Intelligent Cable Jetting (Blowing) Machine: Records Installation Parameters and Safeguards Cable

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Abstract

A jetting (blowing) device to install cables into ducts is presented which detects and records installation parameters. In this way cable faults are minimized, and when occurring they can be found easier. Also an electronic safeguard has been implemented (half automatic) and in the future even a full automatic device is planned (not only safe installation guaranteed but also enhanced performance). Today the device monitors cable pushing force, slip in the mechanical drive, air pressure and temperature and cable velocity.

The maximum pushing force depends on cable and duct parameters, can be calculated in principle, but is usually determined by a crash test. The theory of cable (in duct) buckling and a factory (lab) test proposal for qualifying the maximum cable pushing force will be treated also in this paper.

Keywords: Optical cable; duct; installation; jetting; blowing; pushing force; crash test; slip; temperature; pressure; ducts; intelligent.

1. Introduction

Figure 1. Damaged cable, was pushed too hard during installation in duct

Installing cables into ducts by jetting (a synergy of pushing and blowing) has become the standard technology to install optical cables into ducts, with several advantages over the traditional technique, pulling with a winch [1,2]. Today there is an increasing demand (especially in Germany and the USA) for intelligent cable jetting devices which detect and record the installation parameters, to find the cause when a cable fault occurred. Cable installers miss direct feedback on their installation work and network owners are usually confronted too late with these faults, see e.g. Figure 1.

Detecting and storing (electronic monitoring and registration) the right cable installation parameters can give the required indication to guarantee quality of the network. A device that does this all is described in this paper. As a further step also an electronic safeguard has been implemented (half automatic function). For the future even a full automatic device is planned.

2. Equipment

In Figures 2 and 5 a functional drawing and a picture of the intelligent jetting device are shown, respectively. Critical parameters during jetting of cable in duct are typically:

1) The force at which the cable is pushed. For instance excessive buckling of the cable (inside the underground duct) can occur, while this is not recognized during installation.
2) Slip between the mechanical drive and the cable can cause damage.
3) Too high (air) temperature for installation (exceeding cable specs or negative impact on installation).
4) Too high air pressure. Usually more dangerous for the duct than for the cable.
5) Too high cable velocity. The higher the cable speed, the larger the chance of "accidents"

Although not all of these parameters really cause damage, they are all monitored as a function of installed cable meters (x) in the "intelligent" jetting device. Temperature (T_d) of the compressed air, ambient temperature, air pressure (p_d), motor pressure, cable speed (v_c) and drive belt speed (v_d) are measured directly. From this the pushing force (F_a) and slip are obtained indirectly (calculated) by the machine. The calculated pushing force was verified by several tests where it was measured as a function of motor pressure and drive belt speed. The machine warns for too high speed and temperature and shuts off when slip occurs or a preset value of the maximum pushing force is passed. The latter depends on cable and duct parameters, can be calculated in principle, but is usually determined by a crash test (see Section 4). The theory of cable (in duct) buckling and a factory (lab) test proposal for qualifying the maximum cable pushing force will be treated as well in this paper (see Section 4).

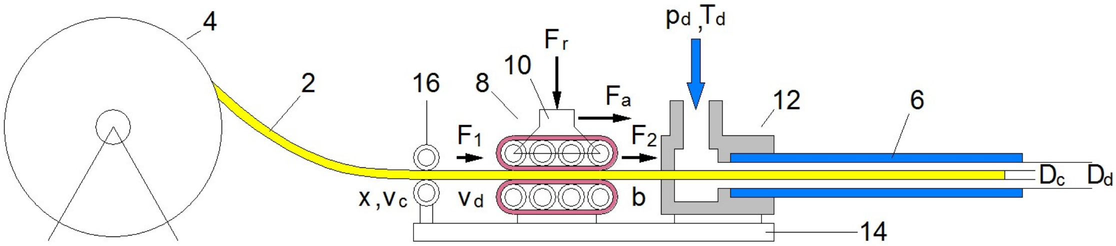

Figure 2. Functional drawing of "intelligent" jetting device

		Jetting Report	
Project-#	Jetting process report example		Date, Begin time: 2/15/17 6:10 PM
Trace Section	Trial circuit PSA		
Company name	Plumettaz SA		Operator: CHP
Remarks	New report to present the PDF layout in english		
Duct specs		**Cable specs**	**Devices**
Manufacturer: Wavin		Manufacturer: Nexans	Jetting machine: IntelliJet-P02
Duct type: SNR12 (12x2,0; 12/8)		Designation: A-D(ZN)2Y nx12	+ Slipping clutch [ ] + Lubricator [ ]
Duct assy: 3x12 in 50x4.5		Cable Ø: 6.3 mm Fiber amount: 72	Lubricant: MicroJetting Lube
Color/marks: Red		Reel Nb.: 654321	Compressor: MK17
Inner design: Grooved		Metering: Start: 204 m End: 2485 m	+ Oil separator [X] + aftercooler [X]
Duct temperature: 15 °C		Cable temperature: 10 °C	Cable Tap type: [X]
Summary:	Max pushforce: 275 N (Measured by the crashtest)		
Trace distance: 2303.0 m	Weather: 20.0 °C, 50.0 % humidity.		Jetting temperature: 26.6 °C
Jetting duration: 02:06:44	Operating mode: recording + supervision		GPS Location: 46,9593°; 7,4671°; 559 m

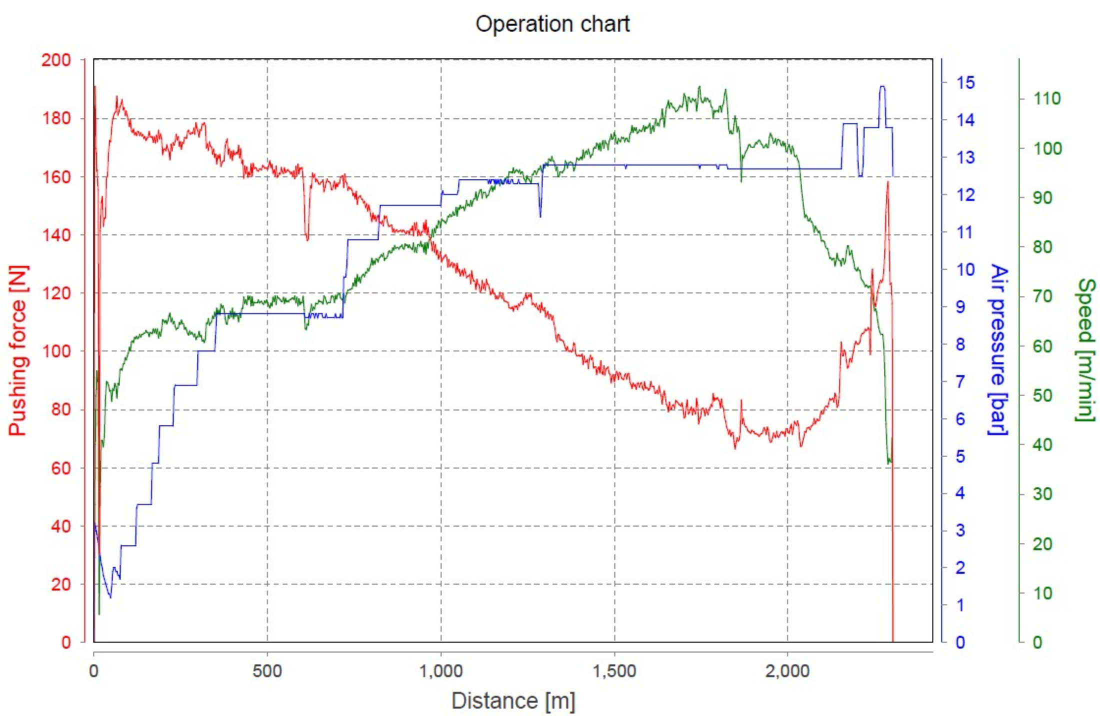

Figure 3. Jetting report

3. Tests

3.1 Calibration tests

The jetting device is first calibrated for the different parameters. For the pushing force a loop of cable is run through the device at different motor pressures, while measuring mechanically the pushing force, see Figure 4. The cable runs for this test also through a looped duct circuit of which the tortuosity can be regulated (folding extra loops), as well as the force before entering the loop (applying a small friction force). In this way mapping of the pushing force as a function of motor pressure and cable speed is done.

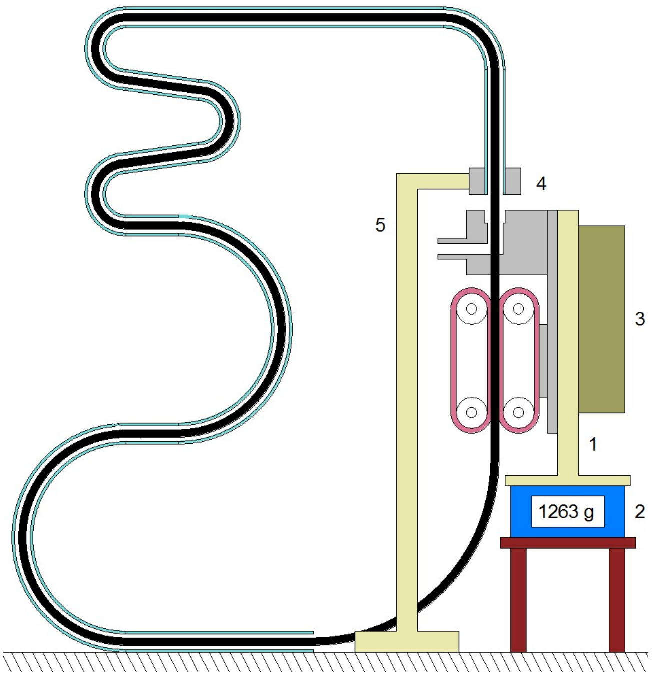

Figure 4. Schematics of calibration of pushing force

3.2 Running tests

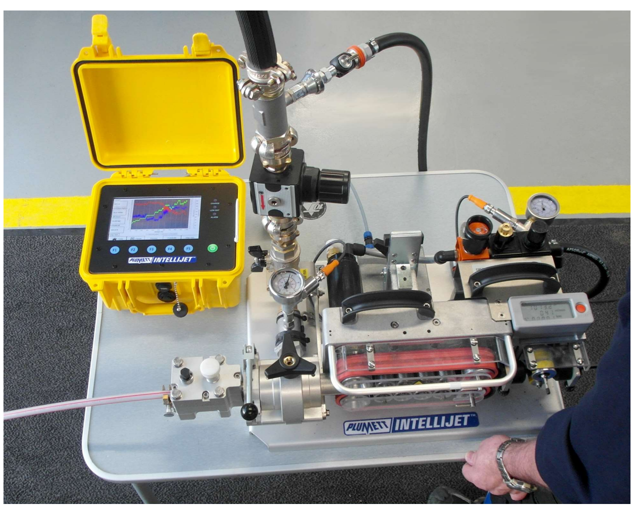

Figure 5. Jetting device made "intelligent"

Tests have been done with 6.3 mm OF cables in a 1500 m long 10/8 mm microduct (in a "Figure 8" configuration) and in a field installation in a 2300 m long 12/8 mm microduct, see Figure 3.

Besides monitoring and storing the parameters (shown in Figure 3 are pushing force, duct air pressure and speed) as a function of installed meters, also the half automatic functions (can be switched off with "mentioning" in protocol) were tested. The machine could make an automatic stop when slip occurred, or when a preset value of the maximum pushing force was reached. Before the stop a warning was given (yellow blinking display).

3.3 Future

It is planned for the future to let the machine do the full control of the installation from crash test to the end of the installation. Not only safe values of the parameters are guaranteed here, also the most economic combinations will be selected, enhancing the performance of the installation. For instance care will be taken that a right balance between air (duct) pressure and pushing force is set, a balance which is not always respected, especially in difficult installations, often working far away from optimum.

Besides the intelligent version (and upgrade kit) of the device for cables 4-16 mm, now also a device for 1-8 mm becomes available.

4. Maximum Pushing Force

In this paper an installation device is described to secure safe installation of the optical cable in the duct. An important parameter here is the maximum pushing force on the cable, which shall not be exceeded during installation. Although a maximum pulling force is usually specified for optical cables, there is usually no indication given for the maximum pushing force. As the pushing force is applied to the cable jacket, this is already a difference with the pulling force, which is usually specified for a pulling force applied to the whole cable, including the strength member. Also the cable may buckle excessively in the duct when it is pushed. Here the stiffness of the cable plays a role, as well as the "space to buckle" in the duct. It is recommended to perform a field crash test before the installation, determine until which pushing force the cable appears "undamaged" (checked visually) and adjust the maximum pushing force accordingly. More security is given by a factory (lab) test (standard). An idea of both tests is given in this section.

4.1 Field crash test

The crash test is a test which is done in the field before the cable is installed in the duct. A length of e.g. 1 m of transparent duct (of the size used for the installation) is mounted in the jetting device. At the end the duct is closed by an end stop. Then the cable is run at full speed until crashing at the end. This is done with step by step increasing pushing forces, until the force appears to be too high. The criteria for this might be:

1. Slip between the drive mechanism (belt or wheel) and the cable. This is dependent on the device (and on wear of its components), on the device settings (cable pinch force) and also on weather conditions (temperature, rain) and lubricant used.
2. Buckling of the cable between drive mechanism and pressure chamber (not relevant for devices with the drive wheel inside the pressure chamber). This is also dependent on the device (effective free buckling distance b between drive mechanism and pressure chamber; note that this is only half the distance defined in [3], because the ends are not perfectly forced straight aligned). This kind of buckling is usually catastrophic.

$$F < \pi^2 \frac{B}{b^2} \tag{1}$$

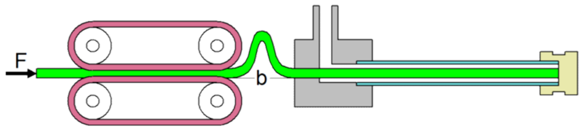

Figure 6. Buckling of cable after drive belt

Formula (1) for the maximum push force F depends on the cable stiffness B (often not known by the man in the field) and the effective free buckling distance b, also difficult to estimate (where the cable leaves the belts, there is a transition zone from "pressed" to "free", hard to determine).

3. Excessive buckling (snaking) of the cable inside the duct. This is dependent on the space for the cable (diameter D_c) inside the duct, and hence on the duct internal diameter D_d. It is difficult for the operator to judge which degree of snaking is allowed. The observed confined buckling length b might serve as a guide [4].

$$F < \frac{2B}{(D_d - D_c)R_b} \tag{2}$$

$$b > \pi\sqrt{2(D_d - D_c)R_b} \tag{3}$$

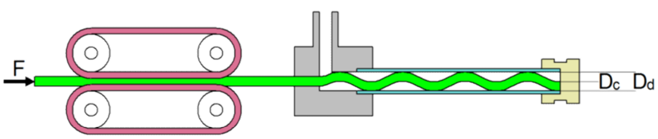

Figure 7. Buckling of cable in duct

Formula (2) for the maximum pushing force F depends again on the cable stiffness B. But, the observed confined buckling length b in formula (3) is directly related to known parameters D_c, D_d and the cable's minimum bend radius R_b (sine buckling as worst case [4]), no need to know the cable stiffness and the pushing force! It is not yet sure that respecting the minimum bend radius is a sufficient condition for the cable to guarantee 100% optical performance. This could be confirmed in the Factory test.

4.2 Example of factory (lab) test

An example of a factory test is given in Figure 8 (under pulling force) and in Figure 9 (under pushing force). A short section of duct (again e.g. 1 m and may be transparent) is placed near a driving mechanism (might be one from a jetting device). A cable is mounted inside the duct and through the driving means, with sufficient length on both sides to be able to perform optical measurements. A blocking sleeve (e.g. a thin metal cylinder) is mounted (e.g. glued) on the cable inside the duct between end stops with feedthroughs for the cable (not for the cylinder). The test can be done 2 directions, one giving a crashed pull (Figure 8), the other a crashed push (Figure 9). Optionally the temperature is regulated over the short section of test duct, the drive belt and a still shorter piece of dummy duct (inside the blue rectangle).

First a pulling test can be done. This isolates the effect of applying the force on the jacket from buckling. Also a slip free condition can be set. The criterion for passing this test can be visual and/or optical. Then a pushing test can be done, now also measuring the effect of buckling of the cable inside the duct. The test can be repeated a few times to and fro. A maximum pulling force and a maximum pushing force (lower) will be found. Alternatively the cable is not tested until its limits, but until a pre-determined max.

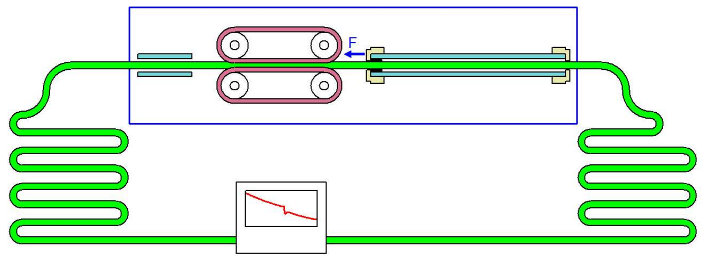

Figure 8. Example of factory test under pulling force

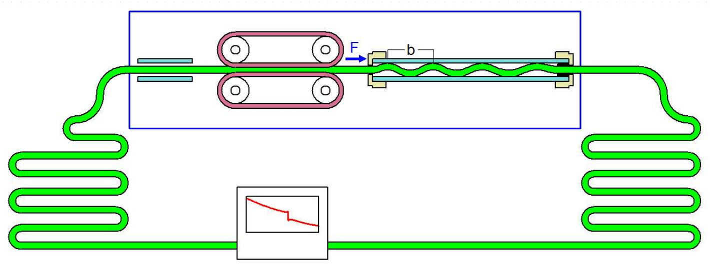

Figure 9. Example of factory test under pushing force

4.3 Damaged length in case of too high force

It is often debated how much cable needs to be replaced when the cable was installed with excessive pushing or pulling force. In this paper no recommendation is done for this, but some physics which might help to take the right decision are presented.

In case of too high pulling forces, an idea of the magnitude of residual forces is given in [5], concluding that the effect of the high cable stress is usually not exceeding 50 m, that the residual force is less than 50% of the maximum force for a perfect straight duct, even usually less than 1/3rd of the maximum force for more tortuous trajectories, and that stress induced crack growth in the optical fibers is not likely to play a role at all when the fibers did not break during installation.

In case of too high pushing forces, the force reduction is even faster than with pulling, because buckling of the cable generates extra friction [3]. The force reduction in force F is given as a function of position x (straight ducts) by formula (4), with F_0 the force at x=0 (at the jetting device) and f the coefficient of friction between cable and duct (0.08 in the example) [3]. In Figure 10 an example is shown for a cable with diameter D_c of 6.5 mm, weight W of 0.4 N/m, stiffness B of 0.2 Nm^2 and minimum bend radius R_b of 130 mm (20 × D_c) in a 50 mm duct with internal diameter D_d of 40.8 mm (relatively large duct for such a small cable, but for the smaller microducts really a high pushing force is needed to get excessive buckling, e.g. 879 N for a 10/8 mm microduct, makes no sense). It follows that the maximum applied pushing force F_0 at x = 0 shall not be larger than 90 N. Also here most of the forces are gone when the distance to the jetting device exceeds 50 m.

$$F = \frac{F_0}{1 + f\frac{D_d - D_c}{\pi^2 B}F_0 x} \tag{4}$$

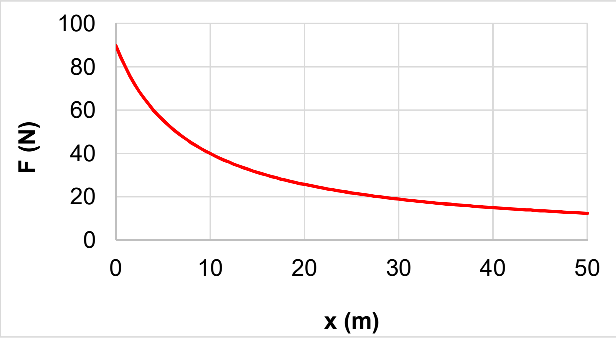

Figure 10. Pushing force reduction for a 6.3 mm cable in a 50/40.8 mm HDPE duct

5. Conclusions

A jetting device to install cables into ducts which detects and records installation parameters, and also has a half-automatic shut-off function, is presented. It monitors cable pushing force, slip in the mechanical drive, air pressure and temperature and cable velocity. A crash test and a lab test for the pushing force is also described.

6. Acknowledgments

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7. References

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8. Authors

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Christian Pache received his Diploma as Microtechnic Engineer at the HEIG-VD in 1992. At the same time, he successfully realized the drive transformation of common car from fuel into electrical. After 8 years of experience at ABB Geneva in the mechanical development of railway transformers and auxiliary converters, he completed postgraduate training with a diploma in project management (2001). Practicing this knowledge one year at Demaurex SA (CH) and then 3 years as IT-teacher (MS-Office & Project). 9yrs at Maillefer Extrusion SA (CH) as Project manager, Sales and Component Manager, doing extrusion lines manufacturing and machine development. Christian.Pache@plumettaz.com is now since two years active as Project manager at Plumettaz SA (CH) in the development of new intelligent functions on some existing cable-jetting machines such as the IntelliJet and Intelli-MicroJet, in close contact with a German partner: Vetter GmbH Kabel-Verlegetechnik.