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The Application of Ultrasonic Surface Detectors to Hopper Dredge Production Monitoring

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Abstract

Ultrasonic surface detectors were installed on the US Army Corps of Engineers hopper dredge WHEELER for measuring dredge production. Ultrasonic sensors were installed over the bow and stern of the vessel, port and starboard, to measure vessel draft as a function of dredged material load in the hopper. Four ultrasonic sensors were installed over the hopper to measure the bin water depth in the hopper. This paper describes the ultrasonic sensor operation and installation, and data acquisition and analysis for the test series.

Introduction

Hopper dredges are primarily used to maintain navigation channels in marine environments. These dredges contain large onboard storage areas for storing the dredged material as the dredge operates. Upon filling the hopper, the dredge travels out to a designated dumping site, where the hopper load is dumped through doors in the bottom of the hopper, or pumped out. The measurement of the load in the hopper can be accomplished by several methods. The preferred technology for measuring the load in the hopper is the load displacement meter. Differential pressure transducers located on the hull of the dredge sense the change in

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draft as the dredge hopper is filled. This change in draft is related to the load in the hopper by the vessel load displacement table. This table describes the draft of the vessel as a function of vessel weight.

This paper describes the testing of acoustic sensors as an alternative method for measuring the dredge draft and depth of material in the hopper. The tests were conducted on the Corps of Engineers hopper dredge WHEELER during July 1991, by personnel from the US Army Corps of Engineers Waterways Experiment Station (WES), Hydraulics Laboratory. The WHEELER was dredging in the Mississippi River and off the coast of Galveston Texas during the test period. The work was conducted under the Dredging Research Program (DRP) sponsored by Headquarters, US Army Corps of Engineers.

Transducer Description and Operation

The acoustic sensors used in the tests were rated for measuring distances up to 21 m. The sensors were about 0.45 m in length, and approximately 5.0 cm in diameter (Figure 1). The operating frequency, 45 Khz, is high enough so that environmental noise around the hopper area generally does not interfere with the signal, but it is low enough that temperature and density changes in the air can affect the data. The unit has 29 programmable functions available to the user for determining the proper transducer settings for any given application. These functions are used to set the range of measurement (minimum and maximum distances), the calibration of the sensor, and the input and output parameters. Additionally, the units can be used to control other remote functions based on the sensor output. A temperature sensor is incorporated into the unit to compensate for temperature changes. The accuracy of the sensor is reported to be 0.2 percent of the maximum range of operation. For our application, the maximum range was 12 m, with an accuracy of +- 0.024 m.

Sensor Installation

The draft acoustic sensors were mounted off the bow and stern of the WHEELER for determining the draft as a function of vessel weight (Figure 2). The data for the four draft sensors was averaged for the final draft calculation.

The hopper acoustic sensors were mounted forward and aft in the hopper for determining the depth of bin water in the hopper before dredging (Figure 3).

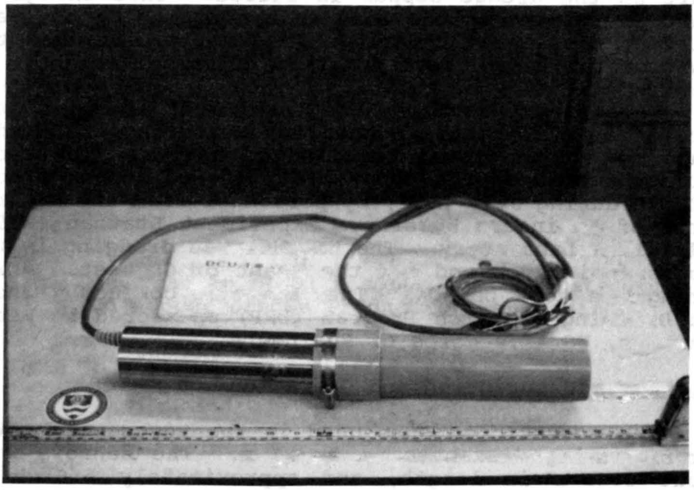

Figure 1. Acoustic sensor used in production monitoring tests

Figure 2. Draft acoustic sensor located off WHEELER bow

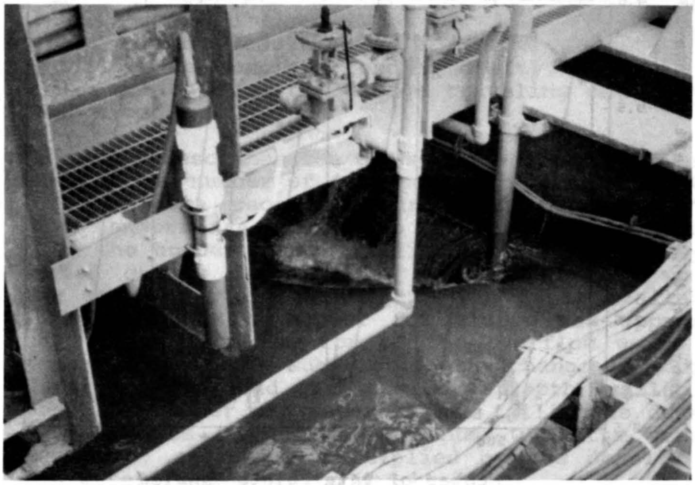

Figure 3. Aft hopper acoustic sensor location

Data Acquisition

The acoustic sensors were programmed to continuously average the data over a ten second interval. Every ten seconds, the averaged draft and hopper depth data for each transducer were recorded on a personal computer through an RS-232 data interface. Software written by the Instrumentation Services Division of WES converted the draft measurement to hopper load using the load vs displacement table for the WHEELER, and converted the hopper depth measurement to hopper volume using the Ullage table for the WHEELER.

Test Results

Figures 4 and 5 describe acoustic draft and hopper depth data for the first 6 hopper loads taken from Sabine Pass on September 5, 1991. The loads are designated as L1 - L6 on the figures. The sediments found at Sabine Pass consist of fine silts, therefore, no overflow of the hopper was permitted. Figure 4 describes the change in draft as a function of number of data points recorded. Each data point represents ten seconds of averaged data. At the top of the data record (beginning draft) the hopper is empty except for bin water. The dredge is not as stable when empty, resulting in more vessel motion. The acoustic sensors

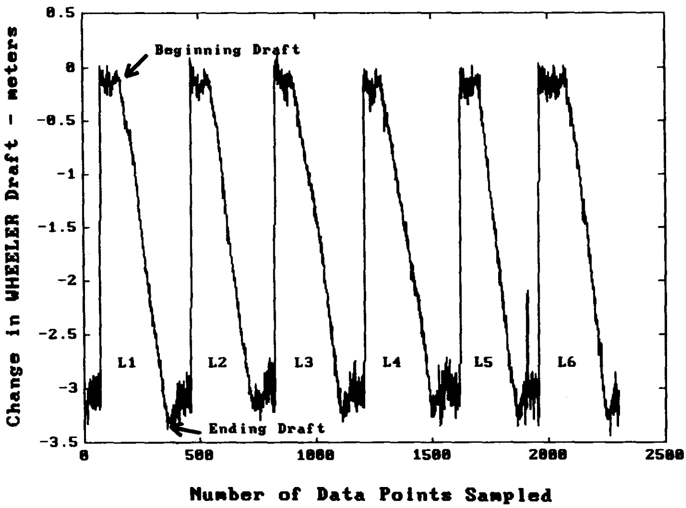

Figure 4. Draft acoustic sensor data

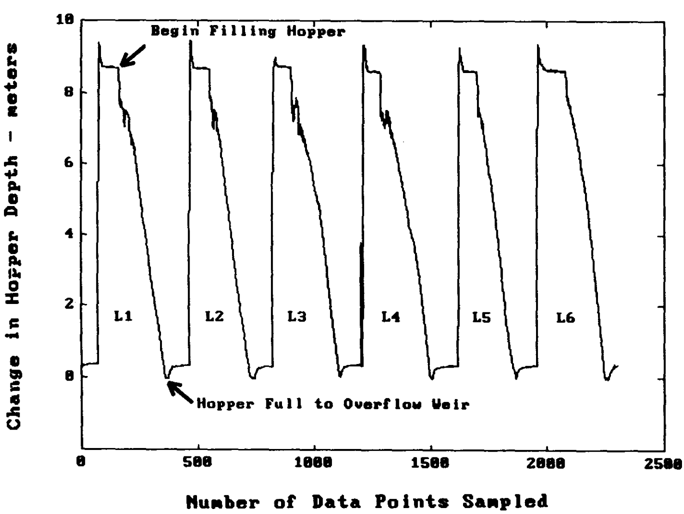

Figure 5. Hopper acoustic sensor data

pick up this motion, as well as any surface wave action. As the dredge begins to fill, the vessel motion is damped, resulting in a cleaner data record. After filling is complete (ending draft), the sensors again see motion from the dredge traveling out to the disposal site.

Figure 5 describes the change in hopper depth as a function of the number of data points recorded. At the top of the data record (begin filling hopper) the acoustic sensors are picking up the surface of the bin water in the hopper before filling begins. The hopper is filled during dredging up to the overflow weirs (hopper full to overflow weir). The total available depth in the WHEELER hopper for slurry was approximately 13.0 m (from the top of the overflow weirs to the hopper doors). By subtracting the change in hopper depth for a given load from the total depth available, the depth of hopper bin water before filling is determined. This is converted to volume with the vessel Ullage table, and, when multiplied by the density of the bin water, converted to weight.

Discussion

The hopper acoustic sensors proved to be dependable over the test duration. Although the sensors were subjected to harsh environmental conditions, they maintained their calibration throughout the two months of testing. The data from the hopper sensors had good resolution, with minimal signal noise.

The draft acoustic sensors maintained calibration over the test period and provided good resolution of the dredging cycle. The major problem with using acoustic sensors for draft measurement is the detection of vessel motion at the beginning and ending of the filling cycle. Accurate measurement of starting and ending draft are essential to measurement of load. Wave action as well as vessel motion at these points resulted in data scatter of up to +-1.0 ft. Because the motion is somewhat random, smoothing the data through filtering or averaging routines may be difficult.

Acknowledgements

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