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Underground pipeline laying using the pipe-in-pipe system

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Abstract. The problems of resource saving and environmental safety during the installation and operation of the underwater crossings are always relevant. The paper describes the existing methods of trenchless pipeline technology, the structure of multi-channel pipelines, the types of supporting and guiding systems. The rational design is suggested for the pipe-in-pipe system. The finite element model is presented for the most dangerous sections of the inner pipes, the optimum distance is detected between the roller supports.

1. Introduction

Methods of trenchless pipelay technology have a number of benefits in comparison to trenching, such as:
- low ecological damage;
- lack of necessity to develop and backfill bottom trenches, reinforce the coasline;
- reliability improvement due to the pipelay in a non-fractured rock to deeper depths;
- reduction of operating costs due to the lack of necessity for underwater inspections and the works on preventing periodical pipeline flooding;
- wild landscape conservancy, and many others.

The main drilling methods are directional drilling, method of curved pipes, Geokhod tunneler, screw-driven tunneling, microtunneling, tunneling, and pipe-in-pipe system.

2. Methodology

Trenchless pipeline technologies are used, in particular, for the main oil and gas pipeline laid under the artificial and natural barriers including the underwater crossings (see table 1).

Table 1. Main trenchless pipeline technologies

Trenchless pipeline	Field of application, benefits	Limitations
Directional drilling (325-1720 mm pipe diameter)	crossings under water reservoirs, roads, buildings, and other constructions; natural barriers, watersides; used when necessary to avoid surface damages.	Impossibility of pipeline repair and reconstruction works in case of emergencies.
Method of curved pipes (530 -1420 mm pipe diameter)		Restricted crossing length; impossibility of pipeline repair and reconstruction works in case of emergencies

Geokhod tunneler. Mining diameter up to 3 m; weight – 19 t		In development (Tomsk Polytechnic University)
Screw-driven tunneling		In development (Tomsk Polytechnic University)
Microtunneling (Herrenknecht tunneling system). Mining diameter up to 4 m; laying length – 1500 m		It is restricted by geological conditions and requires large space for assembly area
Shield tunneling		High construction cost. Minimum pipe diameter – 2 m.
Pipe-in-pipe method	used in multi-channel pipelines; simplicity of pipeline repair and reconstruction; drag force reduction in tunneling	Insufficient structural reliability of supporting and guiding systems

Except for the pipe-in-pipe methods, all other methods presented in table 1 are provided with the inverted syphon comprising coaxially welded pipes and representing a single-channel pipeline.

The inverted syphon is a multi-channel pipeline comprising the outer pipe and, at least, one inner pipe installed in the internal space of the outer pipe using the supporting and guiding systems.

There are several types of multi-channel pipelines with different design features:

- comprising at least one inner pipe installed in the outer pipe using plastic spring frames (fig. 1 a), [4];
- comprising at least one inner pipe installed in the outer pipe using supporting centering devices in the form of roller supports (fig. 1 b);
- comprising the outer pipe and at least two inner parallel pipes fixed to each other by the elastic compensating mechanism (fig. 1 c), [6].

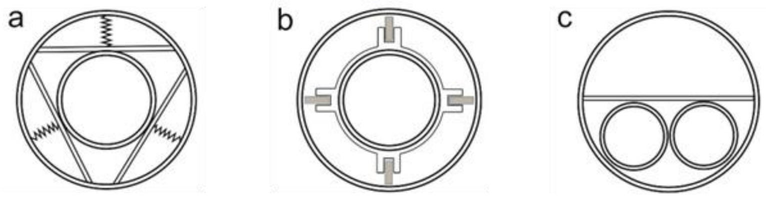

Figure 1. Types of multi-channel pipelines

The pipe lining can be also provided with the variety of wood and polymer lining materials. There is a range of the supporting and guiding systems that facilitate the pulling and centering of the inner pipeline and form a two- and multi-channel inverted syphon.

Several types of supporting and guiding systems are currently used for the pipeline arrangement. They are as follows:

- dielectric rings or spacers (fig. 2 a) are made of two or three semi-rings connected to one ring by metalware (bolts, nuts and washers) and fixed to the pipe. Spacer is made of the types 276-73 (83, 84) polyethylene in compliance with GOST 16338 [3].

- roller guide ring (fig. 2, b) are made of two or three semi-rings connected to one ring by metalware (bolts, nuts and washers) and fixed to the pipe. The dielectric rollers made of polyamide blocks are fixed to the outer pipe and facilitate the pipeline pulling. These polyamide blocks serve as a dielectric to prevent the contact between the inner and outer pipes [3].

- guide rings of PMTD type (fig. 2, d) are made of two semi-rings connected to one ring by bolt connection. The roller sliding supports manufactured in compliance with GOST 10589-87 of the dielectric material (polyamide-610), are installed and mounted to the outer surface of the PMTD ring. To reduce the drag force when pulling the pipeline, the sliding supports are mounted to the upper semi-ring, while the roller supports are mounted to the lower semi-ring [3].
- guide rings with a rocking roller (fig. 2, c) are made of three metal semi-rings with bolt connections. The lower support element has two rollers and rotates to a certain vertical angle [5].

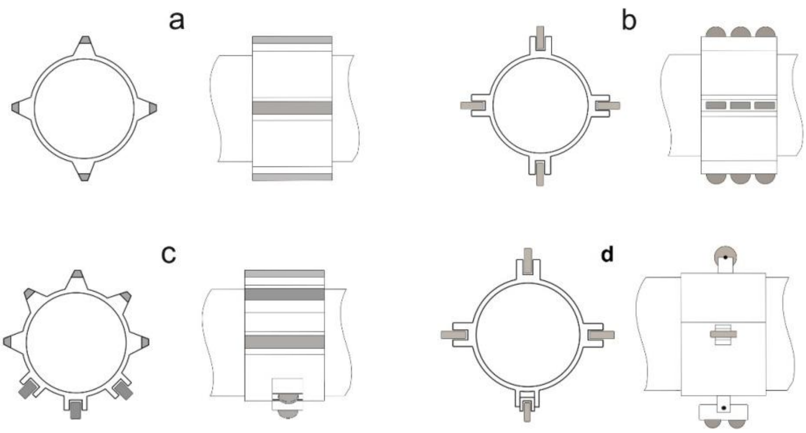

Figure 2. Types of supporting and guiding systems

The roller guide rings and the type PMTD rings are the most advanced guiding systems that allow reducing the drag force and the improvement of the structural reliability of the multi-channel pipeline.

The multi-channel pipeline with the roller guide rings was selected for the finite element modeling (FEM). The pipe section between the roller supports was analyzed and the pipeline axial displacements and stresses were identified using the ANSYS finite element program. FEM of the pipeline displacement is presented in figure 3.

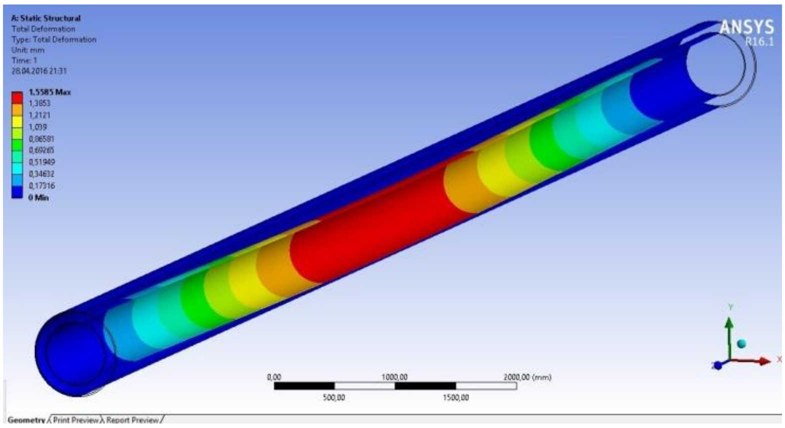

Figure 3. FEM of axial displacement of pipeline (distance between supports – 15 m)

3. Results and discussions

The dependence between the estimated von Mises stress and the pipeline displacement relative to the distance between roller supports is presented in table 2. The pipeline is subjected to plastic deformation tests using the finite element modeling. The task conditions are as follows:
- 530 mm pipe diameter;
- 8 mm wall thickness.

Table 2. Estimated von Mises stress and pipeline displacement relative to the distance between roller supports

N	Distance between roller supports, m	Dead load, N	Axial displacement, mm	von Mises stress, MPa
1	10	10202.4	0.32	5.7
2	**15**	**15303.6**	**1.5**	**13.3**
3	20	20404.8	4.8	20
4	25	25506	11.7	34.5

According to table 2, the most dangerous pipeline section is in the centre and the interface of the roller support and the outer pipe, i.e. the maximum stresses are observed, which reduces the pipeline reliability. The maximum axial displacements of the pipeline are observed in the central part between the roller supports. Depending upon the maximum axial displacements, the optimum distance between the roller supports is 15 m.

4. Conclusions

1. The structural analysis of the multi-channel pipeline and the types of the supporting and guiding systems showed that the most efficient technology is the pipe-in-pipe system.
2. The multi-channel pipeline was designed using the supporting and guiding systems in the form of the roller guide rings. FEM analysis of the inner pipe section between the roller supports showed that the optimum distance between them is 15 m since the pipeline bending relative to its axis tends to zero.

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