Abstract

It is very difficult to estimate depth of a metal object using signal of a traditional eddy-current metal detector which moves in constant distance from the ground. We show that the information about the object size and depth can be acquired from this signal during the detector lift-off. This could increase the discrimination ability of mine detectors which results in more efficient, safer and faster demining process.

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Keywords:
metal detection; metal content discrimination;

1. Introduction

Innovative approaches to humanitarian demining are an important task, as the demining action moves to magnetically difficult areas such as locations with magnetic soil or with high density of the metal clutter, which causes high number of false alarms [1, 2]. Many approaches have been used to recognize the landmines and discriminate them from the clutter [3], but the developed techniques were complicated and they were never generally accepted by the demining operators and institutions. Kellermann has proposed an easy and innovative approach: after the suspicious object is found using conventional horizontal sweeping, the detector head in swept vertically (in height), and the detector signal is stored together with a height information [4]. In the simplest case this data allow to distinguish small shallow objects from large and deep objects. The practical implementation of this procedure requires an integrated head-to-soil distance-metering. The original requirement of deminers was to develop add-on device to complement existing metal detectors using their acoustic output. Using simple test pieces we systematically verified the proposed principle measuring 1. the analog ac voltage directly at the output of the search head 2. real and imaginary voltages in various stages of the analog signal processing chain of the professional metal detector 3. signal at the acoustic output of the detector.

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2. Measurements

We have simulated such setup, using the continuous-waveform (CW) head of the Schiebel ATMID mine detector (Fig. 1) SR-830 lock-in amplifier. The amplitude and phase of the voltage induced into the search coil (without non-linear processing) is shown in Fig. 2. To measure the ground distance during the field experiments we have used infrared triangulation distance sensors Sharp GP2Y0A21 based on PSD sensor (Fig. 3a). We also measured the acoustic signal (Fig. 3b), but this variable frequency signal fast saturates and does not give enough information for subsequent signal processing. Therefore we decided to use original electronics of the metal detector (Re and Im signals after synchronous detector and log amplifier).

For all of the measurements we used a set of standard objects - steel balls of various diameters, the "minimum metal content" mine simulator (Fig. 1 b) and brass shell (Fig. 1c). The objects were placed in air and in a "difficult" red soil, containing large fraction of superparamagnetic and ferromagnetic particles. This type of soil is known to have frequency dependent susceptibility which gives false signal to metal detectors [2]. The sensor head was placed on a non-magnetic positioning table with its center above the test piece and the amplitude and phase responses were recorded. Fig. 3b shows an example of the measured data: magnitude of the internal signal as a function of distance for two INOX balls. For the same signal level, the slope is smaller for larger object (which is in bigger distance). An example of phase characteristics is shown in Fig. 4. In general, we were able to recognize the object and estimate its depth using the phase information, which gave more reliable data for both methods based on neural networks and least-squares algorithm. While detection in air gave very stable results, data measured in magnetic soil were more difficult to process. In general the soil signal could be compensated, but the estimation was less reliable. The possible future solution is to use multi-frequency methods.

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Fig. 1. (a) Schiebel ATMID detector used in the present study d) metal ball and calibration piece and c) brass shell used as test targets [6,7]
Fig. 2. Induced voltage directly measured by an external DSP lock-in amplifier: (a) Amplitude response for small and large INOX balls b) phase response for small and large INOX balls in air and in magnetic soil [5]

Fig. 3. (a) Detail of the detector head equipped with the optical distance sensor b) dependence of the acoustic signal frequency on the horizontal position of the search head for 3 sizes of the metal balls. The search head was swept in 150 mm distance. [5,6]

Up to now we have dealt with symmetrical objects. In order to demonstrate the complexity of objects with less regular shape, we performed a series of measurements with brass shell. Similar objects are very common in mine fields. Signal characteristic (Fig. 4) is strongly dependent on the shell orientation with respect to the search head.
Fig. 4. Signal from the brass shell (real part) a) horizontally scanned in two directions (real part), b) vertically scanned for two shell orientations with respect to the search head [7]

3. Conclusions

We have demonstrated that collecting the signal of the metal detector during lifting from the normal position gives rich set of information which may allow to discriminate between different objects. Signal processing by DSP lock-in amplifier is not possible in field applications. On the other hand the acoustic output of the metal detector cannot be used as it reduces the information present in the induced voltage. We have shown that the practical solution is to use internal analog signals of the detector. When non-symmetrical objects are present, discrimination problem becomes much more complex and it seems that in such case vertical scanning should be accompanied by horizontal scanning across the suspected region in two mutually orthogonal directions.

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References