BIPLASTIC PIPES FOR HIGH-PRESSURE OIL PIPELINE SYSTEMS

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A high-performance, corrosion-resistant biplastic pipe for high-pressure oil pipeline systems is presented. The pipe combines an outer load-carrying layer formed from unidirectionally glass-reinforced plastic (GRP) sublayers by wet multi-circuit winding and an inner sealing layer of high-density polyethylene. Both demountable and permanent joints, tees, and other parts are constructed for these pipes. The biplastic pipes ensure reliable operation of oil pipeline systems under a pressure of up to 200 bar. The experimental results and calculated estimates of the strength of biplastic pipes are presented. The results of using these pipes in oil pipeline systems in the Perm' region are discussed.

At present, the oil pipeline systems of oil and gas production plants consist predominantly of metal pipes. Along with high strength, relative simplicity of joints, and low cost, metal pipes have some drawbacks, namely low corrosion resistance, incomplete utilization of strength characteristics, formation of different sediments on the inner surface of pipes, etc.

Corrosion, causing the greatest material damage to pipeline systems, reduces their service life, leads to emergency situations, increases the operational and repair expenses, as well as causes losses of the products transported, decreases their quality, and results in environmental pollution. The intensity of corrosion has recently especially intensified due to the increased amount of fluids in the oil produced and the application of different reagents in the process of oil recovery. To ensure an appropriate oil discharge, the lower oil-bearing horizons are supplied with water, as a result of which they become filled with oxygen and sulphate-reducing bacteria. The emulsion extracted often contains only 10-15% oil, while the remainder is water. This brings about an active chemical reaction at the interface of the pipe and the liquid being transported. In the presence of water, the iron substitutes for hydrogen and, in combination with sulfur, forms iron sulfite. The hydrogen, in the atomic state, diffuses over the thickness of the pipe wall and leads to loosening and destruction of the metal, which, in turn, results in failure of pipes due to the formation of merging microcracks. At some oil fields, this phenomenon causes a disastrous effect.

The known methods of protection of metal pipelines with the purpose of prolonging their service life and raising their reliability have essential drawbacks. Thus, the use of inhibitors reduces the pipeline failure level, however, the protective layer formed by these agents is soon carried away by solid inclusions contained in the stream lifted from oil wells. Therefore, the expenses for securing the inhibitor protection are quite significant. The application of different coatings (linings) on the inner surface of metal pipes is also a complicated and expensive procedure. In this case, the most important problem is the development of a reliable protection of the joints upon installation of pipelines. The existing technologies do not ensure efficient protection of the joints of lined metal pipes in field conditions, which subsequently leads to the formation of corrosion centers and their intense growth in these zones.

A cardinal solution to the problem of increasing the reliability of oil pipelines is the application of nonmetallic pipes. For low-pressure pipelines, the use of pipes made of monomers (polyethylene, polypropylene, polyvinylchloride, etc.) is most effic...
cient [3, 4, 6–8]. The polyethylene pipes have high operational properties, namely low specific gravity, resistance to hostile media, as well as to corrosion and stray currents, and low resistance to the flow of gas and water. However, wide application of polyethylene pipes in oil and gas industry is restricted by their low strength; for example, according to the operating instructions [9], the maximum working pressure in technological pipelines made of plastic pipes must not exceed 1.75 MPa. The reinforced plastics used in pipe constructions make it possible to increase the working pressure in pipelines by an order of magnitude (to 24 MPa and more). In this case, the basic problems consist in securing the leakproofness of pipes, ensuring the strength and tightness of joints, creating a range of shaped parts, and developing reliable methods of pipeline installation, especially in winter conditions.

At the “Composite-Oil” Co., the two-layer biplastic pipe shown in Fig. 1 has been designed [10]. The outer load-carrying layer of the pipe is made of glass-reinforced plastic (GRP) and the inner one is formed of high-density polyethylene (HDPE). The adhesion between the GRP and polyethylene is ensured by introduction of an additional interlayer of copolymer of ethylene with vinyl acetate (sevilen). In addition, to protect the GRP shell against the hostile environment and unregulated humidity, the pipe contains an outer resin layer. For these pipes, both demountable and permanent joints (Fig. 2) were designed [11]. The permanent adhesive-mechanical joint (see Fig. 2a) includes specially treated thickenings at both ends of the pipes, GRP connecting segment couplings, and a GRP fastener. The thickenings at the pipe ends, which provide increased strength of the joint, are formed upon winding of the pipe, according to a special scheme of reinforcement, with subsequent machining. Figure 2b shows a demountable flange joint for the connection of a biplastic pipeline to an existing metal fixture and equipment, which ensures the required leakproofness and strength of the joint.

For mass production of biplastic pipes, a technological process has been designed based on the method of wet winding with subsequent curing of the GRP layer under the action of infrared radiation [12–16]. This process includes the following stages:

1) preparation of materials,
2) extrusion of a polyethylene pipe,
3) slipping of the polyethylene pipe over a mandrel,
4) application of an adhesive sevilen film,
5) winding of a GRP layer according to a program in the automatic mode, with the control and regulation of the process parameters required,
6) polymerization of the GRP layer by infrared radiation heating in a special chamber with subsequent curing in air,
7) removal of the pipe from the mandrel and machining of the pipe ends to fit the connection elements, which is carried out in 24 h after their manufacture,
8) testing of the prepared pipe for internal pressure; estimation of the strength and leakproofness according to the pressure drop and the results of outer inspection, and
9) manufacture of sections of biplastic pipes (at the customer’s request), on a special stand equipped with a stationary welding device, by means of adhesive-mechanical connection elements (see Fig. 2a).

For biplastic pipes, the range and production technology of connecting parts, namely bends (Fig. 3), tees, and reducers were designed. The main problem, in that case, was to develop an efficient technology permitting one to obtain the designed shaped articles with the prescribed accuracy of geometrical parameters, high quality, given physicomechanical characteristics of materials, and reasonable manufacturing cost. The methods of hand-operated molding lead to high cost of shaped articles, because of high material and labor expenditures, and render a stable production of high-quality articles impossible. Therefore, the manufacture of complex-shaped connecting parts of biplastic pipes is based on the method of “wet” winding on a machine specially designed for this