DEVELOPMENT OF POLYMER CONSOLES

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ABSTRACT

The article introduces the development of new polymer consoles for high-speed transport. The results of research of electrophysical characteristics of fiberglass rods are provided. The possibility of a wider use of fiberglass based on epoxy binder is shown. Polymer consoles are tested for mechanical and electrical load, as well as the latest design of end terminals. The test was conducted including lightning impulse voltage.

Keywords: high-speed transport, console, contact network, polymers, fiberglass, electric strength, mechanical properties, durability.

Background. *Polymer materials that are recommended for use in devices and nodes of contact network should have a complex of properties, high mechanical and dielectric strength and for a long time (at least 20 years) maintain these properties under the impact of different weather conditions (moisture, temperature changes, sunlight, various contaminants in the air).*

Of particular interest to parts and devices of the contact network is fiberglass – polymeric materials in which a fiberglass filler is used as a reinforcing material.

Experience in the use of polymer materials in contact network devices in Russia and abroad is described in [1, 2]. In this test results of the newest bearing elements of contact network, made based on composite materials, are indicative. This primarily refers to the consoles of the contact network.

Depending on the number of overlapping routes, as known [3], the console is divided into single-track, double-track, multitrack. The use of polymer console allows to eliminate fixing mounting brackets, to lighten reference and support structure of the contact network, to enhance stability of a suspension cable greatly, which is a prerequisite for reliable networks at high speed of trains. The use of such consoles increases work safety under stress greatly.

Objective. *The objective of the authors is to consider new type of polymer consoles.*

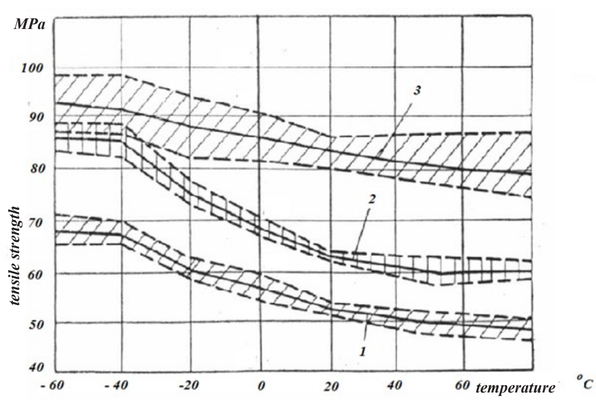
Methods. *The authors use general scientific and engineering methods, comparative analysis, graph construction, evaluation approach.*

Results.

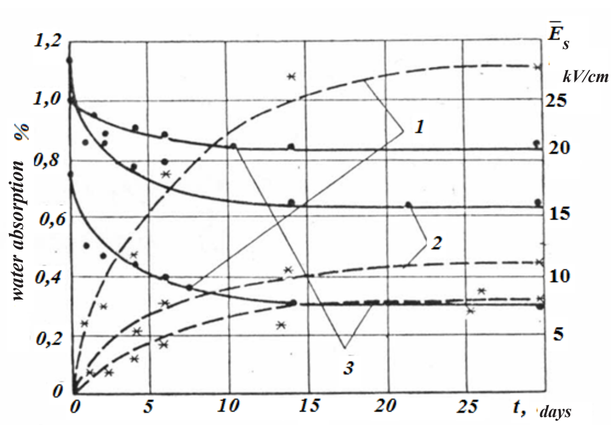
1.

In the first phase of development, which we were assigned to do, it was necessary to determine on which binder polymer structures must be made.

Research was conducted in respect of samples on polyester, epoxy-polyester (resin content of ED and NP 1: 2) and epoxy binders. Reinforcement of



Pic. 1. Dependence of tensile strength of fiberglass rods on temperature: 1 – on polyester binder; 2 – on epoxy-polyester binder; 3 – on epoxy binder.



Pic. 2. Dependence of electric strength E s (–), water absorption (-–) of fiberglass rods on time τ of stay in the water. Designations are the same as in Pic. 1.

Table 1

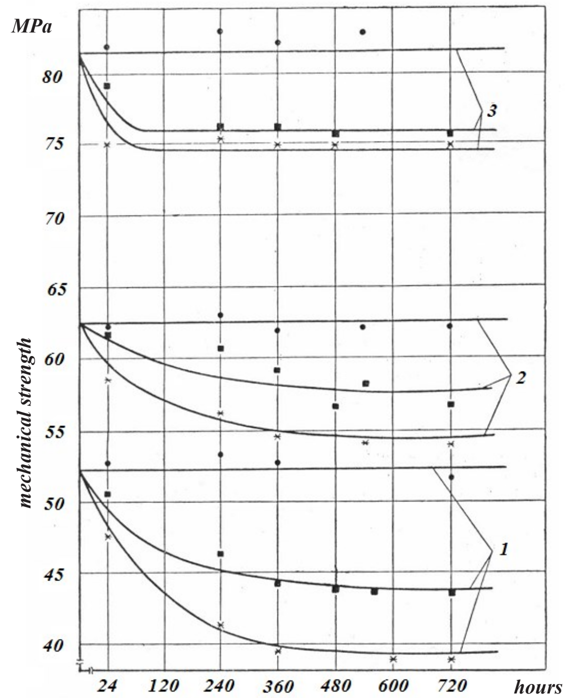
Strength characteristics of fiberglass pipes, recommended for polymeric consoles of a contact network

Type of material	Tensile strength, MPa			Elasticity modulus, hPa	
	tension	compression	deflection	tension	compression
SPP – E	850	431	890	52–53	30–38
SPP – Ev	920	660	1000	52–57	33–38
SPP – Ep	780	435	830	52–55	34–38

Table 2

The values of deflections for direct loading [mm]

S, kgs	Pk, kgs	Name of load	Point a	Point b	Point c	Point d
			Total deflection	Total deflection	Total deflection	Total deflection
300	250	Permissible	20	19	21	224
500	500	Test	37	32	33	310
Deflection under test load			37	32	33	310
Rod's length			3626	3378	3378	3441
Actual relative deflection			1/98,0	1/105,6	1/102,4	1/11,1



Pic. 3. The dependence of mechanical strength σв of fiberglass rods on time τ at relative humidity of 98% and temperature of 20°C(●), in water at temperature of 20°C(■), in water at a temperature of 80°C (✱). Designations are the same as in Pic. 1.

fiberglass rods is a glass roving – aluminum-boric-silica glass composition with a lubricant № 289. The glass content in the composite on mass is 70%.

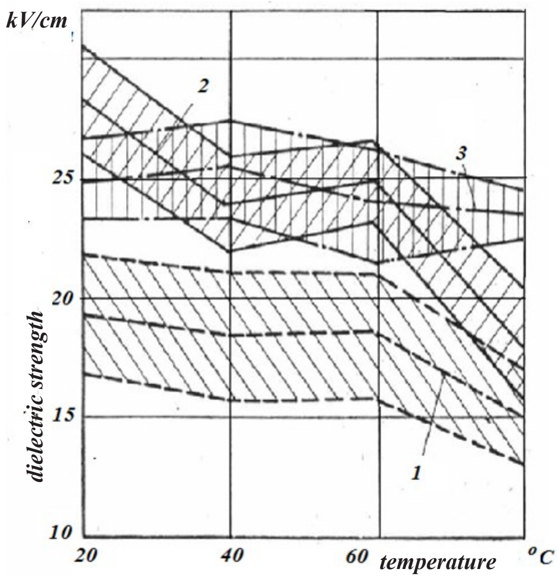
Methods of mechanical testing are presented in [4]. Fiberglass tensile tests were performed in the range of temperature change from –60˚to +80˚C. As at high and low temperatures with normal samples a control sample with thermocouple mounted in it was placed in an environmental chamber. Increase in material strength (Pic. 1) was accompanied by an increase in the scatter of the test results.

The greatest strength was observed in fiberglass rods on epoxy binder. In the field of positive temperatures it reduced.

Analysis of the dependency indicates the need to take into account reduction of strength of the material in the calculation of rods operating at high temperatures.

Water absorption of rods was determined according to techniques operating in Russia. Fiberglass rods on epoxy binders have much lower water absorption as compared with the rods based on polyester and epoxy-polyester resin (Pic. 2). As a first approximation time was determined to achieve equilibrium of samples, i.e. moisture saturation point of the material. It is not less than 30 days.

Reduction of mechanical strength of fiberglass (Pic. 3) is set from the time of moisture action. Thus, exposure of the samples at a temperature of 80˚C,



Pic. 4. Dependence of dielectric strength Es of fiberglass rods on temperature. Designations are the same as in Pic. 1.

after staying in water for 720 h allowed to fix the decrease of strength data of fiberglass on polyester resins – by 25,31%, on epoxy-polyester – by 14,4%, on epoxy – by 9,7%.

Dielectric strength of rods (Pic. 2) was examined via industrial frequency voltage. Voltage was applied along fibers to the samples of 10 mm thick. Rods on epoxy binder have a higher dielectric strength as compared with others. In the first seven days of wetting dielectric strength of samples decreases sharply due to heavy moisture absorption. After 15 days of stay in water, it is stabilized.

Studies of dielectric strength depending on temperature was carried out in the range of 20–80°C (Pic. 4). They showed that with increasing temperature the strength decreases, and most strongly in fiberglass rods on epoxy-polyester resins, less – in rods on epoxy binder.

Analysis of dependence of volume resistivity of fiberglass rods on duration of stay in water (Pic. 5) showed that ρv value in the first day of their stay in the aquatic environment falls sharply. The smallest ρv decrease is observed in rods with epoxy binder.

Based on survey data it found that to manufacture polymer console structures it is necessary to use fiberglass pipe on epoxy binder.

The strength characteristics of fiberglass of pipes, recommended for the manufacture of consoles in tension, compression, bending, are given in Table 1.

Tubular profiles were produced by pultrusion technology.

Let's briefly acquaint the readers with pultrusion process:

– Continuous glass roving is pulled through a die hole, while it is impregnated with a binder with simultaneous heating, contributing to hardening of a binder;

– Polymer object is subjected to additional surface treatment, and is cut into pieces of a certain length;

– If necessary, reinforcement of a polymer product can be carried out in a direction other than 0°;

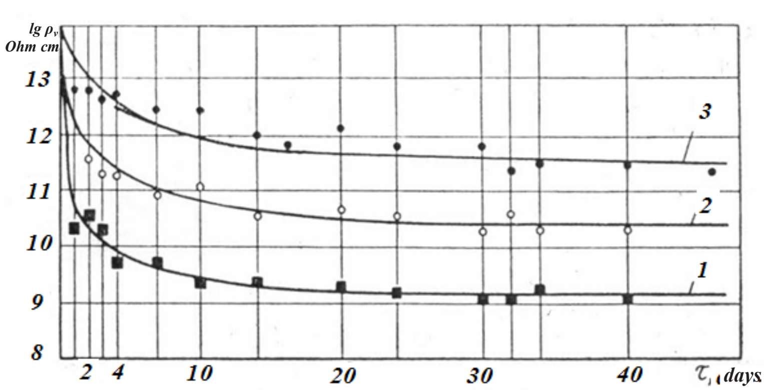
– The production process is continuous.

To fill an inner cavity of a composite pipe a polyurethane foam filler (PFF) with a closed cell structure was used. This solution allows to prevent condensation buildup during operation.

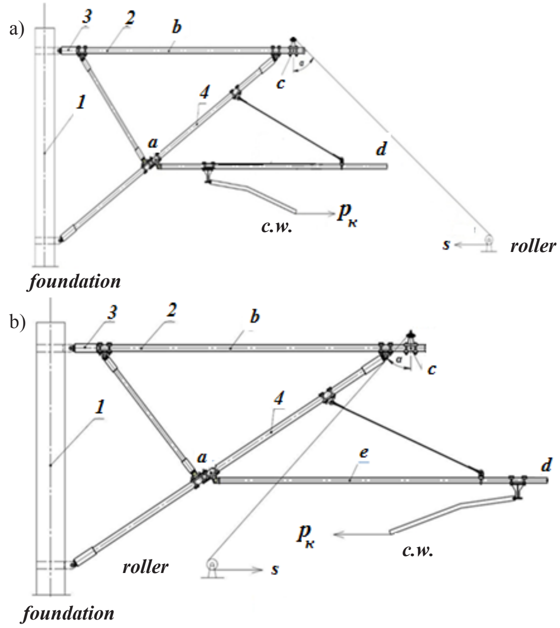
Process of filling with water of an inner cavity of a pipe was made using a mixing and dosing system, which is designed for two-component polyurethane casting systems.

Preparation of external surface of a pipe to application of a protective coating was performed using non-chromate epoxy primer with active corrosion protection.

The coating consisted of two-component universal polyurethane-acrylic enamel. This enamel has high protective properties – long-time preservation of open film, it is resistant to UV and



Pic. 4. Dependence of dielectric strength Es of fiberglass rods on temperature. Designations are the same as in Pic. 1.



Pic. 6. Developed polymer consoles: a – direct loading; b – reverse loading; 1 – support column; 2 – console horizontal element; 3 – fittings of consoles; 4 – strut of the console; a, b, c, d, e – measuring points of consoles elements deflection.

weathering, high water resistance, as well as enhanced tracking-erosion resistance.

2.

One of the main issues of mechanical calculation of polymer consoles is to define their geometric dimensions.

Console of fiberglass pipes was calculated on tensile load of 70 kN and bending moment in the plane of the staple of the end terminal 4 kN • m (breaking strength in bending 8 kN).

As a result of this work a tubular element with an external diameter of 60 mm, internal – 44 mm was selected.

After selection of the diameters of fiberglass pipe we turned to select a material of which an end terminal is to be made.

We stopped on the fact that the first batch of end terminals is to be made of aluminum. The connection of fiberglass pipe and end terminal is mechanical (bolt).

The second batch of end terminals was made of polyamide. Connection of pipe with end terminal is glue.

The study of strength of proposed end terminals was made on the console samples to 1200 mm in length.

The destruction of the connection of a fiberglass pipe with polyamide end terminal was made, usually on metal of end terminal – gap of «staple» or of the «body» of end terminal. The average value of breaking force of the connection «fiberglass pipe – end terminal made of polyamide 66» – 2050 kg.

A typical form of destruction of the samples with aluminum end terminals – crushing of fiberglass pipe at the point of connection with bolts of the end terminal (plastic deformation of bolts). This type of destruction was observed in all samples of this connection. The average value of breaking force «fiberglass pipe – aluminum end terminal» is 5150 kg. On the basis of research it was decided to finalize the connection node of the end terminal of polyamide, in terms of increasing the strength of the end terminal.

Bending. Tests to determine breaking load and destructive bending moment of tubular elements of a console with aluminum end terminals was performed on samples with a length of 1300 mm. In the middle part of the sample vertical force was applied. Tests were carried out till destruction of the samples. The average value of the breaking load was 2800 kg, destructive bending moment was 8,91 kNm.

Tests to determine the magnitude of deflection at control points of the console were made on collected samples (Pic. 6). Material of console rods is unidirectional fiberglass coated with a developed protective layer. Material of end terminals of rods is aluminum.

The loads applied to the design of the console were measured by dynamometers in accordance with GOST 13837. Deflection measurements were made at each stage of loading (see. Table 2, 3) at the points a, b, c, d, e by a deflectometer.

Test of console in assembly in direct loading demonstrated:

– Deflection of console's rods in standard embodiment do not meet «Technical requirements for polymer consoles»' in terms of maximum permissible relative deflection – 1/100 of the length of the rod;

– When fastening of a strut is shifted to end terminals, deflections of all rods of the console (except for the fixing element) are close to the limits set in specifications – 1/100 of the length of the rod;

– Visible damage to the console elements under test load are not available, there is no slippage of mounting fittings;

– Fiberglass rod of a fixing element does not comply with maximum permissible relative deflection.

In reverse loading:

– Deflection of all rods of the console (except for the fixing element) corresponds to «Technical requirements for polymer consoles» in terms of the maximum permissible relative deflection;

– Visible damage at the console elements under test load does not occur, there is no slippage of mounting fittings;

Table 3

The values of deflections for reverse loading [mm]

S, kgs	Pk, kgs	Name of load	Point a	Point b	Point c	Point d	Point e
			Total deflection	Total deflection	Total deflection	Total deflection	Total deflection
260	250	Permissible	16	13	16	73	2
560	460	Test	20	15	18	246	41
Deflection at test load			20	15	18	246	41
Rod's length			3626	3378	3378	3061	3061
Actual relative deflection			1/181,3	1/225,2	1/187,7	1/12,4	1/74,7

– Fiberglass rod of the fixing element does not meet technical requirements, except that it loses its stability at a test load.

High-voltage tests. Dielectric strength test of developed polymer consoles like direct and inverse fixing element was conducted in accordance with GOST 1516.2. Their purpose was to check dielectric strength of console insulation, rod and strut, in particular:

– Dielectric strength test in dry and rain;

– Dielectric strength test of insulation when subjected to standard lightning impulse.

When tested in the dry state, rod and strut were fixed horizontally. At one end of the rod or the strut voltage of 145 kV was applied. The other end was grounded. The applied voltage was maintained for two minutes. During this time there was no overlap of insulation of both the rod and the strut.

Tests in the rain – a special sprinkler was used. At one end of the rod voltage of 125 kV was applied. The other end was grounded. Rain fell uniformly at an angle of 45° to the horizontal. Rain parameters were determined in accordance with GOST, water conductivity was 110 mkSm / cm. Sample holding time was 5 minutes. Insulation overlap did not occur.

In the latter case the rod was fixed vertically. At one end voltage of 70 kV was applied. The other end was grounded. Rain parameters were the same as in the previous experiment. The applied voltage was maintained for at least 5 minutes. During this time there was no overlap of insulation.

Test on lightning impulse voltage. At one end of the rod and the strut an impulse with waveform 1,2 / 50 ms and an amplitude of 240 kV was applied. The other end was grounded. The applied voltage was maintained for 5 minutes. During this time there was no overlap of insulation.

Determination of the insulation breakdown voltage in the dry state. The rod and the strut were fixed vertically. One end of the test elements was grounded. On the other end continuously growing AC voltage of industrial frequency was supplied. Upon reaching 236 kV value (the maximum for the test set), the applied voltage was maintained for two minutes. During this time there was no breakdown or overlap of insulation.

Conclusions.

1. New polymer consoles were developed for high-speed transport.

2. There is a need to increase the diameter of main rods, using fiberglass rods D70 / d55 and D80 / d65, and finalize a connection node of an end terminal with fiberglass rod assembly and construction of the console terminations of polyamide in order to increase to ensure sufficient stability of the rods of the console in terms of maximum permissible relative deflection.

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Article received 10.03.2015, accepted 16.04.2016.