Feasibility study on the use of oil-well tubing in construction of intermediate support for 6-10 kV high voltage overhead power lines in the development of oilfields

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Abstract. This article is devoted to assessing the technical effectiveness and economic feasibility of oil-well tubing in construction of intermediate supports for overhead power lines (6–10 kV) in the development of oil, gas and condensate field in the conditions of Far North. The article considers the technical possibility and economic feasibility of using the built-up cross section of the intermediate support of overhead lines consisting of two tubes welded together. The SCAD office software was used to calculate the strength of the proposed section for the design load, taking into account the impact of climatic factors. A comparative analysis of the construction cost was performed for 1 km of overhead power lines made of conventional materials and oil-well tubing. The calculations showed the feasibility of using this material for the construction of 6-10 kV overhead lines.

1 Introduction

Development of oil fields is a costly process, especially for the facilities located in the Far North [1]. This activity includes the following stages: land development for cluster sites [2], constructon of highways and crude oil collectors, construction of high-voltage overhead lines. The high cost of construction and assembly operations is directly connected with the severe weather conditions and difficult access to the facilities. [3] Construction of high-voltage overhead lines is one of the main items of expenditure in the development of cluster sites. The search for optimal solutions in the context of application of non-conventional constructional materials would significantly decrease expenditures, thereby increasing economic benefits not to detriment of quality of construction and assembly operations. [4] Application of used oil-well tubing in the construction of intermediate supports for 6-10 kV overhead lines can serve as one of the solutions. [5]

In the process of WO operations, large stocks of used oil-well tubing are generated, which requires certain measures for their recovery or disposal [6]. The use of this type of material in the construction of overhead lines can serve as an option for their implementation.[7]

2 Methods

To assess technical feasibility and cost-effectiveness of this type of material, the following is required:

- Preliminary theoretical calculation of strength for the design load taking into account the icy-wind impacts of the Far North regions [8].
- Calculation of the actual construction costs of 1 km of intermediate supports for 6–10 kV overhead line made of oil-well tubing pipes taking into account the operations aimed at the support manufacturing.
- Comparison of cost of this type of works production and the cost of typical design solutions for constructing intermediate supports for 6–10 kV overhead lines.

In order to assess the bearing capacity of the support made of the proposed material, it is necessary to calculate the rack's design load taking into account icing and wind impact, which is significant for the Northern latitudes.

We take data from Noyabrsk located in the Purovsky district of the Yamal-Nenets Autonomous district of the Tyumen region as the original data. The city belongs to the 1D sub-district of construction with harsh climatic conditions. There are a lot of deposits belonging to the Russian fuel and energy industry. [9] Air temperature of the coldest five days, with an accuracy of 0.92, is -40 °C [10]. The calculated value of the snow cover weight for V area is 3.2 (320) kPa (kgf/m2). The rated value of the wind pressure for the Ist area is 0.23 (23) kPa (kgf/m2) [11].

Assume that the oil-well tubing pipe is 114.4 mm in diameter and 10.5 m long with a wall thickness of 7.0 mm [12].

The calculation of a pipe of 114x7 mm in diameter shows that when the pipe is used as a single rack for the

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overhead line support, the flexibility constraint is not met: [13]

$$\lambda = \frac{l_{ef}}{i} = \frac{1050 \cdot 2}{3.791} = 553.94 > 350$$

Next, we consider the option of using a composite section consisting of two pipes welded to each other with steel plates with a 1m step along the entire length.

The support layout is shown in Figure 1.

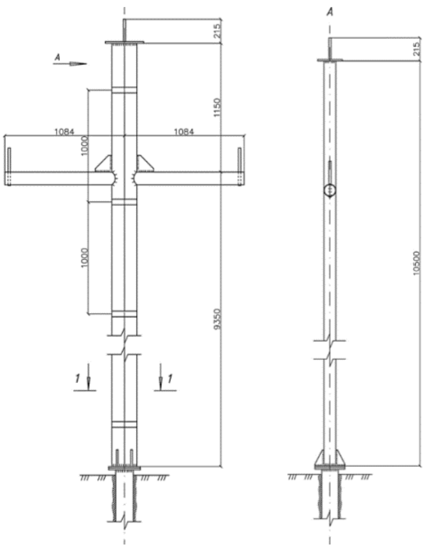

Fig. 1. The Support Layout.

We determine the geometric characteristics of the composite section. The section consists of 2 pipes of 114x7mm (Figure 2).

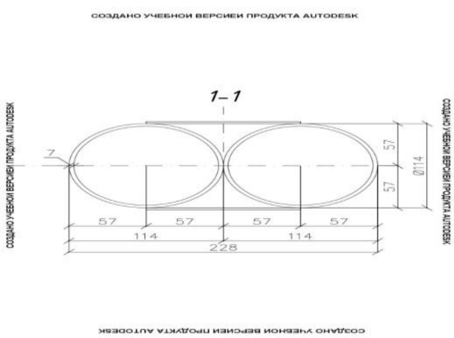

Fig. 2. Composite section of the support.

The area of the composite section is:

$$A_{comp}=2 \cdot A_1=2 \cdot 23.531=47.062 \text{ cm}^2.$$

The moment of inertia relative to the X and Y axis of the cross-section of one pipe is:

$$I_{x1}= I_{y1}=338.193 \text{ cm}^4$$

The moment of inertia of the composite section relative to the X axis is:

$$I_{x,comp}= 2 \cdot (I_{x1}+A_1 \cdot a^2)=$$

$$2 \cdot (338.193+23.531 \cdot 5.7^2)=2{,}205.43 \text{ cm}^4$$

Where a is the distance from the section center of one pipe to the center of the composite section equal to 5.7 cm. The moment of inertia of the composite section relative to the Y axis is:

$$I_{y,comp}= 2 \cdot I_{y1}=2 \cdot 338.193=676.386 \text{ cm}^4$$

The moment of resistance of the composite section relative to the X axis is:

$$W_x=I_{x,comp}/d=2{,}205.43/11.4=193.46 \text{ cm}^3$$

Where d is the pipe diameter equal to 11.4 cm. The moment of resistance of the composite section relative to the Y axis is:

$$W_y=I_{y,comp}/r=676.386/5.7=118.66 \text{ cm}^3$$

Where r is the pipe radius equal to 5.7 cm. The radius of inertia of the composite section relative to the X axis is:

$$i_{x,comp} = \sqrt{\frac{I_{x,comp}}{A_{comp}}} = \sqrt{\frac{2,205.43}{47.062}} = 6.85\,cm$$

The radius of inertia of the composite section relative to the Y axis is:

$$i_{y,comp} = \sqrt{\frac{I_{y,comp}}{A_{comp}}} = \sqrt{\frac{676.386}{47.062}} = 3.79\,cm$$

SCAD office software was used to perform the calculation.

The support design scheme is shown in Figure 3.

Table 1. Load summary.

No.	Item	Load	γ_c	Design load
1	Deadweight of the support made of pipes 114x7 mm in diameter	36.92 kg/m	1.05	38.766 kg/m
2	Ice load	0.275 kg/m	1.3	0.357 kg/m
3	Deadweight of AC-120 power cable	0.383 kg/m	1.3	0.4979 kg/m
4	Deadweight of the installer with tools	0.1 t	1.3	0.13 t
5	Traverses for the wires (leftward and rightward)	18.56 kg/m	1.05	19.383 kg/m
6	Wind load affecting the support			
6.1	Downwind	18.4 kg/m²	1.4	25.76 kg/m²
6.2	Upwind	13.8 kg/m²	1.4	19.32 kg/m²

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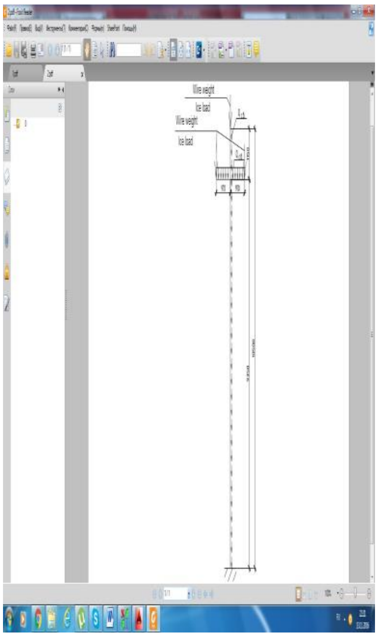

Fig. 3. Design Scheme.

The greatest bending moment arises at the breakage of wires rightward under the combined impact of wind and ice loads. [14] Figure 4 shows diagrams of bending moments at the worst combination of loads, taking into account the wire breakage. [15]

Figure 5 shows the load without wire breakage.

Further we perform a calibration calculation of the strength and stability of the composite section at these stress options. According to Clause 9.3.2 of SP 16.13330.2011, Steel Structures: built-up section of the rack at m>20 is calculated as that for the bending element.

$$e = \frac{M}{N} = \frac{28259}{405.09} = 69.75\,cm,$$

where N is the compression force, M is the maximum moment in the section

$$m = \frac{e \cdot Aa}{I} = \frac{69.75 \cdot 47.062}{118.66} = 27.66$$

a) b)

Fig. 4. Diagrams of bending moments in case of wires breakage (a – maximum moment Mx, b – maximum compressive stress N).

a) b)

Fig. 5. Diagrams of bending moments without wires breakage (a – Maximum moment Mx, b – Maximum compressive stress N).

Table 2. The Cost of 1 km Overhead Line Route Made of Oil-Well Tubing.

No.	Justification	Name	Unit	Q-ty	Unit cost, rub	Total cost, rub
1	2	3	4	5	6	7
1	TEP04-01-041-03	Auger drilling with CO-2 type machines with a drilling depth of up to 12 m in group 3 soils	100 m	0.4	7700.63	3080.25
2	TEP08-01-003-07	Covering of the underground m/K piles with (hot) bituminous-rubber cement in 2 layers	100 m^2	0.12	586.7	70.4
3	SCM-101-2016	Insulation bituminous-rubber cement MBR to protect the aluminum shell and armor against corrosion	kg	30	8.06	241.8
4	TEP05-01-095-06	Installation in wells in frozen and permafrost soils: steel piles up to 0.2 m^3	1 m^3 piles	2.78	1,386.45	3854.3
5	SCM-103-0534	Weld-free casing pipes of D and B groups steel with a short triangular thread, outer diameter 194 mm, wall thickness 10.9 mm	m	58	1031.3	59815.4
6	TEP05-01-009-01	Concrete filling of hollow piles and shell casing piles with a diameter of up to 80 cm	1 m^3	2.78	866.54	2408.98
7	TEP05-01-063-01	Filling of voids between the well wall and the pile body with a matrix	1 m^3	1.38	55.38	76.42
8	SCM-402-0004	Ready-mix masonry cement matrix, grade 100	m^3	1.38	378.78	522.71
9	TEP13-03-002-04	Priming of the aboveground metal surfaces with GF-021 primer in one hit	100 m^2	0.11	424.91	46.61
10	TEP13-03-004-26	Coating of the aboveground metal surfaces with PF-115 enamel in 2 layers	100 m^2	0.11	1336.73	147.04
11	TEP09-06-001-02	Assembling: trays, grilles, fastenings of strip and sheet steel	1 t	0.0628	1214.74	76.28
12	ТСЦ-201-0768	Individual structural elements of buildings and structures with a predominance of heavy plate steel, average weight of assembly unit up to 0.5 t	t	0.0628	10588.54	664.96
13	TEP33-04-003-01	Installation of reinforced concrete supports of 0.38 overhead lines of 6–10 kV with traverses without consoles: single-column	1 support	20	199.26	3985.2
14	At the price of scrap metal	Used oil-well tubing pipe of 114 mm, wall thickness of 7 mm	m	420	129.5	54390
15	TEP33-02-013-05	Installation of mounting parts for supports and additional suspension brackets of up to 0.2 t	1 t	0.1792	1214.74	217.7
16	SCM-201-0764	Individual structural elements of buildings and structures with a predominance of pre-welded profiles, the average weight of the assembly unit of 0.1 to 0.5 t	1 t	0.1792	9145.9	1638.94
17	TEP13-03-002-04	Priming of the metal supports in one hit	100 m^2	1.5	424.91	639.07
18	TEP13-03-004-26	Coating with PF-115 enamel in 2 layers	100 m^2	1.5	1336.73	2005.1
Total direct costs in prices of 2001						133881.16
In prices for the 4th quarter of 2016 as established by the decree of the government of the Yamal-Nenets Autonomous District dated November 11, 2016 No. 1072-P [7] 133,881.16 * (7,3)						997332.47

The strength for the first combination of loads is calculated according to the following formula:

$$\frac{M}{W_{n,min} R_{y\,\gamma_c}} \le 1.$$

Here A is the cross-sectional area, R_y is the design steel resistance, γ_c is the safety factor for responsibility.

$$\frac{28259}{(193.46 \cdot 118.66 \cdot 2450 \cdot 1)} = 0.005 \le 1$$

Based on the calculations, we obtain that the strength and flexibility constraint of the rack is met.

In order to assess the economic feasibility, we conduct a comparative analysis of the estimated cost of constructing of 1 km of a 6–10 kV overhead line made of the proposed material and the material used in standard design solutions without taking into account cabling and wiring products and mounting fittings.

We take the cost of buying black scrap metal in Noyabrsk as the cost of oil-well tubing, since the piping is already owned by the Company and there is no need for its procurement and delivery. The average cost for 1 kg of scrap metal is 7 rub. Thus, the price of 1 m oil-well tubing pipe amounts to 129.5 rub. [16]

Table 2 shows a preliminary estimate calculation of the construction cost of 1 km overhead line supports with a span 50 of meters using a composite section made of oil-well tubing. [17]

3 Results

According to the results of the preliminary estimate calculation of the constructing cost for 1 km of overhead line using a composite section of oil-well tubing, the costs for the main types of construction and assembly operations without taking into account cabling and wiring products and mounting fittings amounted to 997332.47 rub.

The cost of the construction and assembly operations was determined according to unit prices stipulated by TEP-2001 (Territorial unit costs). The prices calculated in 2001 are indexed to the prices of the current period (fourth quarter of 2016) by using the regional Yamal-Nenets Autonomous District index for zone 3, excluding overhead costs and estimated profits for these types of works.

Table 3 shows a preliminary estimate calculation of the construction cost of 1 km of overhead line supports with a span of 50 meters using traditional materials.

Table 3. The cost of 1 km of overhead line made of traditional materials.

No.	Justification	Name	Unit	Q-ty	Unit cost, rub	Total cost, rub
1	2	3	4	5	6	7
1	TEP04-01-041-03	Auger drilling with CO-2 type machines with a drilling depth of up to 12 m in group 3 soils	100 m	0.4	7700.63	3080.25
2	TEP08-01-003-07	Covering of the underground m/K piles with (hot) bituminous-rubber cement in 2 layers	100 m^2	0.12	586.7	70.4
3	SCM-101-2016	Insulation bituminous-rubber cement МБР to protect the aluminum shell and armor against corrosion	kg	30	8.06	241.8
4	TEP05-01-095-06	Installation in wells in frozen and permafrost soils: steel piles up to 0.2 m^3	1 m^3 piles	2.78	1386.45	3854.3
5	SCM-103-0534	Weld-free casing pipes of D and B groups steel with a short triangular thread, outer diameter 194 mm, wall thickness 10.9 mm	m	58	1031.3	59815.4
6	TEP05-01-009-01	Concrete filling of hollow piles and shell casing piles with a diameter of up to 80 cm	1 m^3	2.78	866.54	2408.98
7	TEP05-01-063-01	Filling of voids between the well wall and the pile body with a matrix	1 m^3	1.38	55.38	76.42
8	SCM-402-0004	Ready-mix masonry cement matrix grade 100	m^3	1.38	378.78	522.71
9	TEP13-03-002-04	Priming of the aboveground metal surfaces with GF-021 primer in one hit	100 m^2	0.11	424.91	46.61
10	TEP13-03-004-26	Coating of the aboveground metal surfaces with PF-115 enamel in 2 layers	100 m^2	0.11	1336.73	147.04
11	TEP09-06-001-02	Assembling: trays, grilles, fastenings of strip and sheet steel	1 t	0.0628	1214.74	76.28
12	ТСЦ-201-0768	Individual structural elements of buildings and structures with a predominance of heavy plate steel, the average weight of assembly unit up to 0.5 t	t	0.0628	10588.54	664.96
13	TEP33-04-003-01	Installation of reinforced concrete supports of 0.38 overhead lines of 6–10 kV with traverses without consoles: single-column	1 support	20	199.26	3985.2
14	Price list	Seamless pipe 159x8 steel 20	m	210	2076	435960
15	TEP33-02-013-05	Installation of mounting parts for supports and additional suspension brackets of up to 0.2 t	1 t	0.1792	1214.74	217.7
16	SCM-201-0764	Individual structural elements of buildings and structures with a predominance of pre-welded profiles, the average weight of the assembly unit equal to 0.1 up to 0.5 t	1 t	0.1792	9145.9	1638.94
17	TEP13-03-002-04	Priming of the metal supports in one hit	100 m^2	1.5	424.91	639.07
18	TEP13-03-004-26	Coating with PF-115 enamel in 2 layers	100 m^2	1.5	1336.73	2005.1
Total direct costs in prices of 2001						435960
In prices for the 4th quarter of 2016, as established by the decree of the government of the Yamal-Nenets Autonomous District dated November 11, 2016 No. 1072-P 133,881.16 * (7,3)						3182508

According to the results of the preliminary estimate calculation of the cost of constructing of 1 km of overhead line route using traditional materials, the costs for the main types of construction and assembly operations without taking into account cabling and wiring products and mounting fittings amounted to 3,182.508 rub.

According to the results of the preliminary calculations, it can be concluded that the use of oil-well tubing is technologically feasible and reduces the cost of construction of intermediate supports of the overhead lines by 69%.

In order to introduce the given technology into production, it is necessary to:

- Develop a design solution for the application of used oil-well tubing in the construction of intermediate supports for 6–10 kV overhead lines in the Far North;
- Develop item unit prices for the process of manufacturing and installation of this type of supports.

4 Conclusion

The introduction of this technological solution will significantly reduce the cost of construction by minimizing the cost of procurement and delivery of new piping, as well as eliminate the cost of disposal of the used oil-well tubing, which will contribute to achieving the goal of waste-free production. [18]

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