# Improving Integration of Ultrasonic Sensor and Hand Probe

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**Abstract**. In mine detection within the humanitarian demining probing is a reliable technique, but accompanying with a relatively high level of risk and large duration. The adding of ultrasonic sensor to hand probe was demonstrated to overcome insufficiencies of traditional hand probing. The ultrasonic sensor should not screen the hand probing based on a physical contact between the hand probe and a buried object. In this paper we evaluate novel proposal for realisation of the relevant parts of ultrasonic sensor which maximally follow requirements for hand probe geometry.

## Introduction

Humanitarian demining is the only process using which the mine affected regions are recovered regarding their socio-economic use. Current humanitarian demining combines mine awareness, questionnaires for local population, mine detection, mine removal, quality management system and other segments [1]. Mine detection is the part responsible for the significant part of the overall duration and accompanied risk. Techniques in mine detection include use of metal detectors, trained dogs and hand probing. In addition, demining utilises machine demining.

Hand probing is a technique in which a hand probe is used in order to detect the presence of buried objects [2]. Generally, multiple probing around a detected buried object enable deminers to conclude about its shape, thus characterise it as a mine or some non-dangerous object. However, because of a large risk connected with establishing a contact of a hand probe and a buried object, after establishing the first contact, other techniques are utilised, e.g. use of metal detectors, or excavation. Every indication has to be treated equally seriously. Because of relatively small part of mines in the set of buried object causing indications (typically 1:100 to 1:1000), that causes tensions and overall enhances the risk of demining. Still, the hand probing is rather reliable technique for humanitarian demining mine detection, which can be used in all situations, in many of which other methods are inapplicable.

More formally, hand probing has high enough probability of detection, yet also high false alarm rate. That makes it a high quality detection equipment, but low quality classification equipment.

Some time ago that discrepancy was recognised, and efforts were conducted in order to improve mine detection of humanitarian demining through improvement of classification function of hand probe [3]. The proposed solution was integration into hand probe of a miniature ultrasonic sensor capable of materials characterisation, Fig. 1. The material to be characterised was the surface layer of the buried object in the vicinity of a

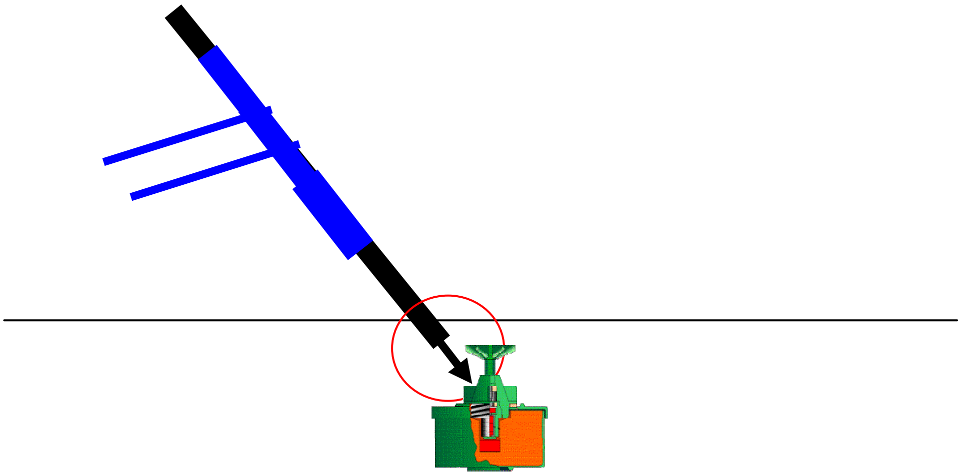

**Fig. 1.** Sketch of a working principle of a hand probe with integrated ultrasonic sensor. Blue – automated system for hand probe manipulation, black – hand probe, red circle – area of functioning of an ultrasonic sensor mounted near the hand probe tip.

contact point with the hand probe. The preliminary results revealed the capability of ultrasonic pulse-echo technique to differentiate among diverse objects, but in restricted, laboratory environment [4, 5]. In the general approach, the planar propagation of ultrasonic impulse was exploited. The experiments were accompanied with the theoretical modelling of ultrasonic propagation through multilayer structure, which combined external layers of hand probe, a contact layer between the hand probe and buried object (i.e. water, soil or other material depending on the local conditions) as well as the external layer(s) of buried objects.In this paper we address the problem of obtaining the ultrasonic transducer, i.e. the piezoelectric, in a form suitable for implementation into the hand probe, which fulfils other requirements set by the geometry. In the second section we describe in detail the model, extract that particular problem, and in third section describe its prospective solution. The paper ends with summary of results.

**Model**

The model for ultrasonic propagation firstly addressed is shown in Fig. 2 and described in the existing literature [3, 5, 6]. Simplicity of its geometry enables one to analytically treat different parameters and track the influence of their modification.

However, in realistic applications, the area of the cross-section of the realised structure would be too small to enable reliable enough signals, in comparison with the

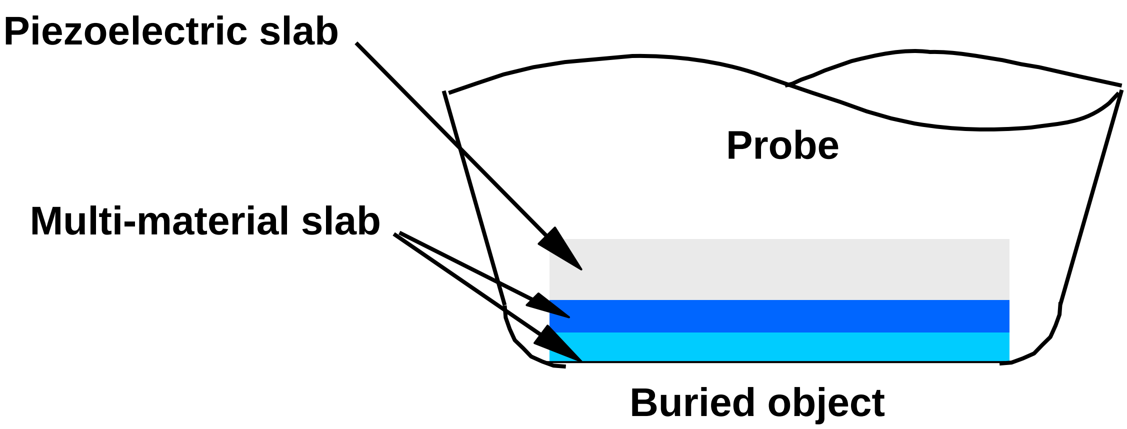


**Fig. 2.** Sketch of a multi-layer tip of a hand probe.

expected noise, thus the functioning of the confirmation sensor, i.e. classification sensor, would not be reliable [7].

In order to overcome that problem, several modifications of the geometry were analysed. First, the modification of the electrodes of the piezoelectric disc was used in order to see whether more complex shapes of the emitted ultrasonic impulse overall bring about larger modification of the pulse by the buried object material [7, 8].

## Piezoelectric sensors determined by geometry

Current status of researches is focused on preparation of the piezoelectric sensing part aligned with the profile of the hand probe's tip. That can be, generally, done in several ways, and let us present and compare here two of them. As piezoelectric specimen are manufactured in a complex way including foundry. During that phase, a mould can be prepared to resemble the inner part of the hand probe's tip. That process is rather complicated because of the rather small series of piezoelectric specimen to be manufactured for the purpose of mounting into the tip. Furthermore, in the preparatory phase, the shape of the tip is subjected to modifications because of better alignment of mechanical requirements for performance and requirements imposed on the ultrasonic sensor. That would, in turn, complicate even more the process of preparing moulds.

The other process is that in which piezoelectric specimens are used having conventional shapes, e.g. discs. They are granulated, and further mixed with a material brining about compact, strengthened form of the, thereby produced, composite. Such a material will, in general, not have characteristics of a macroscopic piezoelectric immediately, but after a proper pre-polarisation. The pre-polarisation is performed in the appropriate geometry, e.g. within the field of a biased capacitor having plates of a suitable geometry.

Both processes of piezoelectric specimen preparation are of multiple phases, and have some phases non-conventional. It is estimated that in the first phase, in which the final shape is not determined, the process with granulation is exploited, and eventually, after practice helps extract the optimal shape of the tip, the phase with moulds is to be exploited. Both processes ends with a thin internal coverage of the tip with the piezoelectric material, making rest of the interior a suitable places for conductors and backing. The thin piezoelectric layer, despite its tri-dimensional curvature, resembles well the previously exploited model of plan-parallel layers through which the ultrasound propagates, in most of its area.

## Summary and conclusions

The confirmation capability of the hand probe, for use in mine detection, can be developed through integration of the miniature ultrasonic sensor. That sensor characterises material with which the hand probe is in contact, and should be suitable for low-metal-content mines. The restrictions imposed by geometry makes determination of the optimal form of the sensor a non-trivial task. Currently, the approach to the optimal solution, is investigated with the form in which the piezoelectric specimen is put as the coverage of the internal surface of the shallow tip of the hand probe.

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