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Study on Optical Fiber Insertion in Underground Telecommunication Networks Using Hydraulic Similarity

Mircea Grigoriu[a], Marius Constantin Popescu[b,]*

[a]*University Politehnica Bucharest,313, Splaiul Independenței, Bucharest,Postcode 060042, Romania*
[b]*Western University of Arad, 94-96 Revolutiei Blvd., Arad,Postcode 310025, Romania*

Abstract

The European regulations require a new approach of cities facilities networks, including the communication ones. In this respect, the communication providers generalize the underground networks, following the streets trails. The transmission support consists in a network of tubes, protecting a number of micro-tubes/microducts, which protect the real transmission facilitators made by optical fibers. Presently, the producers of this type of devices promote special norms of information on characteristics and installation of the product, but there are not reliable accepted standardized methods for optical fibers insertion in pre-installed micro-tubes/microducts and for the devices forces computation, necessary for underground communication networks. The micro-tubes are already installed in the protection cables and together are buried in the ground on different routes. It appears the necessity to introduce the fibers in the micro-tubes in this situation. Generally, it is a significant difference between the practical reality and the producers norms and indicators. In order to explain this situation, and considering the optical fibers dimensions, and the necessity to insert the fibers using specific lubricants, the paper propose a similarity model of the optical fibers insertion in the micro-tubes with the hydraulic model of laminar incompressible fluids flow in parallel or concentric micro- layers. In this phase, there are presented the results of experimental measurements and tests on in situ networks, composed by different types of materials and lubricants, as support for the hydraulic similitude.

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* Corresponding author. Tel.: +4-072-132-9997; fax: +4-021-402-9865.
E-mail address: grigoriu.mircea@gmail.com

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1. Introduction

Nomenclature

τ	longitudinal effort within the fluid layers
u	velocity of the fluid
δ	total transversal dimension of the fluid layer
du	velocity variation across the transversal dimension
dy	transversal dimension infinitesimal variation
μ	dynamic viscosity
h	friction loss
K	constant
l	pipe length
D	pipe diameter
g	gravity acceleration
λ	friction losses coefficient of Darcy

More and more telecommunication operators are forced for different reasons (network expansion, specific EU or local regulations which introduce interdictions for aerial cables, aesthetics) to replace aboveground telecommunications networks with underground fiber optic networks. In this context, the telecommunication operators demand to the producing companies to supply new materials and equipment (fibers, micro-tubes, specific lubricants and installation equipment) capable to be used in extended underground networks. It is important that fibers should be introduced in the micro-tubes after these are already buried.

Presently, there are no technical specifications imposed concerning the micro-tubes laying and the optical fiber insertion, and also on the specific materials and equipment. The telecommunication services providers orders to the producers communications products only in terms of micro-tubes dimensions: diameter and length, without any control of the micro-tubes position inside the protection cables. But, obvious, this type of condition becomes essential for the natural process of network installation. Producers supply special equipment to introduce (under pressure of air or hydraulic support) the fibers, but they are not able to compute the necessary force to be provided for a specific diameter and length, in special condition of lubrication and considering the real fibers position in the tubes.

The problem consists in the hydraulic losses of energy arising between the optical fiber and interior micro-tubes evaluation, considering specific condition of each micro-tube.

The principal types of friction losses identified are:

- Longitudinal (linear) losses, caused by the linear fiber displacement along the micro-tube
- Singular (local) losses, caused by the changes in direction or section of the micro-tube, guiding the fibers.

The material locations of the local losses are called *singularities*. There are represented by deviations from the perfect linear position, which differs from a micro-tube to another. Their effect is a specific additional loss of energy, which values could be important, comparable to the linear losses themselves.

From the operation point of view, the singularities can reduce the signal efficiency, but this is not the paper subject. For a given micro-tube parameters (diameter and length), the number of singularities are significantly reducing the specific insertion equipment efficiency. The equipment providers offer technical specifications for a proper working, considering the micro-tubes absolute perfect as dimension and linear direction. From the energy loss point of view, the producers offer some diagrams of the effective fibers insertion lengths for a given force provided. Basically, the technical specification inform on the optimum distance to introduce the optical fiber [1].

Taking into consideration the extreme small amount of the fibers diameter and extreme thickness of the layer of lubricant, the fibers displacement along the micro-tubes walls can lead to a similarity model with the hydraulic model of laminar incompressible fluids flow in parallel or right or curved micro-layers for the infinitesimal layers of incompressible fluid displacement along the solid walls delimitating the fiber.