Blown cable

© Kabculus
www.kabculus.com

March 29, 2006

1 Introduction

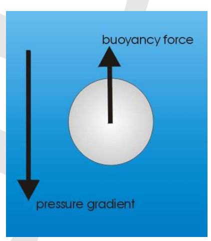
Under certain circumstances it is possible to rapidly install cable with compressed air. To do this it is generally necessary to have a pre-installed duct. The duct is ordinarily buried in the ground, with its ends exposed above ground. That is typically done during some sort of construction period. The cable is installed at a later time, when other circumstances make its presence necessary or advantageous.

2 Propulsive forces

Cable blowing uses buoyancy forces and air drag to install the cable into the duct.

2.1 Buoyancy forces

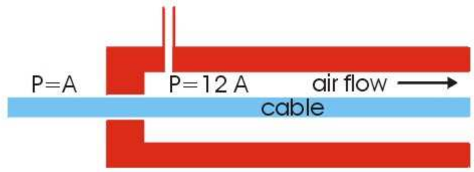
Consider first the buoyancy forces. When a body is immersed in a fluid, it experiences local forces which oppose the pressure gradient in the fluid. For example if a table tennis ball is immersed in a swimming pool, it experiences an upward force corresponding with the pressure gradient in the water, which points vertically downwards.



By establishing an axial pressure gradient in the air in the duct, it is possible to generate corresponding axial body forces on a cable inside that duct. The force on the cable then acts in the opposite direction to the pressure gradient.

2.2 The duct head

The usual method is to attach an apparatus containing an air seal for the cable and a connector for the duct at the duct entrance. The duct is then pressurised, typically at about 12 atmospheres, by means of a compressor that pumps air into the apparatus. At the other end, the duct is open, and the pressure there is one atmosphere. Consequently there is a pressure gradient pointing from the open end to the pressurised end. It should be noted that this pressure gradient is generally not constant. It causes a buoyancy force on the cable, acting towards the exit.



2.3 Stuffing device

In the immediate vicinity of the air seal, there is a very large pressure gradient between the inside and the outside. This is because the external air is at a pressure of 1 atmosphere, and the internal air is at a pressure of 12 atmospheres, and the distance over which this pressure change occurs, that is the axial thickness of the seal, is very short compared with the length of the duct. Naturally this very large pressure gradient results in very large buoyancy forces in the cable tending to push it back out of the seal. In order to overcome this force, and push the cable into the duct through the seal, the apparatus usually includes some form of traction that can grip and motivate the cable. Typically, two rubberised tracks grip the cable between them, and rotate together in such a way as to drive the cable through the seal and into the pressurised chamber.

2.4 Air drag

Because the duct exit is at a lower pressure than the entrance, there is a flow of air from the entrance to the exit. This flow has to be maintained throughout the installation process. Where the flow passes over the cable, it creates a dragging force by interacting with the surface of the cable. The magnitude of the force depends on the surface texture of the cable, the flow speed of the air, and the state of that flow. The flow can be laminar or turbulent, or a range of intermediate conditions. In addition to the drag on the cable, the air flow creates a drag on the duct itself. These two drags, on the cable and on the duct, correspond with an equal and opposite drag on the gas, which tends to impede its progress towards the exit.

The two forces of buoyancy and air drag combine to produce an overall force on the cable towards the exit. This force is distributed over the length of the cable. It tends to be greater towards the exit, because that is where the air flow and pressure gradient are greatest.

3 Impeding force - friction

Of course these are not the only forces acting on the cable. There are other forces that occur where the external surface of the cable and the internal surface of the duct interfere with one another. One of the most important of these is the frictional force. It opposes the aerodynamic forces and tends to prevent the cable proceeding towards the exit. The frictional force tends to be much larger in bends in the duct than elsewhere. This is generally referred to as "the capstan effect".

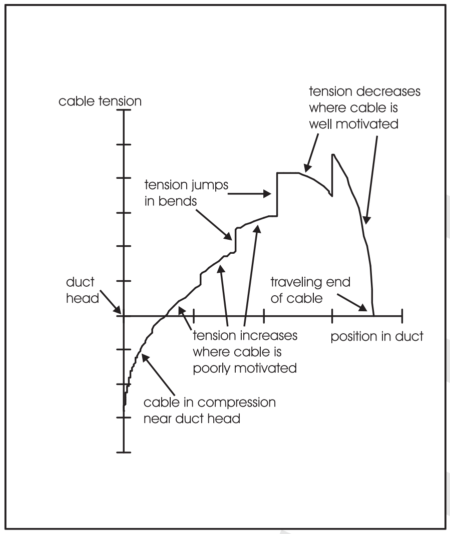
4 Cable tension

4.1 Capstan effect

To properly understand the capstan effect, it is necessary to take account of another force. That is the cable tension. When cable passes through a bend, the cable tension interacts with the reaction between the cable and the duct wall. Ignoring cable stiffness, the reaction is proportional to the tension. This then produces a backward acting friction force per unit length of the cable that is approximately proportional to the tension. In order to balance this, the backward acting tension on a unit length has to be less than the forward acting tension on that unit length. Hence the tension must increase as the cable passes through the bend. The tension is greater immediately downstream of the bend than it is immediately upstream of the bend. The relationship is exponential.

4.2 Tension profile

The cable tension increases, going down stream (towards the exit), in each and every bend. If it were not for the aerodynamic forces, the cable tension would never decrease going down stream. This would result in rapidly increasing tension. This is the reason why it is typically impossible to pull a cable through a long duct by means of a pre-installed hawser. The tension in the hawser, where it passes through bends, would be so large as to damage the duct or break the hawser itself. The reason why aerodynamic cable installation results in much greater achievable installation lengths than does cable pulling is because of the resultant distributed body force. It is possible for the cable tension to decrease from one bend to the next bend going downstream, towards the exit, because of the aerodynamic propulsion.



When cable is blown through a duct, hawsers are typically not used. Consequently the travelling end of the cable is free, and the tension there is zero (except when traversing bends, in which case it can be negative, i.e. in compression).

5 Improved cable motivation towards duct exit

When the cable end is not far from the exit, the air flow there is relatively high, and this results in good cable motivation in such regions. The consequence of this is that the cable tension decreases between bends. Near the duct entrance the air flow is relatively slow (although the mass flow rate is everywhere the same) and this results in poor cable motivation. Thus in upstream regions the cable tension tends to increase, whilst in downstream regions it tends to decrease.

6 Possible cable compression at duct head

If the duct is long enough, and if a sufficient length of cable is inserted, then the tension will become negative near the duct head. In other words, the propulsive effect of the air in the downstream regions is no longer sufficient to keep the cable in tension near the duct head, and it is necessary to push it from behind. Consequently the cable stuffing device situated just outside the duct head has to provide not only the force due to the pressure gradient pushing the cable back out of the duct, but also that force required to make up for the loss of tension. In such cases the device is ordinarily rapidly overwhelmed, and the cable insertion ceases.

