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THIRD-GENERATION DISMOUNTABLE ASSEMBLED PIPELINES FROM COMPOSITE-MADE PIPES

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The merits of composite-made structures and efficient methods for making third-generation dismountable assembled pipelines from fiberglass pipes are studied. The results of the studies for improving the design of bell-and-spigot type of joints are furnished, the major factors determining the reliability of the joint are identified, the mechanisms of the influence of geometric parameters on the strength characteristics of the joint are established, and a new design of the pipe joint is proposed.
Keywords: *dismountable assembled pipelines, pipeline reliability, leak-tightness and strength of joint, lock ring, polymer composites, crack resistance, permeability.*

Dismountable assembled pipelines (DAP) can be installed quickly, dismounted in previous and mounted in new directions, involve minor engineering work for their laying on the ground, etc. In this context, the sphere of application of DAP in current situations has been expanding, encompassing not only military, but also other fields [1]. The first-generation domestic DAP began to be used in armed forces from the middle of the last century, initially as storages and later as main pipelines. The operating and test pressure of the pipelines was respectively 2.5 and 3.8 MPa and the delivery capacity ranged from 700 to 2000 tons/day.

The second-generation DAPs, which have their kins in the world to this day, were developed and used in early 1970's for military supplies. They were designed for high operating pressure (up to 6 MPa) and

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supply of 1.2-7 thousand tons/day of fuel. This generation of DAPs are provided with quickly detachable socket-and-spigot type of joints, whose design allows mechanized pipeline laying. The pipes and linear equipment of the second-generation DAP are fabricated from high-strength alloy steels.

Nowadays, DAPs are used for fuel supplies to armies and in other spheres, for example, for transporting oil and oil products to difficultly accessible regions with harsh natural and climatic conditions, for supplying oil products and water to handle natural and technogenic emergency situations.

At the same time, in spite of having a number of advantages, second-generation DAPs do not fully meet the increased reliability, environmental, and preservability requirements. In light of this, development of third-generation DAPs with increased reliability, mechanization of mounting-dismounting and loading-unloading operations, modularity, and extended life cycle of the DAP equipment is becoming a pressing task. It is essential to introduce simultaneously devices for detecting damages, calculating, monitoring quality and filtration of oil products, and automating controlling processes, and to ensure high mobility. Accomplishment of these tasks, including search for new constructional materials and technical solutions that would have made it possible to markedly extend the operating life of the pipelines, reduce their bulk, and enhance safety and reliability, broaden the range of transported products, and make them economically more gainful in terms of both production and operation efficiency.

At the present stage, such materials include composite materials (CM), which can be used to make high-strength and corrosion-resistant light-weight high-pressure pipes. In practice, however, making DAPs using pipes from composites is constrained by a number problems requiring scientific studies, which include, in particular, loss of strength and leak-tightness of the DAP, low crack resistance and high permeability of the CM pipe wall under the impact of internal pressure, combination of deformation of strengthening and sealing layers of the wall and associated probability of leakage of the pumped product with subsequent loosening up of the composite structure, structural reliability of the DAP due to inadequate reliability of the pipe joints in the pipeline strings, which affects the operating life and environmental safety of the pipeline. Special attention should be paid to economic efficiency of DAP fabrication, to relatively high cost of CM, and so to the entire linear section of the DAP. In this context, research on development of design and technological methods for ensuring crack resistance, leak-tightness, and longevity of DAP based on CM pipes is deemed urgent.

Of the glass-, carbon-, and organic-fiber based composites, organic-fiber composites are the best suited for pipes in terms of strength and weight characteristics, followed in order by glass- and carbon-filled plastics (Table 1).

However, because of high cost, use of organoplastics for new-generation DAP fabrication is economically unprofitable. So for the near future, it will be expedient to use glass plastics, which are relatively cheaper while being quite high in strength, for fabricating pipes and linear equipment. Studies

Table 1

Indices	Organoplastic	Fiberglass plastic	Carbon plastic
Strength, kgf/mm^2			
tensile	140-230	43-132	24-48
compressive	10--38	33-59	15-37
bending	120--150	54-90	30-40
Young’s modulus, kgf/mm^2	5300--9700	2000-4850	11000-13000
Density, g/cm^3	1.25--1.35	1.7	1.4-1.5

of DAP consisting of fibreglass-reinforced plastic pipes allow roughly 2.5-fold reduction of the weight of a single pipe with better properties compared to a steel pipe. Switch to fibre-glass-reinforced plastic pipe manufacture will save scarce metallic materials. Use of 1 ton of fibreglass-reinforced plastic will save at least 3-5 tons of steel.

In the 2000s, DAPs were fabricated from fibreglass-reinforced plastics (PMTS-150-150) whose basic distinction from the existing ones was the presence in the fibreglass-reinforced plastic pipe body of steel butt-joined piece (spigot-and-socket joint), which allows the PMTS-150-150 pipes to be used independently and in combination with steel pipes of DAP. The characteristics of the PMTS-150-150 and PMTP-150 pipes are listed in Table 2.

The shells of the butt-joined pieces are attached to the fibreglass-reinforced pipe by an adhesive composition. But this type of attachment of DAP components requires adherence to an important requirement, namely, compatibility of deformations of various constructional materials. Nonadherence of this requirement at the points of attachment to the pipe body during operation of the pipeline gives rise to development of microcracks in the adhesive composition structure. So, to bring up the DAP to the required reliability level, it needs design and technological modification, for example, the pipe body and the joints must be of the same constructional material, namely, fiberglass-reinforced plastic.

Considering that the moving pipe joint, whose reliability indexes decisively influence the effectiveness of use of the whole pipeline, is the heaviest component of the linear section of the DAP that is failure risky. Because of the specific conditions of DAP operation, only such types of joints can be used for them that ensure leak-tightness of the pipeline under excessive pressure and rarefaction, the same strength as the strength of pipe body, the possibility of shortening and lengthening of the pipeline depending on various operating and climatic conditions, the possibility of increasing safe angular divergence of one pipe relative to another, and simplicity and the required speed of installation of the pipeline [2]. In view of this, the near-term important task remains to be creation for the DAP of new-generation pipe joints having better characteristics of constructional reliability with validation of the pipeline strength criterion, followed by development of methods of its determination for static and dynamic DAP loading conditions.

For studying the key geometric parameters of bell-and-socket joints, the correlation of the following dimensions of the main constructional members of the joint, which characterizes the ability to resist failure and to ensure the strength of the joint under external and internal dynamic loading, was established [3]:

$$\Omega_1 = d_k / D_M \tag{1}$$

where d_r is the cross-sectional diameter of the lock ring and D_s is the diameter of the annular projection of the joint collar at the point where the lock ring is set.

Table 2

Indices	PMTS	PMTP
Pipe weight, kg	36.6	80.9
Operating pressure, MPa	6.4	6.0
Testing pressure, MPa	8.0	7.3
Delivery, ton/day	3200	3000
Service life, yr	min 25	12

Correlation (1) was taken as one of the key criteria of strength of the DAP while conducting studies on its elevated reliability level.

Also established was a second correlation of dimensions of the main constructional members of the bell-and-socket joint that characterizes its ability to ensure steady equilibrium state of the parts of the annular locking device under dynamic loading conditions:

$$\Omega_2 = l_1 / d_{in} \tag{2}$$

where l_1 is the linear dimension of the entering part of the collar in the bell-and-socket joint and d_{in} is the inner diameter of the pipe.

The increase in contact area upon deep fitting of the entering part of the collar in the bell-and-socket joint (dimension l_1) facilitates increase in frictional forces, and upon transfer of the bending load initiated by the turn of the pipes in the joint, significantly relieves the ring lock device from the bending stress, ensuring its steady equilibrium and enhancing reliability of the pipe joints. For designing bell-and-socket joints for the third-generation DAP, the value of the correlation (2) can be taken as the second criterion of pipeline strength [3].

The approaches developed to determine the optimum design of bell-and-socket joints, which ensures improved strength properties of the joint while operating DAP, found expression in the creation of a new-generation dismountable assembled pipelines fabricated by domestic technologies using advanced constructional materials. Based on the investigation results, a basic model of the linear member of the DAP, which retains the high technological adaptability of the designs and all the merits of its fabrication by winding methods and ensures thereby reduced weight, enhanced reliability, and extended longevity, is proposed.

The results of tests of specimens of the structures of the promising DAP having bell-and-socket joint and pipe wall thickness of 5 mm confirm their working fitness when loaded by a hydrostatic pressure of 7.5 [4].

Within the confines of the investigations of the processes of functioning of various moving pipe joints for DAP it was found that alongside bell-and-socket joints, spheroidal hinged joints could be the most reliable and effective.

Spheroidal hinged joints have much greater angular mobility compared to bell-and-socket joints and, because of greater angle of the limiting pipe turning, can, in conjunction with other CM characteristics, significantly relieve the linear section of the DAP from bending stress [5, 6]. The joint is fabricated from light CM reinforced, for example, with fibres from high-strength supramolecular polyethylene or its hybrids [7]. An important advantage of hinged joints is that under any conditions of loading of the DAP by a bending moment exceeding the friction moment in its spherical support, the lock ring holding the collar in the bell-and-socket joint is loaded uniformly over the whole circumference of the contact, ensuring its steady equilibrium within the angle of relative turn of the pipe in the joint.

Construction of the third-generation DAP, alongside updating of the linear section, also presupposes improving and introducing light forged fasteners, advanced safety valves, pressure regulators, and double-action check valves. To reduce the time of deploying the technological systems in the DAP complex, there must be provisions for standard modular separator intake-actuation units, filters, computing units, and samplers. Reducing labor input and operation time for deploying DAP continues to remain urgent [8].

Construction of the third-generation DAP with introduction of new technical solutions will help supply fuel to armies qualitatively and timely under any situations and use them as a dual-purpose means of ensuring efficient oil products supply.

REFERENCES

1. V. V. Nikitin, V. I. Zagorskii, V. G. Akunin, et al., *Use of Main Pipelines and Oil Products Pipelines for Fuel Supply to Armies* [in Russian], Voenizdat, Moscow (1976), p. 208.
2. A. V. El'kin, *Updating Operation and Improving Design of Moving Pipe Joints of Field Main Pipelines* [in Russian], Candidate's dissertation, UVVTU, U'lyanovsk (2000), p. 183.
3. A. V. El'kin, Al. V. El'kin, D. A. Drozdov, et al., *Territor. Neftegaz.*, No. 5, 72-78 (2015).
4. Russian Federation Patent 143993.
5. V. V. Sereda, A. V. El'kin, et al., *Transp. Khran. Nefti*, No. 11, 23-29 (1999).
6. Russian Federation Patent 154270.
7. B. V. Baidakov, V. I. Natrusov, T. E. Shatskaya, et al., "New materials for pilotless aircraft," In: *UAV.RU. Spl. Issue INTERPOLITEX-UVS.TECH*, 25-26 (2013).
8. Russian Federation Patent 2524784.