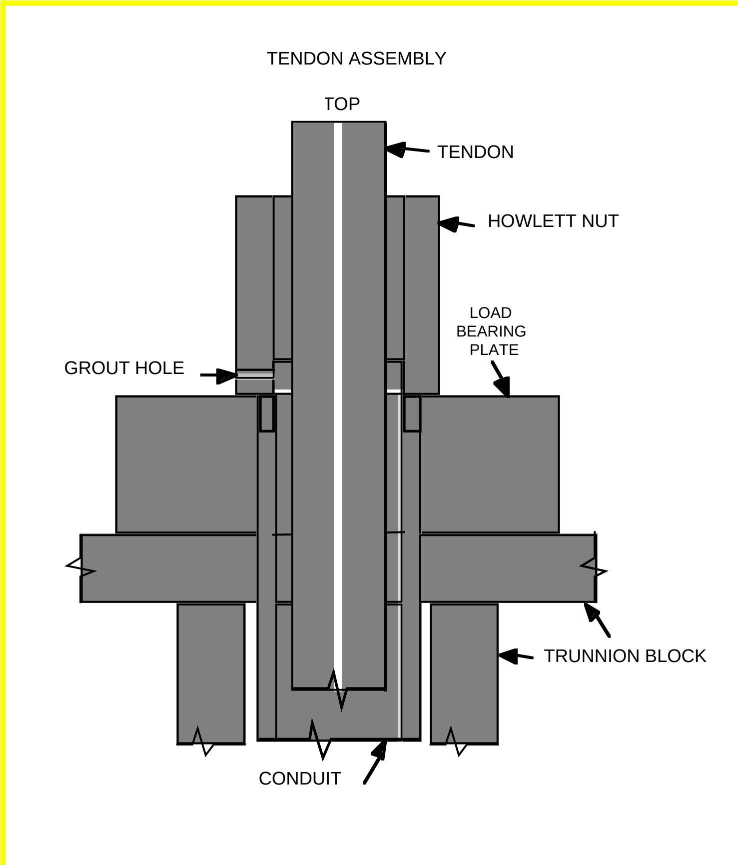

Figure 2. Diagram of tendon assembly showing how the gate is attached to the tendon. The ultrasonic transducer was mounted on the top of the tendon.

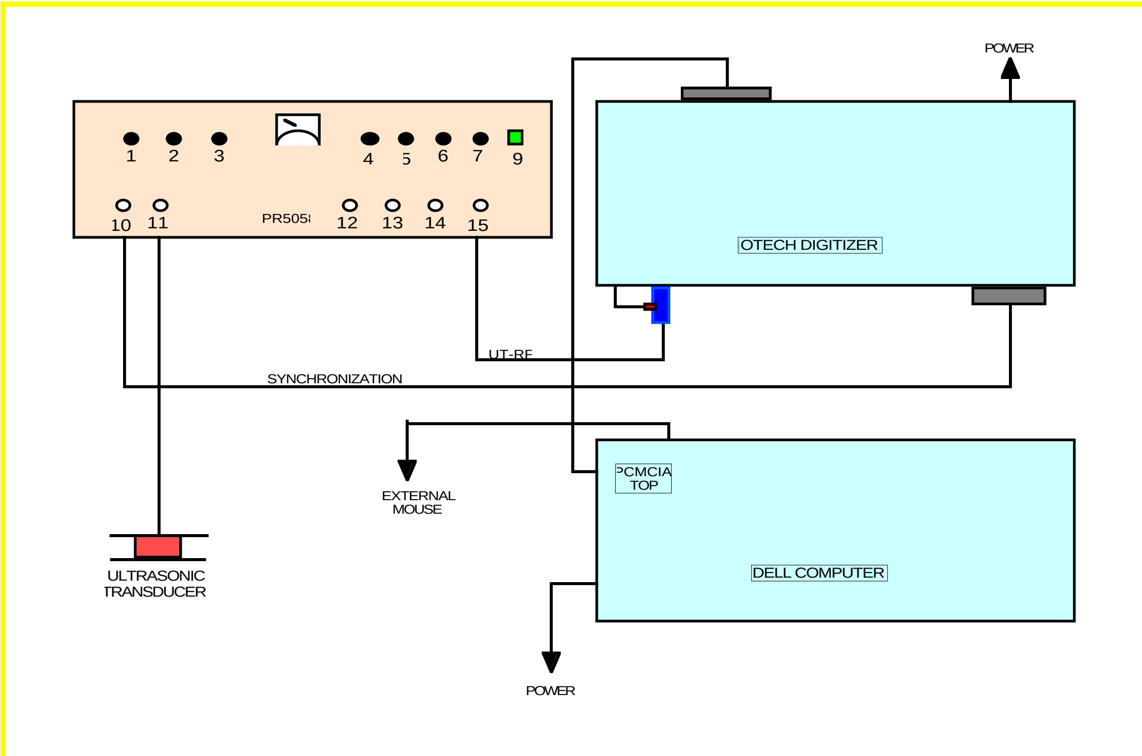

Figure 3. Block diagram of the ultrasonic system for data acquisition and analysis of the tendon condition.

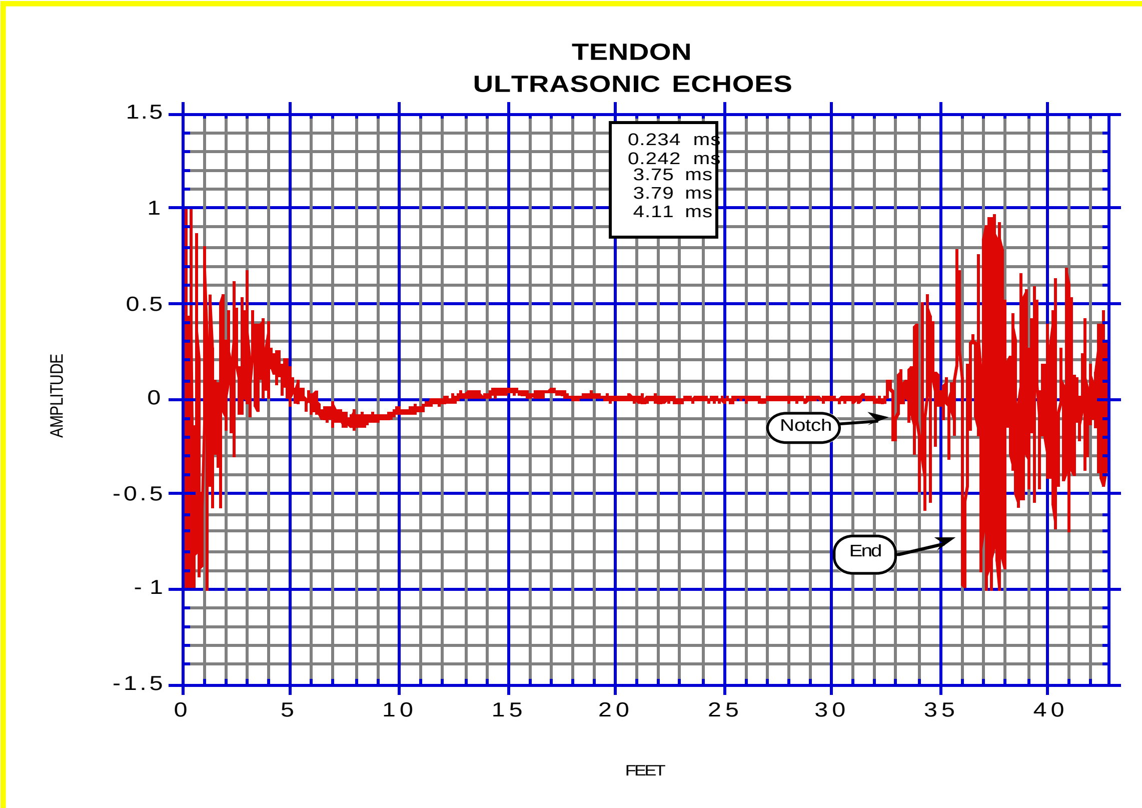

Figure 4. An example of the ultrasonic signal from a tendon. The ultrasonic signal reflected from a notch in this calibration tendon is shown. The notch is 36 feet from the end where the transducer is located.

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