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On-the-go measurement of soil water content and mechanical resistance by a combined horizontal penetrometer

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Abstract

A combined horizontal penetrometer was designed for the on-the-go and simultaneous measurement of soil water content and mechanical resistance. The maximum sampling rate for both sensors was 10 Hz and the maximum operating depth was 20 cm. For the water-content sensor, its measurement principle depends on the electric field of the fringe-capacitance. In order to evaluate the applicability of this combined penetrometer, four experiments in the field were carried out. These experiments included: (1) soil water content profiles test; (2) soil compaction measurement test; (3) effect of the operating velocity on the water content and resistant force measurement; (4) effect of operating depth on the force measurement. The experimental results show that the combined horizontal penetrometer is a practical tool since it can provide more useful information of soil physical properties.

Keywords: Soil compaction; Water content; Penetrometer; On-the-go measurement

1. Introduction

Increased interest in investigating the influence of soil strength on plant growth has brought to various penetrometers. Moreover, the measurement of local soil strength may be used for real-time regulation of tillage parameters in precision farming (Sirjacobs et al., 2001). As a practical application, horizontal penetrometers have been employed for characterizing the distribution of the soil mechanical resistance under different depths (Alihamsyah et al., 1990; Clemer and Stomerbaugh, 2000; Sirjacobs et al., 2001; Chong et al., 2004). On the other hand, due to the fact that the soil mechanical property strongly depends on water content (Kodesova et al., 1998, 1999; Vaz et al., 2001), over the past decade several types of the vertical combined penetrometer have been developed. By using these combined penetrometers, the operators can simultaneously obtain

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two vertical profiles associated with water content and cone index. Among all kinds of the combined penetrometers, several soil water content sensors have been employed for this purpose. The first is time domain reflectometry (TDR) sensor (Topp et al., 1996, 2003; Morrison et al., 2000; Vaz and Hopmans, 2001; Young et al., 2001). The second method is to integrate an infrared moisture sensor into the penetration rod (Newman and Hummel, 1999). Apart from these sensors, a relatively cheap capacitance sensor is combined with the penetration rod (Singh et al., 1997) or the penetration cone (Sun et al., 2003). Compared with the TDR-combined penetrometers, the capacitance sensor penetrometer has several advantages: (i) rapid response for continuous measurement; (ii) low cost; (iii) relative robustness in terms of geometrical structure.

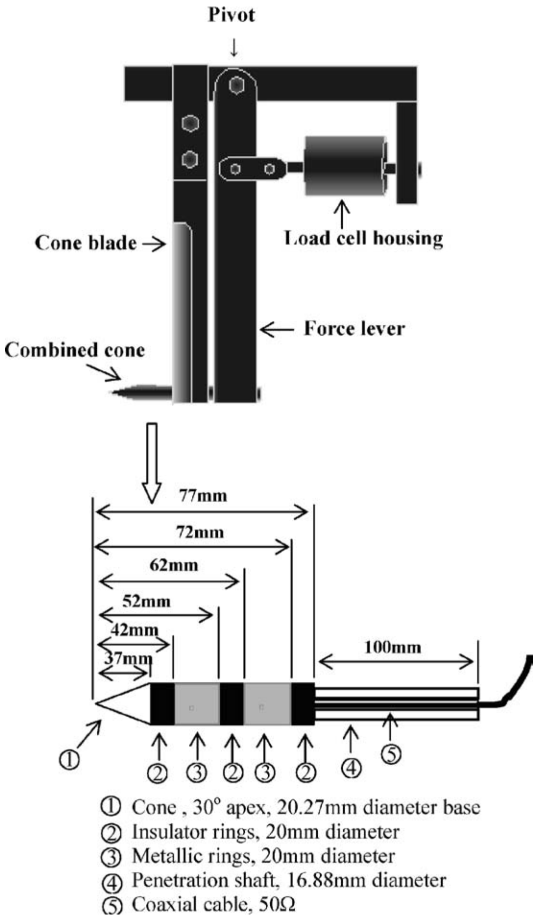

Fig. 1. Diagram of the horizontal combined penetrometer.

Since both soil strength and water content are important factors for regulating soil tillage and for performing soil variability maps in precision farming, the objectives of this study were to develop a horizontal combined penetrometer for on-the-go measurements of soil water content and mechanical resistance and to evaluate its performance in the field.

2. Material and methods

2.1. Soil mechanical resistance measurement

Fig. 1 is a detailed diagram of the measurement system for the soil water content and mechanical resistance. Like the most of conventional horizontal penetrometers, this prototype consisted of four components: a cone penetration rod, a blade, a force lever, and a force sensor with strain-gage load cell. The length and width of the blade were 40 and 5 cm, respectively. The functions of the blade were two-fold. At first, according to the structure design in Fig. 1, it ensured that the measurement results of the force sensor were independent of the depth. Secondly, it could protect the force sensor from the impact by stone. In order to facilitate the blade penetrating in the soil, the part of the blade was designed with a wedge angle of 60°. The type of the force sensor was HBM-U1 (Hottinger Baldwin Messtechnik). Its nominal sensitivity was (2 mV/V) and the maximal measurement force was up to 10^4 N. Fig. 2 shows a linear relationship between the measured force values and the output signals of the force sensor under the

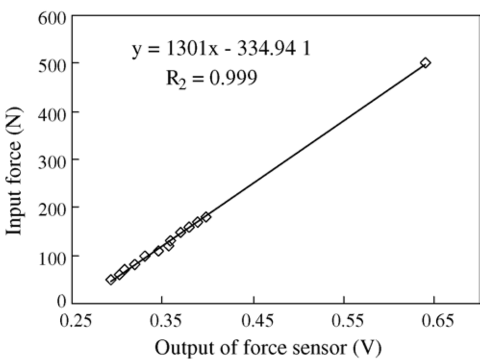

Fig. 2. Calibration results of the force sensor.