Methods of Determining Admissible Bending Radius for HDD Drill String

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Abstract

Economic growth and the successive demand for consumption goods stimulate development of new industrial techniques and technologies. One of such advancements is HDD technology, thanks to which underground pipelines can be disposed in the ground without troublesome digging of the future investment site. When designing the borehole trajectory, attention should be paid to its technical and technological constrains. One of them is the strength of the drill pipes. The HDD process was characterized and relevant formulae for calculating minimum bending radius of drill pipes were presented in the paper. The influence of drill pipes wearing on the increase of minimum bending radius value was shown.

Key words: *HDD technology, minimum bending radius*

Introduction

Economic growth and the successive demand for consumption goods stimulate the development of new industrial techniques and technologies. An advance in new technologies of underground construction of pipeline installments could be observed. The communal and industrial media (water, electricity, gas, internet) transport demand intensifies modernization and construction works in research centres and in companies producing consumption media. Research and implementation works concentrate on new solutions, minimizing technical, technological, economic and environmental problems. One of such advancements is HDD technology, thanks to which underground pipelines can be disposed in the ground without troublesome digging of the future investment site.

HDD technology

A pilot well is drilled in line with the planned trajectory. Depending on the rock hardness, drilling works are performed with the use of an asymmetrical hydromonitor bit, cutter bit or cogged bit. The rock is drilled hydraulically and mechanically. The trajectory of the well axis is constantly or periodically measured; the location of the probe in an antimagnetic connection (disposed right after the bit) is verified. Surface or subsurface radiometric cable or cableless telemetric navigation systems are used. The direction of drilling can be corrected by rotating the drill pipe by a predefined angle.

To obtain the planned final diameter, the borehole is reamed once or several times. After making a pilot borehole, the drilling bit is substituted in the borehole with a cutter or cogged reamer on the drill pipes. The reamer is introduced to the pilot borehole to enlarge the diameter of the existing well. In the process of reaming, drill pipes are successively added to proceed with reaming operations or to trip the casing.

The final stage of HDD is tripping of casing. To do this, a reamer, rotary sub and a head (tripped with the pipe) are disposed on the string. The rotary sub (swivel) prevents the system against rotations and torque of the drill pipes on the tripped casing.

At the stage of HDD designing and performing it is crucial to account for all technical and technological limitations. One of them is admissible radius of drill pipe bending.

Determining minimum value of new drill pipes

Owing to the bending of the string, additional strains appear:

$$\sigma_r = \varepsilon\, E \qquad (1)$$

Relative elongation ε of a drill pipe is determined from the geometrical dependence presented in Fig. 1.

$$\varepsilon = \frac{\Delta L}{L} \qquad (2)$$

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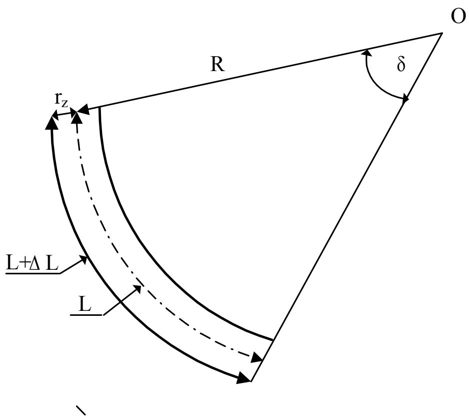

Fig. 1. Geometrical dependences for a section of bent drill pipes.

Elongation of a part of the drill pipe, responsible for the external bending radius, can be determined from the below relation:

$$\Delta L = \frac{\pi}{180} \cdot \left[\left(R + r_z \right) \cdot \delta - R \cdot \delta \right] = \frac{\pi}{360} \cdot d_z \cdot \delta \qquad (3)$$

Employing (3) and accounting for a dependence between spatial bending angle and angle of curvature:

$$\delta = \frac{180 \cdot L}{\pi \cdot R} \qquad (4)$$

equation (1) is transformed to:

$$\sigma_r = \frac{E \cdot d_z}{2 \cdot R} \qquad (5)$$

Having assumed that bending stresses should not exceed admissible values:

$$\sigma_r < \sigma_{dop} \qquad (6)$$

an equation for minimum value of pipe radius bending is obtained:

$$R > \frac{E \cdot d_z}{2 \cdot \sigma_{dop}} \qquad (7)$$

The value of admissible bending strains, causing a permanent of drilling pipes deformations, was discussed in [2], [3]. Various empirical formulae were obtained for each steel type, e.g. for steel grade S-135 the admissible bending strains should be calculated from:

$$\sigma_{dop} = 137895140 \cdot \left(1 - \frac{T}{785193775{,}3 \cdot \left(d_z^2 - d_w^2 \right)} \right)^2 \qquad (8)$$

Accounting for (7) and (8), the following inequity is obtained:

$$R > \frac{E \cdot d_z}{275790280 \cdot \left(1 - \frac{T}{785193775{,}3 \cdot \left(d_z^2 - d_w^2 \right)} \right)^2} \qquad (9)$$

d_z – external diameter of a drill pipe, [m];
d_w – internal diameter of a drill pipe, [m];
δ - angle of spatial bending of a directional well axis, [°];
ΔL – elongation of a drill pipe section, [m];
E - Young modulus, [Pa];
ε - relative elongation of a drill pipe section, [-];
σ_{dop} – admissible bending strains on the string, [Pa];
σ_r – increase of strains in drill pipes, caused by a directional well deviation, [Pa];
L – length of bent pipe element, [m];
R – radius of curvature of a directional well axis, [°];
T- maksymalna wartość osiowych sił ściskających [N].

Based on the relations, minimum admissible values of bending radius for drill pipes made of steel grade S-135 (HDD technology) are obtained. Maximum values of pulling/pushing forces acting of drilling tools are taken into account (tab.1).

Tab.1 List of minimum values of bending radii of new drill pipes made of steel S-135 and used with selected rigs

Rig	**Pulling/pushing force**	**External diameter of drill pipes**	**Internal diameter of drill pipes**	**Minimum value of bending radius of drill pipes**
-	kN	mm	Mm	m
JT920L	38.2	41	28	34.90
JT2720	120	57	43	54.69
JT4020	180	60.3	46.1	63.67
D50x100	225	73	54	71.58
D80x100	362	89	66.2	89.59

Influence of drill pipes consumption with minimum bending radius value

Drill pipes wear out in the course of exploitation. Four wearing classes are defined by API standards [1]:

- New- no signs of wearing of the drill pipe wall;
- Premium – thickness of the wall is not less than 80% its nominal value;
- Class 2 – wall thickness is not less than 70% its nominal value;
- Class 3 – wall thickness is bigger than 70% its nominal value (such string is classified as junk).

Only New, Premium or Class 2 pipes can be used in trenchless technology. The drill pipe wearing has an influence on the admissible bending radius value. Suitable calculations were made at the Department of Drilling and Geoengineering, Faculty of Drilling, Oil and Gas, AGH-UST. Thanks to them it was possible to determine the bending radius values in the function of wearing. The results are presented in fig. 2.

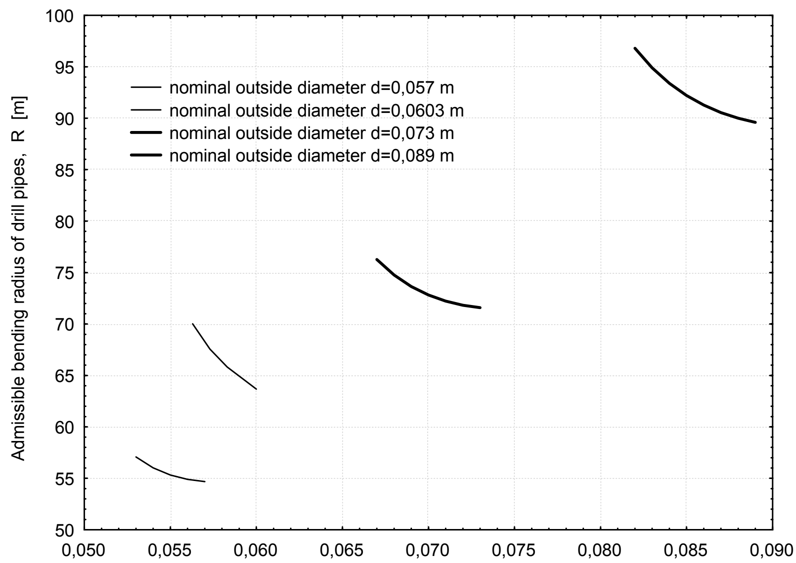

Fig.2 Influence of wearing of drill pipes of steel grade S-135 on the minimum bending radius values.

Resume

With HDD it is possible to apply trenchless construction methods for disposing underground pipeline systems. At the stage of HDD designing and drilling, minimum admissible bending radius values should be used for the drill pipes. A too little value can result in a permanent deformation of a part of the string, being further cause of a break-down or failure.

When determining minimum bending radius values for drill pipes, attention should be paid to its wearing. Equations presented in this paper can be of great help in this respect.

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References

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[2] Nicholson R.W.: Minimize Drill Pipe Damage and Hole Problems. Folow Acceptable Dogleg Severity Limits*, Transaction of the 1974 IADC Rotary Drilling Conference.*
[3] Norma ISO 10407*: 1993 (E)*