Journal of Engineering and Applied Sciences 11 (1): 13-16, 2016
ISSN: 1816-949X

Polymer-Modified Cement as a New Level of Electric Insulation in Electrical Engineering Systems

Alexander N. Ilin, Elvira P. Chernyshova, Mikhail B. Permyakov,
Vladimir M. Andreev, Anatoly L. Krishan and Rustam R. Sabirov
Nosov Magnitogorsk State Technical University,
38 Lenin St., 455000 Magnitogorsk, Russia

Abstract: There were analyzed strength and electric insulating properties of polymer-modified cements over a wide range of change of polymer-cement ratios. There was determined a polymer-modified cement composition optimal for electric insulation. A possibility to use polymer-modified cement as an insulating material for electromagnets was demonstrated.

Key words: Polymer-modified cement, electric insulating material, dielectric, strength properties, possibility

INTRODUCTION

Atomic power engineering has important key features as compared to other power technologies: atomic fuel has million fold power concentration and atomic power engineering wastes have relatively small volumes and can be safely allocated.

Technological development gave rise to a problem of creation of radiation-resistant electric insulation which would withstand the radiation loads of 5×10^7 Gy (limit absorbed dose for fiberglass tape-reinfoirced epoxy-resin electric insulation). The main reason of failure of an electromagnet with such insulation under the action of radiation lies in loss of mechanical strength by a polymer.

In connection with this mineral electric insulation is usually used for the components operated under the high levels of radiation. Electric insulation in the form of coaxial cable with rectangular cross-section which uses magnesium oxide and asbestos-cement electric insulation as an insulator became the most widely-used one. Keizer and Mottier insulation with magnesium oxide features one of the disadvantages namely very low index of electromagnet winding closeness (not exceeding 40%) and correspondingly high cost of the winding. Asbestos-cement electric insulation allows obtaining the winding closeness index proximal to the ordinary windings with epoxy resin insulation. However, void factor and hygroscopic properties of cement materials condition the necessity to enclose electromagnet windings into a tight casing in order to ensure stable electric insulation properties of the material. The asbestos-cement windings production technique is quite complicated and requires special equipment therefore, it is reasonable to use it in case when absorbed doses for the period of service may reach the levels of $10^{10}...10^{11}$ Gy, i.e., by two or three orders higher than the limit doses of polymeric insulation. Some electromagnets take the radiation loads which are $<10^{10}...10^{11}$ Gy but considerably higher than the limit doses for polymeric insulation. It is advisable to use a material allowing considerable simplification of the windings production technique and simultaneously ensuring higher radiation resistance as compared to epoxy insulation for insulation of wiring of such electromagnets.

Analysis of features of various materials having intermediate values of radiation resistance in the range between asbestos-cement electric insulation and epoxy electric insulation showed that polymer-modified cements may be used as the materials mentioned above.

Polymer-modified cement is a material based on a composite bonding agent containing organic polymer and inorganic bonding substance (Chernyshova, 2014; Grigoryev and Chernyshova, 2014; Krishan, 2015; Chernyshova, 2013; Chernyshova, 2015a, b; Krishan and Troshkina, 2014).

The purpose of the research was to ensure that a polymeric component would form an independent structural element within a hardened material as well as a cement component would form its own independent structural element within a hardened material.

On the basis of the above purpose, the basic concept of polymer-modified cement use was represented, i.e., to separate the functions of an electric insulation material between the components of polymer-modified cement. The mineral component ensures durability in respect of

Corresponding Author: Alexander N. Ilin, Nosov Magnitogorsk State Technical University, 38 Lenin St., 455000 Magnitogorsk, Russia

mechanical properties and radiation resistance of a product and the polymeric component significantly improves electrophysical properties of electric insulation since deterioration of dielectric properties of polymers goes behind deterioration of mechanical properties by times with the same radiation dose.

Since, polymer-modified cements have not been used as electric insulation this work offers the results of investigation of mechanical and dielectric properties of polymer-modified cements.

Depending on the type of polymeric component polymer-modified cements may be fluid with processing behavior close to poured cement mixtures and adhesive and viscous like standard epoxy resins. Since, it was supposed that a technology similar to polymeric one would be used the principal attention during investigation was given to adhesive polymer-modified cements which have better mechanical properties as compared to fluid cements (Cherkinskiy, 1984; Chernyshova, 2014; Krishan, 2014).

MATERIALS AND METHODS

The analysis of dependence between the mechanical, electrical and processing properties of polymer-modified cements with various compositions was performed by a factors variation method. The following characteristics were taken as factors determining the change of the specified properties:

- A Polymer-Cement ratio (P/C) which ranged over the interval (from 0÷1 to 1÷0) by weight
- A polymer system type and a type of fillers

The following materials were used for polymer-cement mixture: high alumina cement; epoxy resins ED-8, ED-16, ED-22, E-49, UP-610, DEG-1; hardening agents m-FDA, p-ABA, UP-606/2, triethylene tetramine; water; emulsifier (for combining polymeric system and cement mortar); quartz sand; glass fiber tape. Hardening of polymer-cement mixture was performed through the following procedure:

- Curing at normal temperature during 2 or 3 h
- Steam treatment under saturated steam conditions at (90±2)°C during 15 h (cement hardening and start of epoxy resin hardening)
- Drying at the temperature of 150°C during 4-7 h, final hardening of epoxy resin and removal of residual moisture

Analysis of the electrical insulation properties of polymer-modified cement was made based on the standards for solid electric insulation materials and the strength properties on the basis of the standards for polymer materials.

Simulation of radiation destruction of polymer structure was accomplished by means of heat aging or lack of polymer hardening.

RESULTS AND DISCUSSION

Polymer-cement materials were investigated earlier within a limited range of Polymer-Cement (P/C) ratios, i.e., from 0.01-0.5 (Cherkinskiy, 1984). That's why observation of change of polymer-modified cements properties over the whole interval of P/C-ratios starting from pure cement and ending with pure polymer was the issue of practical interest. The following properties of materials were monitored: electric resistance after curing at the temperature of 20±2°C and the relative humidity of 60±5% within 450 days; electric resistance and compression strength after heat aging at the temperature of 280°C during 1 h; compression strength after curing in hydrochloric acid during 100 h; compression strength and tensile strength after processing treatment; water absorption by weight.

The results of investigation for the formulations listed in Table 1 (adhesive polymer-modified cements) are shown on Fig. 1.

The investigations showed that such dependencies are common for all types of polymer-modified cements. Analysis of the received data allows to mark considerable difference between the properties of the pure cement composition (composition 1) and the epoxy polymer

Table 1: Compositions of formulations

	Components content, mass (%) in formulations							
Materials	1	2	3	4	5	6	7	8
Cement	52.60	49.60	47.00	44.70	33.30	19.20	8.40	0.00
Sand	26.30	24.80	23.50	22.30	16.60	9.60	4.20	0.00
Water	21.10	19.90	18.90	18.00	13.30	7.70	3.50	0.00
Emulsifier	0.00	0.31	0.26	0.24	0.17	0.14	0.07	0.00
Resin ED-20	0.00	4.90	9.40	13.42	33.30	57.60	76.21	90.91
Hardening agent UP-606/2	0.00	0.49	0.94	1.34	3.33	5.76	7.62	9.09

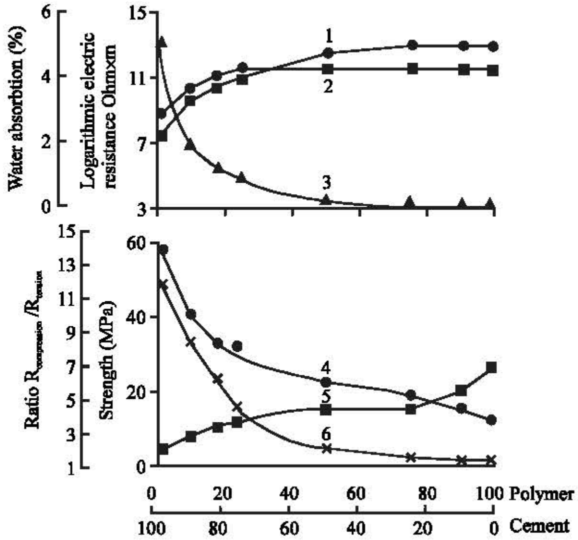

Fig. 1: Change of properties of materials depending on the ratio of polymeric and cement bonding agents: 1: electric resistance at the humidity of 60±5%; 2: electric resistance after heat aging at the temperature of 280°C; 3: water absorption; 4: ratio of compression and tensile strength; 5: tensile strength; 6: compression strength after heat aging at the temperature of 280°C

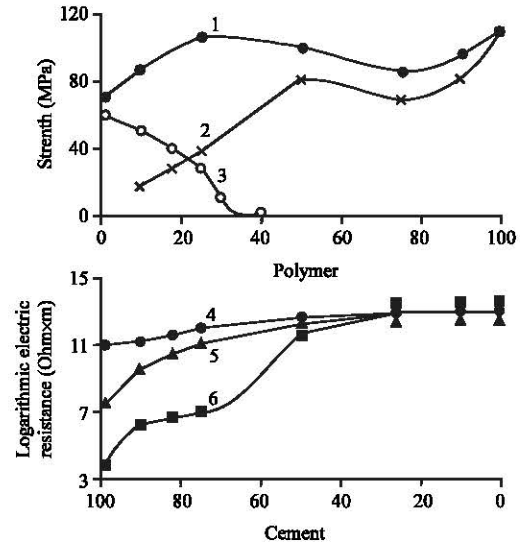

Fig. 2: Change of properties of materials depending on ratio of polymer and cement bonding agents: Compression strength: 1: polymer-modified cement; 2: polymer structure; 3: cement structure. Electric resistance: 4: at the humidity of 0÷5%; 5: at the humidity of 55÷65%; 6: at the humidity of 95÷100%

composition (composition 8): thus, electric resistance (Fig. 1, curve 1) at the humidity of 60±5% shows almost 6-order increase with growth of the content of the polymer bonding agent, at that the maximum growth (3.5÷4-order) can be observed within the range of P/C up to 0.3. In this range of P/C ratio an abrupt (5 fold (curve 3)) reduction of water consumption is registered. After heat aging the polymer part demonstrated heavy degradation which is confirmed by low strength of composition 8 (curve 6). Within the range of P/C ratio of 0.1÷0.3 the materials demonstrate much better resistance to action of temperature. Figure 2 shows change of strength and electric resistance of polymer-cement materials.

The results of investigation of strength of polymer-modified cement (curve 1), the polymer (curve 2) and the mineral (curve 3) structures are given on Fig. 2. It can be marked that polymer-modified cements with P/C ratio up to 0.2 and less are more promising. Within this range electric resistance of the material shows almost 3-order increase as compared to pure cement while the mineral structure strength decreases by 30÷35%. Therefore, even after loss of strength by polymer the material in general will maintain physical integrity and sufficient electric resistance.

These data allow to make a suggestion that polymer-modified cements in relation to their radiation resistance will occupy an intermediate position between the cement and epoxy materials. At that considerable radiation resistance may be expected in the range of P/C ratio where the mineral structure demonstrates bigger strength.

Dielectric properties of polymer-modified cement essentially depend on environmental humidity and polymer-cement material (Fig. 2). With air exposure at the relative humidity of 95÷100% the cement materials demonstrate 7-order decrease of electric resistance (curves 4 and 6) while predominantly polymeric materials (P/C >0.5) show only 1-order decrease as compared to the dried material. With normal air humidity (55÷65%) the cement materials showed 4-order decrease of electric resistance that's why winding with cement insulation are usually encapsulated.

For polymer-modified cements with P/C = 0.2 and higher reduction of electric resistance makes only one order therefore, windings with polymer-cement insulation do not require encapsulation.

In order to summarize we'll give the principal indices of the properties of optimum polymer-modified cement composition with P/C ratio of 0.15 (use of ED-22 resin and p-ABA hardening agent) at the humidity of 55÷65%:

- Compression strength after steam curing (Mpa) = 50
- Compression strength after steam curing and drying (Mpa) = 80
- Tensile strength (Mpa) = 7.5
- Bending strength (Mpa) = 19.0
- Shearing adhesion on copper (MP) = 4.5
- Electric resistance (Ω×m) = 10^9
- Breakdown voltage (MV/m) = 3.5
- Dielectric capacitivity at the frequency of 50 kHz = 7.7
- Dielectric loss tangent at 50 (kHz) = 0.09
- Shrinkage (%) = 0.18
- Coefficient of linear expansion (deg^{-1}) = 15×10^{-6}

CONCLUSION

There was demonstrated the possibility in principle to use polymer-modified cements as an electric insulation material in radiation-loaded elements of nuclear installations.

REFERENCES

Cherkinskiy, Yu.S., 1984. Polymer Modified Concrete. Stroyizdat Publisher, Russia,.

Chernyshova, E.P., 2013. Architectural town planning factor and color environment. World Appl. Sci. J., 27: 437-443.

Chernyshova, E.P., 2014. Formation of colouristic environment of residential area of modern towns and cities. Elect. Magazine, 8: 1978-1982.

Chernyshova, E.P., 2015a. Particularities of the galvanic coagulation method for zinc extraction from hydrotechnogenic systems. Modern High Technol. J., 11: 53-55.

Chernyshova, E.P., 2015b. Chemical aspects of hydrophobization technology for secondary cellulose fibers at the obtaining of packaging papers and cardboards. Int. J. Appl. Eng. Res., 10: 44812-44814.

Grigoryev, A.D. and E.P. Chernyshova, 2014. Stereotypes in design: Positive and negative aspects. Constr. Educ., 1: 41-48.

Krishan, A.L., 2015. Determining of design compression strength of longitudinal reinforcement of concrete filled steel tubular columns. Constr. Archit. Series, 15: 15-19.

Krishan, A. L. and E.A. Troshkina, 2014. Estimation of carrying capacity of eccentrically compressed concrete filled steel tube columns. Adv. Environ. Biol., 8: 1974-1978.

Krishan, A.L., 2014. Strength of axially loaded concrete filled steel tubular columns with circular cross section. Elect. Magazine, 8: 1991-1994.