Direct Pipe ®: Latest innovation in pipeline construction - technology and references.

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1 Introduction

Various methods have so far been applied for crossing works in order to build steel or polyethylene pipelines as pressure lines. Pipe jacking and segmental lining allow for the construction of protective tunnels with subsequent insertion of the pipe string. The HDD method, in contrast, includes the construction of a pilot bore prior to pipe pull-in. Recent developments such as the Easy Pipe method comprise jacking processes -- where tight connection interim steel pipes are pushed towards the target shaft, coupled to a pipeline and then pulled back together. All these methods include a two- or multi-step pipe installation process. The multilevelness of these methods and pertinent aspects such as costs and project duration led to the development of the DIRECT PIPE® method: Steel or polyethylene pipes can now for the first time be jacked efficiently and fast in one operation process.

2 The DIRECT PIPE® method

The development of the DIRECT PIPE® method was based on parameters such as the creation of a one-step pipe jacking method, provision of an efficient alternative to existing methods, reduction of site-infrastructure surfaces and minimization of geological risks (e.g. drill-hole collapse). In addition, disadvantages of the existing methods needed to be eliminated, advantages to be combined and new technologies to be considered. The result is a combination of HDD, Microtunnelling and the Herrenknecht thruster unit Pipe Thruster, which was presented for the first time at the Hanover Fair 2006 and which has been proven in practice. The DIRECT PIPE® method includes the welding and testing of a pipeline (e.g. steel), which is stored on pulley blocks on the launch side. A microtunnelling machine is mounted in front of the pipeline. To facilitate TBM control, two to three angular steel pipes (connection pipes) are installed between the pipeline and the machine. The Pipe Thruster operates as thrust unit from the launch pit clamping the pipeline on the outside and pushing the machine as well as the pipeline into the ground.
The tunnel face is excavated by a microtunnelling machine similar to the pipe-jacking method, which has been established for several decades. The cutting wheel can be equipped with cutting tools adapted to the specific geological conditions. In contrast to HDD technology, larger boulders, hard rock as well as soft soils (gravel) can be crossed.

The tunnel face is slurry-supported using a bentonite suspension. The excavated material is removed via a slurry circuit with separation plant in order to separate the spoil from the slurry liquid before feed pumps transport the liquid back to the tunnel face. The micromachine is controlled from the operating container. A gyro compass is used for machine surveying.

The micromachine, pipes and connection pipes are designed conically, which increases the annular gap between the machine or pipe sleeve and the surrounding ground. Bentonite is injected into the annular gap for lubrication from the cutting-wheel assembly. In addition, a lubrication ring is mounted in the transition area between the connection pipe and the product pipeline, where most of the bentonite is added, in order to reduce the friction between the pipeline and the ground to a minimum. In contrast to pipe jacking, a Herrenknecht Pipe Thruster is set up in the launch pit instead of a jacking frame. The Pipe Thruster clamps the pipeline on the outside and pushes the pipes as well as the microtunnelling machine strokewise forward with its thrust cylinders.
Fig. 2: The Herrenknecht Pipe Thruster presented at the Hanover Fair 2006.

The Herrenknecht Pipe Thruster can be adapted to diameters ranging between 20” and 48” (500 up to 1,200mm) by a simple exchange of the clamping unit. The clamping units can be deployed on any pipe type and coating. The two thrust cylinders are designed for a stroke of five meters and a maximum pull and push force of 5,000kN each by advance rates of 5m/min. The Pipe Thruster is pivotable, the clamping unit can be pushed forward at various angles and the Pipe Thruster with a total weight of 45t has a modular design for easy transportation.

In the rear of the Pipe Thruster, a prefabricated and tested product pipeline is positioned on pulley blocks ready to be thrust forward. Different from pipe jacking or microtunnelling, the DIRECT PIPE® method allows for an installation of the slurry circuit from the start of the project not requiring a delayed installation and successive extension of the circuit: The slurry and pump system is operated parallel to pipe jacking along the entire drive length.

Due to this site configuration, the product pipeline can be installed in one step. The direct installation of the pipeline allows for continuous drill-hole support preventing hole collapse. The DIRECT PIPE® site configuration also allows for a basic launch and target shaft design. It is only necessary to provide a launch seal and firm foundation for the Pipe Thruster on the launch side in order to transmit the thrust forces to the soil. Upon arrival in the target shaft, only the TBM and the connection pipes have to be disassembled; the installation of the product pipeline in the ground is then already completed. Feed and slurry lines as well as control, data and power cables are led through the pipeline on special roller assemblies; they can be easily removed from the pipeline using a rope winch.
Advantages of the DIRECT PIPE® method:
- One-step jacking method, i.e. the product pipeline is pushed into the ground in one step, in contrast to all common methods, which have so far been applied
- Permanent drill-hole support in order to prevent a drill-hole collapse, advantage over HDD
- Cutting wheel and cutting tools of the microtunnelling machine can be adapted to any geological conditions, which is particularly beneficial over HDD
- Minimum space required, only on the launch side: Advantage over other methods, which either require considerable storage space on the launch side (pipe jacking / segmental lining), which require considerable space in order to install the product pipeline on the target side (HDD) or which require space on both sides (Easy Pipe)
- Minimum slurry volume required due to the small overcut
- High performance rates - due to the deployment of the Pipe Thruster and the possibility to install and test entire pipe sections
- The microtunnelling machine, which is equipped with U.N.S. navigation technology and a north-seeking gyro compass, guarantees high-precision target control

3 Pilot project “Rhine crossing near Worms (Germany)”
During the Rhine crossing near Worms in September 2007, the DIRECT PIPE® method made its debut. Contracted by Worms-based EWR Netz GmbH, Herrenknecht installed a culvert with a total length of 464 meters parallel to the Nibelungen Bridge from the Hessian side of the Rhine River towards downtown Worms located on the other side of the river in the Federal State of Rhineland-Palatinate. The culvert is planned to serve as a casing pipe for a 600-mm
diameter water pipeline and will also accommodate several ducts for power and telecommunication cables. The culvert was designed as steel casing with a diameter of 1,200mm (48”). Casing-pipe voids are cement-filled after product pipe pull-in in order to hold the ducts within the casing pipe in place and protect them for the duration of their service life. The new DIRECT PIPE® method, engineered and tendered by the Hamburg-based engineering firm de la Motte & Partner, bidded by the construction company Sonntag Baugesellschaft mbH & Co. KG from Dörth in cooperation with Herrenknecht AG, was preferred over trenchless construction and HDD technology during the award process.

Pipeline route: River crossing

Pipeline route: Ashore

Fig. 4: Alignment map of the Rhine crossing near Worms – top view.

The method was awarded due to its economic benefits and project-specific advantages such as the minimum space requirements on the target side in Worms only allowing a minimum pit size for the recovery of the micromachine; it was also chosen due to the tight schedule, which required a timely realization of the project because of the flooding danger, expected for late September, that threatened the region of Worms and the entire site infrastructure. The irony of fate, the flooding of the Rhine River, caused by heavy rains in Switzerland, already occurred.
during site set-up in mid-August, which means much earlier than expected, leading to a complete evacuation of the jobsite and a delay of approx. one month.

The coverage of the culvert alignment underneath the Rhine River was approx. 5m at a water depth of 10m and 3m in the bank area. The alignment comprised a 100-m long straight drive with a 9.5% gradient and a circle section with a radius of 1,450m towards the target shaft. The maximum water pressure in the middle of the alignment under the riverbed of the Rhine was 1.5bar.

Since site infrastructure was spatially limited due to nearby woods, the pipeline could not be jacked in one step. Instead, pipe sections of 5 x 90m and a first section of approx. 30m length were prepared. The pipeline was extended by welding the pre-installed pipe sections together. Pipeline extension, welding of the pipe sections and coupling of the supply and discharge lines of the machine took between 12 and 15 hours.

Fig. 5: View into the launch pit during machine launch: In the front, the Herrenknecht Microtunnelling Machine AVN1000XC and the Pipe Thruster; in the rear, the first pipe section on pulley blocks.

After start of excavation, the new method exceeded even the most optimistic expectations. Average performance rates of 15cm/min (maximum 25cm/min) allowed for a fast installation of the pipe sections. On average, a 90-m long pipe section was jacked per day; with average thrust forces of only 70 to 80t. The pipe string was lubricated through a lubrication ring (see item 2) from the machine and from an opening behind the launch seal in the launch shaft; pipe lubrication was not carried out automatically through the pipe string. The overcut of 50mm allowed the pipeline to “float” in the drill hole and helped to considerably reduce friction forces.
Upon arrival in the target shaft, it became evident that the largest part of the thrust force had to be applied due to face pressure (which was no longer generated after the target shaft had been reached). The geological conditions could be deduced from the separation-plant material and by analyzing the excavated soil. The alignment comprised approx. 80 % of gravelly-sandy soils and up to 20 % of silty-clayey soils, which positively influenced performance rates.

![Graph showing advance rates Project Direct Pipe® Worms.](image)

**Fig. 6: Advance rates Project Direct Pipe® Worms.**

### 4 Conclusion

DIRECT PIPE® is another method for pipeline installation not only having theoretical advantages over existing methods (in particular over HDD technology and especially regarding large diameters) but also achieving impressive practical results. DIRECT PIPE® allows for project requirements and jacking performances that are not possible with other methods. Future projects will show how far the limits can be pushed with regard to alignment length and performance rates; and there is already a large number of possible upcoming projects due to the high and continuously growing worldwide demand for pipelines and undercrossing structures required for the oil and gas industry, for freshwater and sewage transportation as well as for supply and communication lines.

![Pipe Extension (disconnect, welding, connect)](image)

**Fig. 7: Breakthrough in Worms.**