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Capacitance sensors for measuring suspended sediment concentration

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Abstract

Measurements of suspended sediment concentration are of importance in soil erosion research and soil and water conservation practices and monitoring. A method of measuring sediment concentration with capacitance sensors was advanced in this study. The relationships between the sediment concentration in flowing water and the output of capacitance sensor, as affected by temperature, flow velocity, soil types and salt contents were experimentally investigated with two types of capacitance sensors. The temperature used in the experiments ranged from 0 to 40 degrees centigrade. Salt concentrations (NaCl) in the flowing water ranged from 0 to 5 g/L and the flow velocity varied between 0.5 to 2.0 m/s. Two types of soil (a loam and a sandy soil) with sediment concentration up to 70% were studied. The results showed that suspended sediment concentrations, over a wide range, were linearly correlated with the outputs of capacitance sensors. The outputs of the capacitance sensor increased with temperature, with little influence from flow velocity, soil types and salt concentration. The results suggest that capacitance sensors may be used for sediment concentration measurement of flowing water.

Keywords: Capacitance sensors; Sediment concentration; Temperature; Flow velocity; Soil type; Salt content

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1. Introduction

As one of the most serious natural problems in China, soil erosion by water not only influences present agricultural production, but also accelerates the pace of farmland degradation and causes the reduction of soil fertility. Water loss by runoff lessens the ability of agriculture to withstand extended period of draughts in the semi-arid and arid areas of China and the world. High sediment levels in rivers and canals, such as that in the Yellow River, deteriorate water quality for irrigation and drinking. Fertilizer runoff also contributes to water pollution. All these are not good for stable and sustainable development of agriculture.

Investigations by the Remote Sensing Center in the Ministry of Water Resources of China, indicated that the total acreage affected by soil erosion was 367 million km^2, 38.2% of the total area of the nation (Jiang, 1997) and 179 millions km^2 had been under influence of moderate to severe soil and water losses.

In soil water conservation practices and for scientific research on soil erosion, the determination of sediment concentration is very important. The data on sedimentation are useful for land use planning, environmental impact monitoring and for gaining a better understanding of erosion mechanism. The traditional oven-dry method is still widely used for measuring suspended sediment concentration in flowing water, but it is time and labor consuming. Therefore, fast and precision on-line determination of sediment concentration in flowing water is highly desired.

Capacitance as effected by the dielectric properties has been adopted for moisture determination of soils (Dean et al., 1987; Mead et al., 1994; Evett and Steiner, 1995; Tomer and Anderson, 1995; Paltineanu and Starr, 1997; Starr and Paltineanu, 1998; Shan, 1999; Lane and Mackenzie, 2001) and other solid materials (Lawrence et al., 1999; Marcotte et al., 1999; Nelson, 1991; Osman et al., 2001; Savoie et al., 2000; Snell et al., 2000). The same principle might also be applicable to determine sediment concentration in water flows.

The general objective of this study was to determine if capacitance sensors can be used to measure sediment concentration in flowing water. Specific objectives were to determine the effects of sediment concentrations, temperature, particle size distribution, flow velocity and salt (NaCl) concentration on the capacitance of the suspensions.

2. Principles of measurements and structures of the capacitance sensors

Capacitance sensors have been shown to be sensitive to water content changes in soils and other materials.

The capacitance in the presence of a dielectric material can be expressed as:

$$C = \varepsilon A/d \tag{1}$$

where, C is the capacitance of sensor, ϵ is the dielectric property, A is the area of the sensor and d is the distance between the 2 plates.

Sediment-laden water is a mixture of materials of two phases: solid and liquid phases. Different partitions of sediment and water would result in differences in dielectric constant