Complex solution of problem of all-season construction of roads and pipelines on universal composite pontoon units

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Abstract. A complex construction consisting of a universal floating pontoon road for laying pipelines in automatic mode on its body all year round and in any weather for Siberia and the Far North has been designed. A new method is proposed for the construction of pipelines on pontoon modules, which are made of composite materials. Pontoon made of composite materials for bedding pipelines with track-forming guides for automated wheeled transport, pipelayer, are designed. The proposed system eliminates the construction of a road along the route, ensures the buoyancy and smoothness of the self-propelled automated stacker in the form of a "centipede", which has a number of significant advantages in the construction and operation of the entire complex in the swamp and watered areas without overburden.

1. Introduction

Currently, the subsurface method of laying pipelines with low lifting properties of bogs of the third type is predominantly used (practically complete absence of mineral soil). A considerable amount of soil expansion is observed due to unsteady degradation and metamorphic processes in flooded areas, permafrost soils and in soils with deep seasonal freezing. This leads to the movement of pipelines and the loss of their longitudinal and transverse stability with subsequent escape from the underground position to the day surface with the formation of domes of different configurations. This can lead to a critical value of the strain-stress state of the pipeline wall and its subsequent destruction [1, 2] (Fig. 1).

Figure 1. Domes in the form of vertical spatial curves
In this connection, the task is to create all-season complexes for a full cycle of pipeline construction, described in detail in Podgorbunsky’s paper.

2. Materials and methods
The base of the complex is two main sledge platforms of catamaran type. The distance between the pontoon bodies of the main sledge platforms is such that it is possible to place two auxiliary roller platforms between them, on which all technological operations are performed.

On the main sledge platforms (including on the collector platform), there are portal frames on which the following equipment is located. There is a crane with the removed running base on the main sledge platform. On the additional main sledge platform there is an upper structure with crossing bridges, a closed area for the working personnel of the complex, and a load-lifting mechanism providing vertical and horizontal movements of the machine attached to it for cleaning and insulation of welded joints (Fig. 2).

![Work flow direction](image)

**Figure 2.** A general view of the assembling and laying complex for year-round construction of main pipelines under conditions of Siberia

1 - tensioned carrier wires;
2 - pontoon unit laid on the wires;
3 - laid pontoon unit to be laid;
4 - tracking route;
5 - automated wheeled traffic;
6 - crane mounted on automated wheeled traffic;
7 - pontoon units laid on automated wheeled traffic.

Two main stages can be identified when creating new alternative technological solutions for laying pipelines through bogs:

— the development of technology for the construction of the main pipelines, which combines methods used for laying pipelines and excludes the technology of building pipelines using traditional methods;

— creation of an automated full-cycle assembling and laying complex.

For this, at both stages the authors solved the following main tasks:

— development of technology for pipelines construction in bog areas and with water-saturated soils;

— development of specialized machines, mechanisms and devices that provide a complete construction process;

— development of integrated mechanization and automation schemes.

A rational organization consists in the application of a combined summer and winter organization of construction and installation jobs in order to rationally distribute the resources of production units.
for the pipelines construction. In this case, it is necessary to significantly reduce the volume of winter construction due to the selection of sections of the route where it is possible to lay the main roads in the summer [3, 4].

In this regard, an important role will be played by increasing the capacity of territorial construction and installation organizations in areas of construction concentration, as well as the development of a network of mobile organizations and easily built inventory mobile bases in the form of unit structures.

All newly created versions of full-cycle complexes for year-round construction in bogs and watered areas should meet the following basic requirements: provide for work in the summer period on bogs of all types and watered areas; have a design that provides for work with existing traction means; to have the necessary stability in performing the technological operations and a floating margin at a nominal load (for complexes based on sledge platforms and platforms with air off-loading); ensure the work performance on the full technological cycle.

The technology of year-round construction in wetlands with the use of semi-stationary mechanized complexes is in many respects similar to the considered technology.

The use of the mentioned technology is considered economically efficient in conditions when the bogginess of the routes exceeds 20% and assumes the maximum use of water-flooded routings in the spring, summer and autumn periods. The technology of semi-stationary mechanized complexes is also based a combination of traditional technologies. Sites are selected on a dry section of the route. A construction site is built for installation and insulation of pipe joints, storage of basic structures, construction the launching way for pipeline paying. The interval between the sites of technology of semi-stationary mechanized complexes is 10 - 20 km.

The experience of building pipelines in bogs and water-flooded areas on similar technological schemes exists also in foreign practice. However, the technologies developed for constructing pipeline crossings through bogs using combined methods in the first stage, contain a number of significant shortcomings along with certain advantages.

In particular, there is a slight increase in the efficiency and rate of construction; complexity and high relocation frequency of machines and mechanisms; short work duration between relocations; labor intensity and high cost of additional engineering training (arrangement of the site, entrances, etc.); absence of a united front and route of work performance; dependence of the technology of works performance on the specific route conditions, which, in the final analysis, causes the absence of unified technological schemes; impossibility of laying pipelines through bogs and water-flooded areas under particularly difficult conditions, with a long extension of bogs and lacustrine-boggy areas and the absence of dry ones; absence of original progressive technical and technological solutions.

Due to the imperfection of such combined technologies, in the second stage of development, the main attention was paid to the creation of all-season full-cycle complexes operating on a unit technology, regardless of the season and specific hydrogeological conditions of construction.

In further developments, in accordance with the adopted technology, the complexes for the year-round construction of pipelines in bogs and water-flooded areas were finally divided into transport complexes and assembling-excavating-laying ones [5, 6].

With this kind of division, a different degree of complexity of the construction development was revealed. The simplest one is the creation of transport complexes using already existing air cushion support platforms. Non-self-propelled platforms with load-carrying capacity of 20, 40 and 60 tons were invented by the institution Sibkomplektmontazh, which can be used as one assembly with caterpillar tractors. The use of self-propelled transport platforms on an air cushion SAVR-5GD and SAVR ~40 is even more promising. Caterpillar trucks with a hydraulic drive on special long-stroke controlled mountings or self-propelled transport-technological platforms are used there similar to a platform with a rotary-propeller engine PSTT-1.

Technological schemes were developed which provided for the synchronous promotion of all sledge platforms and schemes in which the platforms could move independently with the help of a
special wire gripper device. The complex forward movement was carried out by a pulling winch and anchors, arranged on pre-selected dry sections.

A version was also developed, in which the movement of the complex was provided by a special universal traction device with heavy lifting capacity. In addition, it was initially assumed that the pipeline would be rigidly connected to sledge platforms, that is, all platforms would be equipped with stationary fixed supports.

However, all these developments had a number of common shortcomings.

A non-self-propelled version and impossibility to perform work in the absence of hard soil to fix the anchors; the platforms equipment by any kind of propeller (rotary-screw, caterpillar, etc.) was considered inexpedient, due to the complexity and unreliability of the structure and the large mass of the platforms; the inoperability of the complex in difficult relief conditions; a large number of pontoon platforms and their extended placement along the length of the installed pipeline caused platform overloads from the weight of the raised section of the pipeline. This, in turn, required an increase in the geometric dimensions and load-carrying capacity of the platform and led to a significant increase in tractive effort necessary for their promotion.

Thus, the analysis showed that in the case of load equalization, the height of the pipeline end above the soil surface at the site of the centering and welding of the root (first) fillet can reach 5-6 meters for a pipeline with a diameter of 1420 mm. Such lifting heights values are for the pipeline from separate 12-meter pipes. These disadvantages are, to some extent, removable, but the performance rate of welding, installation and insulation-packing works is reduced so much that the proposed technological schemes become economically inefficient.

In parallel with the work on the creation of assembly and packing systems based on sledge platforms and platforms with the air cushion, a number of original developments were made. Despite the individual technical and technological solutions that deserve attention, the application of any variant of the assembling and packing systems considered above is not a radical solution of the problem.

Thus, at present, an important task is the development of technology for year-round construction and the appropriate design of the installation and packing complex, combining the advantages of the alternative considered technological solutions and free from their shortcomings.

According to our proposal, for the first time when designing pipelines and along path routings of a new type, the above-mentioned shortcomings can be reduced or completely eliminated [7].

The essence of the method is as follows:

Profile of a complex structure, constructed of composite materials (pontoons for laying) with track-forming guides will provide for the increased reliability along the road, floating and ease of movement for the self-propelled lifting and loading device, designed in the form of a "centipede", which has a number of significant advantages in the construction and operation of the entire complex.

This complex is realized using high-strength composite pontoons made of basalt-plastic composite and mounted under the base of the main pipeline laid on all types of bogs and permafrost soils.

The composite pontoon assembly for the pipeline route base includes a volumetric body, the component parts for the pipeline base made of multi-link units consisting of central and side pontoons, composite longitudinal and transverse wires (ropes) [8].

Each internal spatial power frame of the unit is equipped with solid thin-walled I-beams, connecting elements (locks) of units of the type "male-female" [9, 10]. The deck part of the pontoons is made of sheet material, supported by beams of the I-section. The traffic way is made of beam channels with the caps upwards.

This system during construction completely excludes the use of excavators, pipe layers and pipe carriers for digging trenches. All this creates significant saving of fuel and resources in the construction of such pipeline route and almost excludes the burden removing. The profile of the earth's surface due to the peculiarities of the formation of the relief by natural influences is largely closer to curves with a variable radius, which gives a better negotiation of such route into the terrain of the area [7].
Pontoons in the longitudinal and transverse direction are fastened together by composite wires. Before pulling the composite wires, it is necessary: to check their integrity and compliance with the requirements; to carry out the installation of equipment for unhindered unwinding of wires. The technology of the wires pulling is (see Fig. 3), that between the two closest block-technological wells the point of supply and the point of reception of wires are selected. Longitudinal wires are fixed at certain distances in the land area by "anchors", installed in wells or small buildings, with hydraulic lifts to maintain a constant level of the pipeline in the pontoon system so that they can withstand greater pulling forces and change the geometric position of the track.

Composite wires are suggested to be stretched using a low-power ground-effect machine developed by the authors. In this case, it performs the work on the tension of the composite cables (Fig. 3).

![Figure 3. Tensioning the wires with ground-effect machine over the bog:](image)

1 – ground-effect machine for stretching composite cables above the bog; 2 – composite wire; 3 – automated pipe layer of the "centipede" type; 4 – bog

Also on the pontoons, an oil and gas pipeline is installed and fixed from lateral displacements. The mentioned three constituent components are fixed in a single bundle and in this state the system has a rigid structure with a high degree of reliability, durability and floating under any changes in the surface water level in the swamp and in the pipeline, which has the appropriate design of the strain-stress state compensators. In addition, such pontoon road can be operated year-round, under all weather conditions for repairing routings.

For example, in winter, with large snowdrifts and the presence of ice, a vehicle can be launched in front of the column, which will have a splitting and raking effect, cleansing track for unhindered moving of any kind of equipment.

In connection with the mentioned above, the goal is to build a fundamentally new combined pontoon routing made of composite materials of standard sizes assembled into a single "path" with pontoon properties with the establishment of special metal ruts along the entire length of the route connected along and across by the wires to lay the pipeline system.

An example of a completed project for the construction of a pipeline bed and a routing for all-season use made of high-strength pontoon units using an automated "centipede" complex is shown in Fig. 4 – a, b, c, d.
Figure 4. Construction of a pipeline bed made of composite pontoon units: a – wire routing through the obstacle with the help of ground-effect machine, b – fastening the wire in the well, c – pontoon unit laying on the wires, d – fixing the pontoon unit on the wires

The result of the new achievements in the field of technological and technical solutions for laying the large diameter pipelines through bogs and water-flooded areas resulted in the creation of a fundamentally new technological scheme for the production of both welding and installation works and the development of a general design solution for the installation and laying complex in the automatic mode for year-round construction of pipelines under conditions of Western Siberia and the Far North.

3. Conclusion
As a result of the conducted scientific researches and design work, it is possible to state the following advantages of the proposed technology for the construction of bases for the main pipeline and along the routing:

1. Straightforward configuration of the pipeline routing instead of bypassing the bogs, which reduces the total length of the system by 44%.
2. All-season construction of the pipeline system.
3. The rational principle of tension of longitudinal high-strength composite wires (ropes) by a surface-effect airborne ship
4. Exclusion from the construction of parallel along the routing paths.
5. Reducing the volume by removing burden by 90%.
6. Full automation of the welding production system.
7. Construction of modular warehouses for storage of emergency stocks of pipes.

8. The proposed new materials and construction technology eliminate the thawing of permafrost soils.

9. The connection of pontoon units is made rigid due to the use of the lock type "male-female".

10. Due to the adjustment in the tension of the longitudinal wires, let us avoid the influence of the cycling of the raising and lowering (breathing) of the surface of the bog, which ensures that the appearance of the pipeline domes.

11. Available temperature control of pumped liquid gas and oil.

12. Free access to the pipeline for carrying out the diagnostic work.

13. The covering of the pipeline excludes the impact of solar radiation on waterproofing compound.

14. Protection of the pipeline by a casing excludes hooligan actions of poachers.

15. The constriction of the roadway running parallel to the laid pipeline provides for a year-round access to the system by means of transport units.

16. Pontoons made of basalt-plastic composite have a high strength. They are not subjected to corrosion, have an unlimited lifetime, high rigidity for bending and high stability. They have no embrittlement, are stable to wave oscillations and environmentally friendly.

The implementation of the developed technology and construction methods will ensure a long-term, reliable, environmentally friendly and economically viable option for the nature management of pipeline systems, both in Russia and abroad.

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