EASY PIPE - a New Technology for Trenchless Installation of Large Diameter Steel Pipelines

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Abstract
In the past several methodologies have been developed for the trenchless installation of gas- and oil pipelines underneath obstacles like rivers, railways, runways etc. As the most popular technologies so far the so called Microtunneling (MT) or Pipe Jacking and the Horizontal Directional Drilling (HDD) have proven to be highly efficient methodologies. The newly developed EASY PIPE technology combines elements of both MT and HDD together with innovative procedures and pieces of equipment. As a result EASY PIPE can be used in nearly all kinds of soil and rock without requiring permanent casing pipes and thus opening up new perspectives for cost effective trenchless pipeline installation with comparably low risk during installation.
EASY PIPE –
A New Technology for the Installation of Gas and Oil Pipelines in Difficult Soil Conditions

1 Introduction
In the past several methods and systems were developed for the trenchless installation of pipelines in environmentally sensitive areas. In the field of large diameter steel pipe installation for the oil and gas industry two major technologies have been proven as most efficient methods – the Pipe Jacking methodology (= Microtunneling = MT) and the Horizontal Directional Drilling technology (HDD). The herein described Easy Pipe method (EP) combines elements of these two established construction methods with innovative components extending the range of applications.

2 Current Technologies
2.1 Microtunneling (MT)
The standard Microtunneling method is a so called 1-step construction method whereas the drilling process and the installation of the (conductor) pipes are carried out in a single operation (Fig. 1). The MT-method allows tunnel lengths over 500 m and borehole diameter of more than 2,000 mm. It can be applied in nearly all kind of soil conditions ranging from clay, sand, gravel as well as rock up to more than 400 MPa. Ground water pressure of more than 5 bars is also no restriction to this technology.

Fig. 1: Standard Microtunneling as a 1-step operation for trenchless pipeline installation [1].

Due to the fact that the jacking pipes in the MT-process are normally made of concrete these pipes are not useable in the pipeline systems of the oil and gas industry. Therefore the final steel pipeline needs to be installed inside the concrete casing pipes which means an additional working step as well as a large borehole diameter.
To summaries, the advantages and disadvantages of Microtunneling for the installation of steel pipelines underneath obstacles can be described as follows:

+ MT can be used in nearly all kind of soil and rock
+ MT means a low risk during construction
+ MT can be used for large diameter pipelines

- MT is a relatively slow construction technology
- MT is relatively expensive (large diameter boreholes, conductor pipes)

2.2 Horizontal Directional Drilling (HDD)

The HDD technology is a 3-step operation consisting of pilothole, prereaming and pullback (Fig. 3). With this method all kind of tensile pipelines (e.g. PE, steel) can be installed directly into a borehole. Crossing lengths of more than 2,500 m (12” pipeline) have been achieved and pipelines up to 56” (have been installed successfully by HDD.

The major disadvantage of HDD is the high sensitivity with regard to geological conditions. In particular gravely or stony ground with low cohesion often cause problems when relatively large diameter boreholes have to be drilled before pullback of the pipeline.

This is mainly due to the fact that the borehole is only supported by drilling mud (no intermediate pipes are used). Therefore, in unstable soil conditions the borehole might partially collapse after a certain period of time and might lead to a stuck oil or gas pipeline during pullback operation (Fig. 4).
Fig. 3: Standard HDD as a 3-step operation for trenchless pipeline installation [2].

To summaries, the advantages and disadvantages of Horizontal Directional Drilling for the installation of steel pipelines underneath obstacles can be described as follows:

+ HDD is a relatively fast construction technology
+ HDD is an economical construction method
- HDD is limited to suitable ground conditions
- HDD implements a relatively high risk during construction

Fig. 4: Stuck pipeline during pullback operation.
3 Combination of HDD and MT

There have been several attempts to combine the HDD and the MT technologies in a way that the advantages of either technology are maintained while avoiding the corresponding disadvantages.

The most promising attempt so far has been the so called Push&Pull-Technology (PPT, Fig. 5) of company Herrenknecht AG developed and tested in 2001-2003. After pilothole drilling according to normal HDD-methodology in a first working step the drillpipe is connected to a modified AVN which is used as a reamer in the second working step (reaming and pullback).

Fig. 5: Working steps for the PPT-method.

In the course of intense field testing in Schwanau (Fig. 6 and 7) as well mechanical as hydraulically problems occurred. On the one hand the shear forces on the drillpipe in front of the AVN-cutting wheel were too high and on the other hand no stable mud circuit could be established without centrifugal pumps behind the AVN.

Fig. 6: Start of PPT field test.
Despite the described problems during the field testing of the PPT methodology and equipment this technology is still regarded as a potential alternative to HDD and MT. It has also distributed a large amount to the development of the subsequently described Easy Pipe method, which is regarded to be a less risky technology than PPT.

4 Easy Pipe (EP)

The Easy Pipe technology has been developed to allow for an economic trenchless installation of large diameter (800 – 1,400 mm) pre-fabricated and –tested steel pipelines for comparably long installation stretches (800 m) in difficult soil (e.g. gravel) and rock conditions (e.g. > 300 MPa). With the given geometrical dimensions most of the oil and gas pipeline projects can be covered (Fig. 8).

Fig. 8: Typical dimensions for large diameter oil and gas pipelines installed by HDD (average based on 79 reference projects).
4.1 Method Statement

The EP method is a 2-step operation where in a first step the borehole in its final diameter is installed by standard Pipe Jacking (Microtunneling) operation (Fig. 9). After the drillhead (AVN) has reached the target pit on the other side of the obstacle, the drillhead is disassembled from the jacking pipes. Instead, a connector piece is installed in between the jacking pipes and the pipeline (Fig. 10). In the final working step the pre-fabricated steel pipeline is pulled back into the borehole (Fig. 11).

Fig. 9: Drilling an EP-borehole along a pre-determined alignment by using intermediate jacking pipes.

Fig. 10: Exchanging the drillhead against a connector piece.

Fig. 11: Pullback of the oil or gas pipeline with the intermediate jacking pipes.

4.2 Equipment

Most of the required equipment is already available within the MT industry, for example the navigation system (Fig. 12), the slurry circuit, the power packs and the control cabins. Some other pieces of equipment need technical modifications, for example the main jacking station needs to be prepared for bi-directional operation mode (Fig. 13).
The only “new” pieces of equipment in the Easy Pipe technology are the bi-directional jacking pipes (push and pull). In the present design they are made of steel with a quick coupling system for fast and easy connection of pipes during drilling operation (Fig. 14). These connections can transfer 7,500 kN push and pull with a safety factor of 1,5.
4.3 Geometrical Dimensions

The envisaged pipeline diameters and lengths (Ø = 800-1,400mm, L = 800 m) can be achieved because special designed, bi-directional (push and pull) intermediate jacking stations will be used during the drilling operation. In combination with corresponding bentonite lubrication systems the skin friction during jacking can be reduced and controlled as in the MT industry (where this is common practice). Also, worn-out cutters can be changed downhole when corresponding AVNs are used (e.g. AVN 1200 TC), where a door enables access to the cutting wheel (Fig. 15). During pullback operation the annulus between pipeline and borehole will be filled with high viscosity mud for optimum stabilisation of the borehole and best-possible coating protection.

Fig. 15: Suitable AVN for Easy Pipe application [1].

4.4 Soil Conditions

By adapting the cutting wheel to the actual geological conditions of a crossing nearly all types of soil and rock can be handled by Easy Pipe (and MT). Even areas with bolders (Fig. 16) can be approaches with the EP method as long as the bolders are smaller than 1/3-1/2 of the cutting wheel diameter and the position of the bolders with
regard to the drilling alignment are suitable (cutting wheel must be able to get hold of the bolder in order to destroy it mechanically).

Fig. 16: Bolders in a sandy matrix [1].

4.5 Pipe Integrity and Pipe Coating

Apart from a mechanically damaged product pipe the impact on the pipe coating is an important criteria for a construction method, especially in difficult ground conditions like gravel etc. The lowest impact will occur when the MT-technology is used because the pipeline will be installed inside a concrete tunnel, while the highest impact can be assumed when using HDD as a construction method. Here, the pipeline will be pulled through an “open” borehole where several obstacles (e.g. stones) might have settled sometime during the reaming of the borehole and might lead to damaged coating or even stuck pipe during pullback (Fig. 17).

The EP method is in between these two technologies as far as quality assurance is concerned, because it is impossible that stones or bolders can fall in front of the pipeline. Also, the wall of the borehole will be smoothened during jacking and pullback by means of the jacking pipes (which have more or less direct contact with the borehole wall).

Fig. 17: During HDD pullback damaged pipe (42”).

Fig. 16: Bolders in a sandy matrix [1].
4.6 Drilling Mud

As mentioned above a HDD-borehole is only supported against collapse by the drilling fluid (water-bentonite-mixture). This requires – especially in difficult soil conditions – an extremely effective type of mud and a large amount of volume. At the same time, the drilling fluid needs to transport all cuttings through the borehole to the entry respectively exit point of the drilling alignment. Even with high-quality mud this is a tricky part of the operation, especially in large diameter boreholes, because the travelling speed of the fluid in the borehole is very low (some centimetres per second) thus asking for settlements during reaming phases.

In the MT and EP process only a much smaller volume of drilling fluid with much less quality demands (sometimes even water is suitable) is used. The cuttings are transported via a slurry line from the AVN to the recycling unit thus enabling high velocities and very little settlements inside the slurry line. Settlements inside the borehole can be completely excluded for both EP and MT technologies.

Furthermore, a large amount of drilling fluid necessary for the HDD drilling process will be displaced from the borehole during pullback operation (Fig. 18). All this drilling mud needs to be finally stored in accordance with environmentally concerns.

Fig. 18: Mud pit on a HDD crossing.

4.7 Time

An important aspect for any construction method is the required time for the installation of the pipeline. For Easy Pipe the drilling speed (ROP = Rate of Penetration) is comparable to that of conventional Pipe Jacking. Depending on the soil/rock conditions a daily progress of 15 – 30 m (in 24-hours) is forecasted.
The pullback of the pipeline (second step of the Easy Pipe operation) is estimated to be carried out with an average pullback speed of 150-200 m per day (24 hours).

4.8 Risk

The risk of the Easy Pipe operation is estimated to be much less than for the HDD technology because on the one hand a complete borehole collapse (Fig. 19) can be excluded from the scenarios (there is always a mechanical support of the borehole) and on the other hand the chance for bolders to get in front of the pipeline during pullback operation or in between pipeline and borehole is regarded to be much less than during HDD application.

Furthermore, the available pullforce in the Easy Pipe method is approximately 7.500 kN which is much more than even the biggest HDD-rigs can generate.

Fig. 19: Borehole collapse in the course of a HDD project.

4.9 Cost

At present definite costs cannot be evaluated, since there have not been enough practical tests. First estimations suggest that the Easy Pipe method costs are inferior to the cost of conventional MT (e.g. no permanent concrete pipes required, borehole diameter smaller, no additional working step for the pulling of the pipeline in the concrete tunnel etc.).

In contrast to HDD the specific installation costs do not mainly depend on actual soil conditions. Nevertheless there will probably be a cost advantage for HDD as long as this method can be deployed at all (limitations for HDD mainly due to soil conditions).

Reliable data for the cost profile of Easy Pipe can only be submitted after several projects have been executed under comparable conditions.
5 Conclusion

The newly developed Easy Pipe method is a combination of MT and HDD and will be mainly used for the installation of large diameter oil and gas pipelines underneath obstacles in difficult soil conditions.

When investigating the potential of any construction methodology the two key parameters are RISK and COST. In relation to the existing technologies Microtunneling and Horizontal Directional Drilling the Easy Pipe-specific estimations for these parameters is shown in Tab. 1.

Tab. 1: Estimation of risk and costs for different construction methods.

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<th>MT</th>
<th>EP</th>
<th>HDD</th>
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<tbody>
<tr>
<td>RISK</td>
<td>low (in any soil)</td>
<td>medium (in difficult soil)</td>
<td>high (in difficult soil)</td>
</tr>
<tr>
<td>COST</td>
<td>high (in any soil)</td>
<td>medium (in any soil)</td>
<td>low (only in suitable soil)</td>
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In addition to the established Microtunneling and Horizontal Directional Drilling technology Easy Pipe is another construction method which allows to quickly, safely and economically installing large diameter steel pipelines in difficult soil conditions.

[1] Herrenknecht AG