Are new mechanical aids for indoor or "To The Building" placement of optical fibers needed ?

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Manual pushing and pulling of indoor micro-cables in micro-ducts looks attractive at first glance and has been tried by a number of operators. However, experience and analysis show that these methods, applied in Multiple Dwelling Units (MDU), can be just as hazardous as in outdoor installations. Thus, a new generation of tools, meeting the challenges of indoor micro-cabling in micro-ducts, has been developed and is subject to further improvement.

1. Introduction

With the aim to reach optimal cost-efficiency, the cable industry developed in recent years various innovative indoor cabling concepts. These solutions depend on many considerations, amongst which: initial investment costs, level of upgradeability, Life Cycle Cost (LCC), labor cost and/or availability and rate of deployment. As a result a wide spectrum of products for cabling, in particular for MDUs, are now available. This spectrum ranges from fully custom-designed, pre-assembled and pre-connected cable harnesses to clean cut, pre-ferruled or pre-connected individual fibre units suitable for jetting in pre-installed micro-ducts connecting the MDU Terminal to the customers' Optical Network Terminal (ONT). Therefore micro-ducting will still be used in one form or another for MDU cabling. The length of the micro-duct sections in MDU seldom exceeds 50 meters. This is short compared to section lengths normally found in outdoor underground fiber network constructions. In spite of the general acceptance of cable-jetting by the industry involved in underground fiber networks, contractors active in conventional indoor cabling are often reluctant or even opposed to use this method. This is partially due to their lack of acquaintance with this technology and the seamingly prohibitive cost of available jetting equipment. As a result, most indoor cabling contractors still prefer manual pushing and pulling methods to install micro-cables.

2. General consideration

The constantly growing demand for broadband access by the public is unanimously considered a reality by network designers and operators. As a result of this, FTTH becomes ever more the best solution to secure adequate long term bandwidth requirements to private homes. Until now, except for Japan and Korea, due to the high investment costs needed for FTTH, the availability of alternative, less capital intensive solutions meeting the immediate bandwidth requirements have delayed a full scale development of FTTH projects. During the last years the cable industry, in search for more economical solutions, has developed innovative cabling concepts specifically adapted to urban, suburban and rural conditions. One common aspect to all those new designs is the miniaturization of passive network components such as ducts, cables and accessories. Miniaturization enables a better use of what free space remains in already occupied duct systems and facilitates the use of alternative right-of-ways. However, miniaturization does demand a higher skill level of the installation staff, than that of traditional electrical indoor contractors. For that reason some manufacturers developed a new generation of ruggedized drop cables for FTTH indoor applications [1]. Such ruggedized cables can be safely handled and installed by traditional electrical contractors, accustomed to indoor copper network construction practices, like stapling or pulling in plastic or corrugated electric tubing. Indoor installation contractors are seldom acquainted with the cable-jetting or floating methods currently used for outdoor cable placement in ducts. In addition, the present cost level of outdoor jetting equipment is considered prohibitive by most indoor contractors. With the increased demand for indoor installations small local contractors will be asked to carry them out. Speed of deployment is and will remain a key parameter. The construction methods for copper may not prove fast enough for massive deployment of FTTH, particularly in Multiple Dwelling Units (MDU's). Miniaturized cables and ducts (fiber-units or micro-modules (MM) and micro-ducts of an outer diameter from 2.5 to 5 mm), should not exceed the price levels of 4 to 5 mm ruggedized cables. For indoor electrical contractors micro-tubes are as easy, if not easier, to install than copper drop-cables. Indeed, micro-tubes are easily cut and joined. Manual pulling/pushing in electrical tubing, stapling or placing in race-ways of micro-ducts are perfectly adequate procedures. Of the whole customer connecting installation process these procedures are the most time consuming ones.

3. An adequate tool, why ?

Once the micro-tubes have been installed the insertion of a MM or micro-cable into the micro-tube from the MDU terminal to the ONT can be achieved safely and will only take a few minutes with an adequate tool, i.e. a tool which is affordable and easy to master by a conventional electrical contractor. To answer the question above, we will now be treating the problem of the installation of MMs or micro-cables in pre-installed micro-ducts suitable for indoor application. For ease of understanding a reality true reference model for indoor installation conditions has been defined as described below.

3.1 <u>Reference model</u>

Duct route and bend density

Due to the great variety of building architectures and to satisfy the aesthetic aspect of cabling, the chosen duct routes can be described as erratic, i.e. having numerous sharp bends. For clarity purpose a Reference Duct Route (RDR) will be used to evaluate the insertion performance of MMs in micro-ducts under indoor conditions, the RDR is formed of alternating sections of respectively 1.5 m vertically and 4.5 m horizontally. The distance between 90° curves is 1.5 m. See Fig. 1.

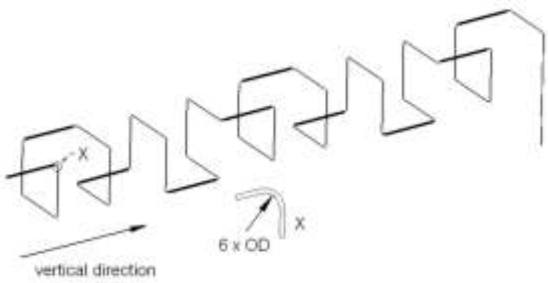

Figure 1: Reference Duct Route (RDR)

Bend radii

As today, the minimum bending radius imposable to a micro-duct is larger than the minimum bending radius acceptable to newly developed Bend Insensitive Fibers (BIF), the above-mentioned RDR will include bend radii, measured on mandrel, equivalent to 6 times the outer diameter of the micro-duct.

Undulation

In addition, when taking the coil-set and the quality of installation into account, the micro-duct sections between the 90° bends cannot be considered straight in this model. In our case, a period of 600 mm and amplitude of 15 mm was chosen for a 4 mm OD duct, respectively 500 mm and 12,5 mm amplitude for a 3 mm OD duct.

Under these conditions the adopted RDR can be considered severe enough to replicate real indoor installation conditions.

Micro-cables and micro-modules

For this study 4 different micro-cables (MC) were chosen.

- For pulling analysis : one light-duty micro-cable (LDMC) Ø 2 mm and one ruggedized micro-cable (RMC) Ø 2.5 mm.

- For pushing analysis : one flexible micro-cable (FMC) Ø 1.5 mm and one stiff micro-cable (SMC) Ø 1.8 mm

Micro-ducts

Two sizes are considered.

- For micro-cables with an OD up to 1.5 mm : a 2 mm ID micro-duct

- For micro-cables with an OD from 1.5 to 2.5 mm : a 3 mm ID micro-duct

Other relevant parameters applicable to the reference model are listed on table 1, below.

3.2 <u>Performance analysis</u>

Calculation basis

The installation performances, i.e. pushing/pulling distances and number of bends passed, are the result of calculations based on the theory of cable installation in ducts [2]. Over the last decade the results obtained with this theory have been closely matching field experiences and thus enjoy a high degree of reliability.

Microcable	Light Duty	Ruggedized	Flexible	Stiff
Code	LDMC	RMC	FMC	SMC
Outer diameter (mm)	2.0	2.5	1.5	1.8
Linear Weight (g/m)	3.0	5.0	1.8	2.4
Stiffness (Nm^2)	$8.0e^{-05}$	$2.4e^{-04}$	$2.3e^{-05}$	$5.5e^{-04}$
Microduct				
Outer/Inner diameter (mm)	4/3	4/3	3/2	4/3
90° Bend Radius (mm)	24	24	18	24
Friction (Dry)	0.25	0.25	0.25	0.25
Friction (Lubricated)	0.10	0.10	0.10	0.10
Undulation Ampl. (mm)	15.0	15.0	12.5	15.0
Undulation Period (mm)	600	600	500	600

Table 1: Micro-cable and duct parameters

Manual pulling

Although considered the preferred method by electrical contractors and some operators, massive scale FTTH deployment in MDUs by manual pulling present several shortcomings like : the pulling line cutting through the micro-duct over bends, manual pulling forces exceeding the maximum allowable tensile load of the micro-cable, whether ruggedized or not, sometimes the failure to reach the duct end and last, but not least, being often more time-consuming than expected. The performance comparison chart shown on Fig. 2, below illustrates this.

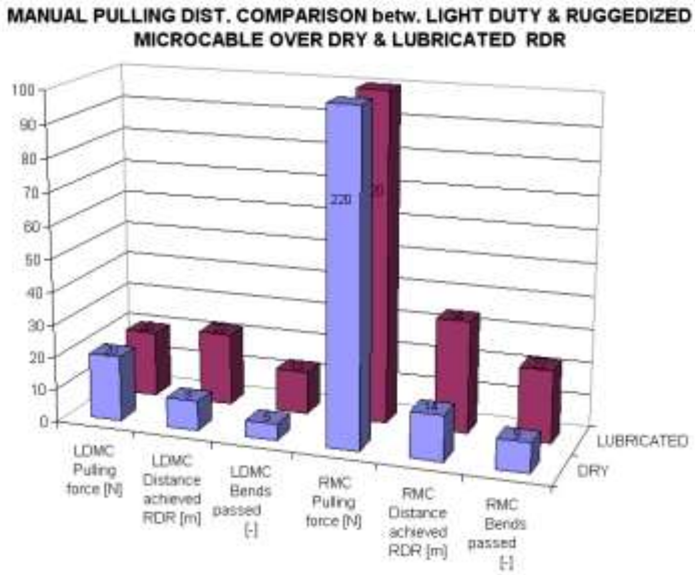

Figure 2: Comparison chart for manual pulling

This chart indicates the maximum pulling distances and number of bends passed with an LDMC and an RMC in a dry and a lubricated duct. Pull distances with an RMC are approximately 50% superior to those achieved with an LMDC, be it in a dry or lubricated duct. Under most favorable conditions, i.e. with lubrication providing for a coefficient of friction equivalent to 0.1, the performance does not exceed 34 m pull distance and 22 bends. It will be noted that a coefficient of 0.1, in presence of LSZH (Low Smoke Zero Halogen) materials is not obvious. Therefore the result shown here indicates that the manual pulling method for micro-cabling in MDUs is subject to strong limitations in terms of distances and number of bends, i.e. pulling 9 to 22 m with LDNC and 14 to 34 m with RMC.

Manual pushing

Among the innovative propositions by the industry the concept of Permanent Access Cables in MDUs has met a favorable response especially for riser applications in MDUs [3]. Permanent Access Cables contain several loose fiber MMs. Access to MMs is possible through window-cuts at any point along the cable. From these windows it is possible to extract a few decameters of MM. The extracted MMs are then pulled in pre-wired micro-ducts or pushed manually into empty ducts for the horizontal connection to the customer. Pushing MMs or micro-cables in micro-ducts appears simple but the operation remains risky and relatively tedious due to the short distance over which they can be freely pushed by hand without buckling between the fingers and the micro-duct entry, see Fig. 3.

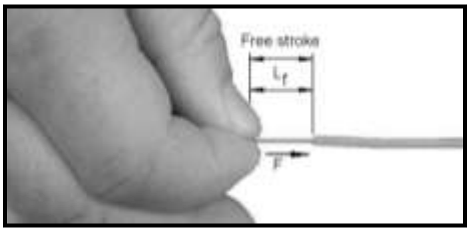

Figure. 3: Free stroke L_f

The free-stroke L_f is a function of the stiffness and the manual force exerted by the installer. This function is expressed in the Euler's Buckle-Formula [4! . The chart issued from this formula see Fig. 4 indicates the free-stroke L_f applicable for a FMC and a SMC .

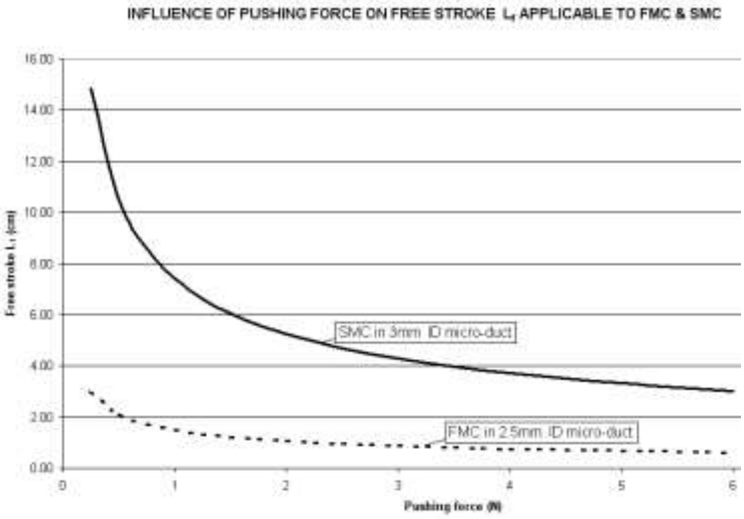

Figure 4: Free stroke L_f versus manual push on stiff and flexible micro-cable

This chart shows that manual pushing of the FMC is not a practical proposition: the max. admissible calculated pushing force (in presence of a 2 mm ID micro-duct) is 6 N. With such a push, the free-stroke L_f is 0.6 cm. For SMC, when the max. admissible calculated pushing force (in presence of a 3mm ID micro-duct) of 20 N is applied, the free-stroke L_f (not shown on fig. 4) is 1.7 cm. Furthermore the operator is must push exactly in line with the tube center-line otherwise the micro-cable will buckle prematurely. One can conclude that it would be advantageous to replace the manual pushing process by a mechanical pushing device, operating with a free-stroke L_f length inferior to applicable L_f. The pushing performances, achieved using FMC & SMC are described in the comparison Chart shown on Fig. 5. Either stiff or flexible, the performances are identical for FMC and SMC. For FMC, it is predominantly the lack of stiffness which limits it's progress over straight sections. For SMC it is predominantly the excessive stiffness which limits considerably the number of bends which can be passed. Considering the short distances achieved and the unmanageable free-stroke L_f manual pushing is not really suitable for indoor installation.

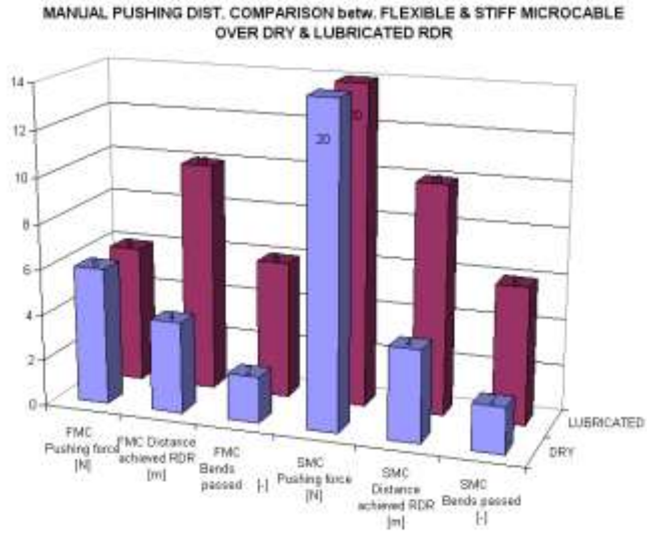

Figure 5: Comparison chart for manual pushing

Is cable jetting, a well proven and accepted method for outdoor underground Fiber network construction, also a valid proposition for indoor cabling? To answer this question a comparison chart is shown on Fig. 6. The calculated distances achieved by manual pulling, pushing and jetting over the RDR are calculated for dry (μ=0.25) and lubricated (μ=0.1) conditions. The number of bends passed (not shown) will correspond to the value of the calculated distance in meter divided by 1.5.

From this chart it appears that RMC can be efficiently pulled provided that the coefficient of friction is close to 0.1. SMC does not perform sufficiently well with any of the three installation methods. Jetting appears to be technically the most appropriate method for placing FMC and LDMC in micro-ducts. But as mentioned before, most existing jetting machinery capable of installing the available range of micro-cables presenting an OD between 0.8 and 3 mm is too bulky and too expensive for indoor

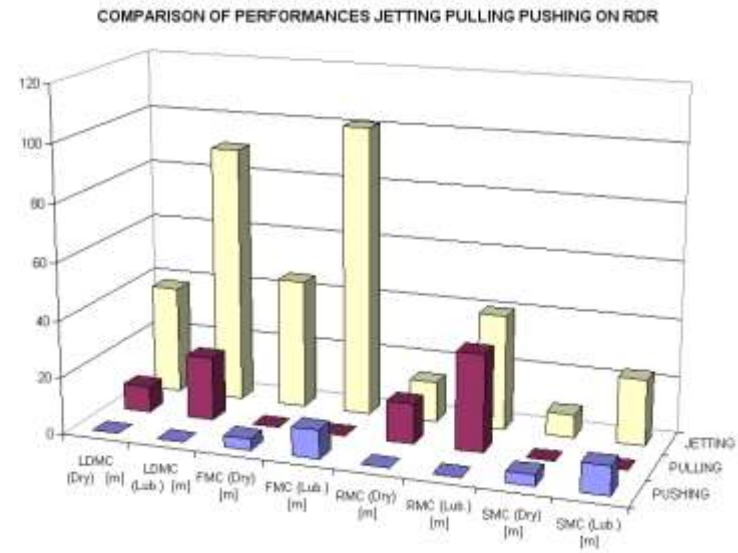

Figure 6: Performance comparison chart between Jetting, Pushing & Pulling

applications. Therefore a new cost-effective machinery capable of pushing or jetting above-mentioned micro-cables in micro-ducts with IDs between 1.5 and 3.5 is needed.

4. Main features of the new mechanical aid

To satisfy the requirements of Operators and contractors the new generation of mechanical aids must be:

- cost efficient, i.e. providing for reduced installation time.

- available at an affordable price, i.e. a cost level fitting the normal operating budget of a small contractor

- user friendly for traditional installers acquainted with copper cablings, i.e. a tool which does not require adjustments by the operator, and adapted to specific network designs with specific micro-cables and ducts, thus eliminating any risk of damage to the micro-cable caused by buckling or burning through slippage.

- versatile, i.e. modular design capable of meeting future requirements of Operators or network designers in terms of different micro-cable and duct configurations, easily modifiable by the installer, in order to maintain an efficient and safe installation within said various configurations, see Fig 7.

- ergonomic, i.e. light and easy to use in confined space, with low air consumption allowing an efficient use of air bottles by avoiding carrying on site cumbersome air compressors and after-coolers

- dependable and economical, i.e. making usage of equipment already belonging to the contractor's tool-box, like standard battery powered drills, etc. No need for special tools.

5. An available product.

A new product, fulfilling the above-mentioned requirements has been developed. The modular concept ensures the safe pushing and jetting of micro-modules and micro-cables with OD from 0.8 to 4mm in ducts. To facilitate the set-up in confined spaces a cartridge combining the inlet guiding, the sealing and pressurized air feeding functions will be first preassembled and then mounted on the pushing mechanism. A factory preset slipping clutch protects the micro-cable against buckling. The "free" gap between the pushing wheels and the entry point of the air inlet chamber is considerably shorter than the applicable stroke length L_f. The apparatus is described on Fig 7 & 8

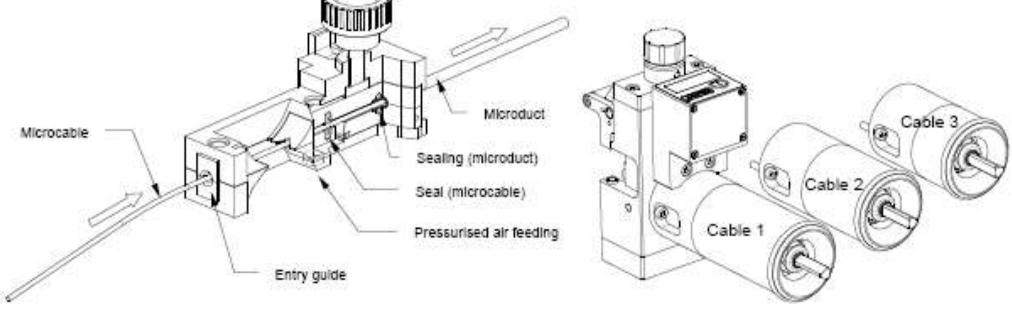

Figure 7: Cartridge design and modular concept

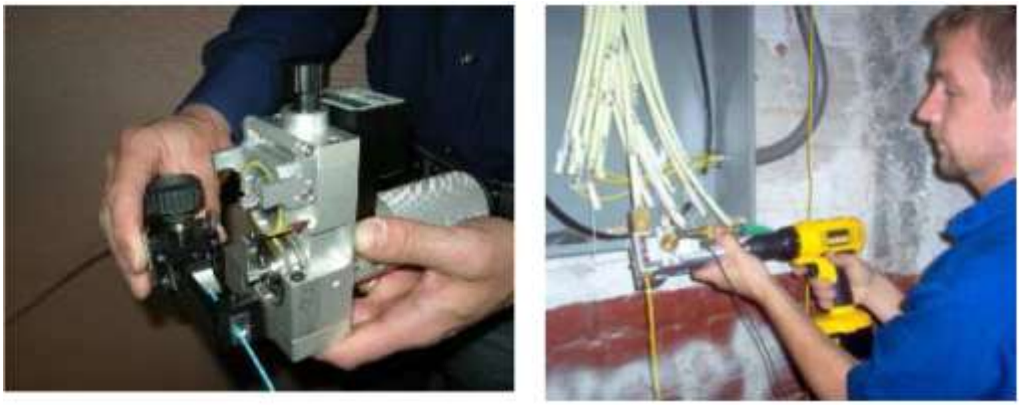

Figure 8: Field trial, installing the cartridge, jetting from MDU Terminal

6. Field experience and conclusion

Fiber drop installation productivity tests have been recently conducted within a large scale FTTH deployment project in MDUs where drop-lengths averaged 30 meters. The respective productivities achieved with manual pulling and with powered pushing and occasional jetting are shown on table2.

	Direction of installation	
	From ONT to MDU Terminal	From MDU Terminal to ONT
Installation method	Drops / day	Drops / day
Man.Pulling in pre-roped duct	10	10
Pushing/Jetting with air bottle	32	240

Table 2: Productivity comparison

It appears that, compared to manual pulling, productivity performance results of Jetting with an adequate tool, such as described before, are far superior. Indeed the tests revealed that the manual pulls were too frequently hampered, sometimes even impossible to achieve, due to the friction build-up caused by the inevitable undulation and numerous bends met in MDUs. A new generation of tools affordable for small contractors, efficient over tortuous routes and user friendly has been developed and successfully introduced.

Acknowledgements

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