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Modeling of an obstacle detection sensor for horizontal directional drilling (HDD) operations

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ABSTRACT

Horizontal Directional Drilling (HDD) is a commonly used construction method for the installation of underground pipelines, conduits and cables in urban areas and across obstacles such as rivers, railways and highways. A key concern in using the HDD method is the risk of hitting existing buried utilities during the pilot boring operation, which could potentially result in significant economic losses, disruption of services and injuries and/or loss of life. The Differential Impedance Obstacle Detection (DIOD) is a “look-ahead” sensory system, developed for the purpose of detecting metallic and thermoplastic pipes in the path of the boring head. The DIOD sensor was numerically simulated, and the model was validated by comparing its predictions with experimental measurements performed on a physical prototype in a controlled environment. Following validation of the model, a parametric study was undertaken to predict the performance of the DIOD under various scenarios that could be encountered in practice.

1. Introduction

Beneath the US landscape lie a vast network of buried utilities and pipelines, stretching for nearly 10.6 million miles, which include natural gas lines, power lines, water distribution and collection systems and optical-fiber communication lines [1]. The need for laying new utilities to support new technologies (i.e., the ‘last mile’ program), coupled with increasing demands of an ever growing population, has resulted in a highly congested underground space, particularly in urban areas. A parallel trend is the increase in the utilization of newer construction methods that minimize excavation, and reduce disruption to traffic patterns and the built environment. Horizontal Directional Drilling (HDD), a trenchless method for installing pipelines and conduits underground, has become in recent years a midstream construction method due to its versatility, cost effectiveness and relatively small foot print [2]. A major concern in employing the HDD method is the occurrence of an inadvertent utility strike during the boring process. As the drill head advances underground, it might damage an existing utility located along its path. Such utility strikes can cause significant economic losses (i.e., service interruptions, damage to a buried utility or building foundation) as well as injuries and fatalities if a hazardous utility (i.e., flammable liquid lines, electrical conduits, natural gas lines) is hit. Thousands of inadvertent utility strikes have been reported over the past fifteen years, some with severe consequences. The Damage Information Reporting Tool (DIRT), sponsored by the Common Ground Alliance, reported 258 HDD related utility hits in 2005 alone across the country [3]. A specific concern during HDD installations in urban areas is the accidental placement of a natural gas line in a way that it transects a lateral connection or a gravity sewer line. Such occurrences, commonly named ‘cross-bores’, could create a long-term risk as an attempt to remove blockade in the drain (induced by the presence of the transecting gas line) could compromise the gas line, resulting in leakage of natural gas into adjacent homes via the sewer system [4]. Fig. 1 shows photographs of typical ‘cross-bores’ created during HDD installations. Between 1996 and 2006 at least 20 explosions occurred in 13 states due to attempts to clear sewer laterals that were blocked by a natural gas line, resulting in loss of life, severe injuries and over one hundred million dollars in damages. In one case (Madill, Oklahoma), the explosion (November 14, 2007) occurred 15 years following the installation of the natural gas line (1992). Projects undertaken by various utilities for identifying legacy cross bores resulted in the detection of an average of 2 to 3 cross bores of natural gas lines into sewer mains and laterals per each mile of sewer main inspected, which translate into several hundred cross-bores for some cities [5].

Current practices for avoiding physical damage during HDD operations include search of GIS based databases (i.e., One Call system in U.S) to identify existing buried utilities within the project boundaries and surface surveys using geophysical tools such as cable locators, ground penetrating radar (GPR) and other locating methods. However, in some cases the One Call system is not fully effective due to inaccurate (or non-existing) records, cluttered environment (e.g., utilities that are stacked vertically or that are braided horizontally), excessive environmental noise (e.g., overhead

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