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NEW MATERIALS FOR ENERGY AND TRANSPORT IN THE NORTH

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ABSTRACT

This work proposes the main principles of energy and transport design in cold regions, including sustainable and safety development on the base of new cold-resistance steels and composite materials application. Particularly the cold resistance high-strength and chemical durable basalt composite materials in association with the low thermal conductivity and light weight stipulate the wide applications in building industry and power engineering in the North. The technology of volume-hardening steels is attractive for the main power and transport facilities in cold climate regions too.

Keywords: sustainable development, safety, composite material, cold resistance

INTRODUCTION

New possibility of East Siberia and Far East innovation growth arises in connection with the deposition of world economic center from West to East in last decade. New industrialization process in Russia could be successfully realized due to closeness to Asia and riches of natural resources. Republic of Sakha (Yakutia) occupies most whole the north-eastern part of Eurasian continent with area of 3 083 500 square km and reaches the beach of two seas in Arctic Ocean. The climate is sharply continental with the great asperity in winter. Almost all territory is permafrost. Average long-term temperature in January is -30,4 and in July is 12,9 °C. Mineral resource ratio of Yakutia in Russia (and in Far East) is, in %: 82 (100) diamonds; 17,2 (30) gold; 5 (46,6)coal; 6,2 (79) iron ore, 28 (36) tin; 81,5 (96,1) antimony; 7,9 (12,5) mercury; 61 (100) uranium. In region has been found and exploited huge resources of carbohydrates and hydroelectric potential.

As a cold country Russia spends about quarter of energy supply for heating, and Yakutia about half. For the resource-saving and efficient energy consumption the smart grid technology and new materials has been proposed.

Far East regional energy security and technogenic safety closely associated in the first place with the efficiency of the energetic resources and realization of the large projects of energy infrastructure in the Republic of Sakha (Yakutia), and with them technogenic and seismic safeguards also (Lepov, 2011). First and foremost, these are the pipe headers such as East Siberia – Pacific Ocean (ESPO) trunk pipeline and coordinated river hydroelectric system on Vilyui and Aldan, then town heat stations, petroleum storage depots and tanks, railway with infrastructure under construction and industrial projects, urban utility services communication complex.

Realization of the Energy and Transport Projects required the solution of several practical problems closely connected to material base of electric power in Russia, Europe and Asia. In this way planned to change the materials of high-voltage transmission tower and insulator for polymer composites with nanofillers, particularly on base of basalt fibre and reinforcement, and apply the ultrafine grained steels for high-strengthened structures exploited in the extreme climatic condition. New technology implies the new methodology of long-range electric power transfer also, with taking into account the Strategy of Power Energy Development of Northeast of Russia till 2030 year (Petrov, 2010) and Conception of Common Smart National Grid.

MATERIALS AND METHODS

The development perspectives of electric grids of power stations are weakly developed now and not accorded to Common Smart National Grids of Far East and East Siberia formation. Huge territory of the region allowed collecting the electric power from non-effective in other cases renewable energy sources.

For the realization of such a Project it is required to solve several practical problems closely connected to material base of electric power in Russia and entire world.

In this way planned the change of material of high-voltage transmission tower and insulator for polymer composites with nanofillers, particularly on base of basalt fiber and reinforcement. New technology implies the new methodology of long-range electric power transfer also, with taking into account the Strategy of Power Energy Development of Northeast of Russia till 2030 year and Conception of Common Smart National Grid.

Continuous basalt fiber is considered by many specialists as one of the most prominent composite materials which possess the unique combination of advantages and at the same time much more cost-effective compared to other high performance fibers. Authorities in Russia and many other countries strongly support promotion of this product into industrial applications (see Figure 1).

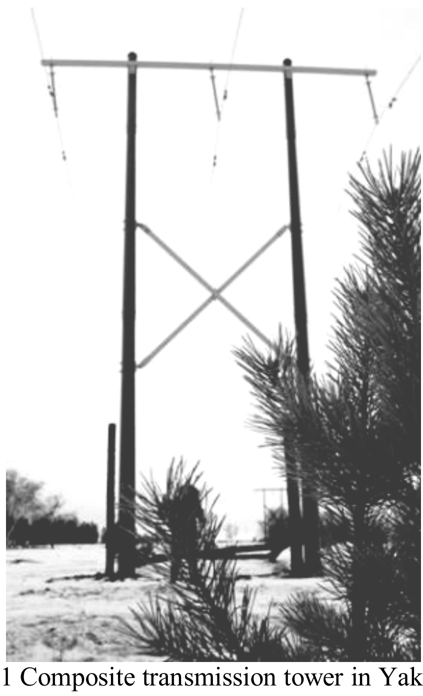
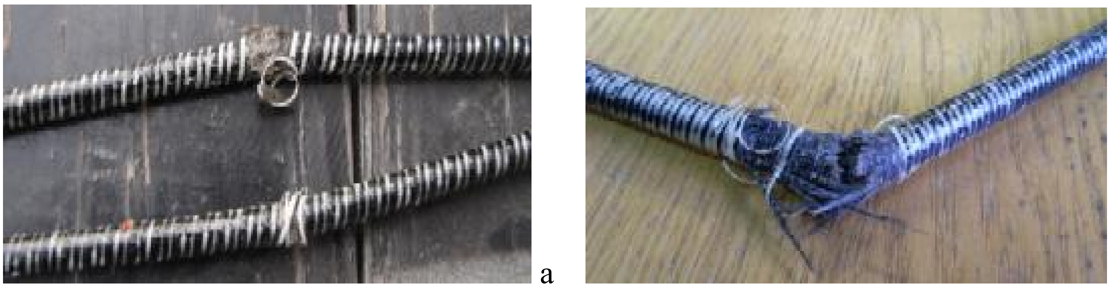


Fig.1 Composite transmission tower in Yakutia.

Three institutes of Siberian Department of Russian Academy of science have carried out a Complex Interdisciplinary Project to develop and apply basalt fiber and advanced nano-modified fiber-filled polymer composites for the Northeast of Russia, particularly the nano-modified basalt fiber reinforcement for structure that exploited in the North conditions. On Figure 2 shown the reinforcements after crossbending test.



a b

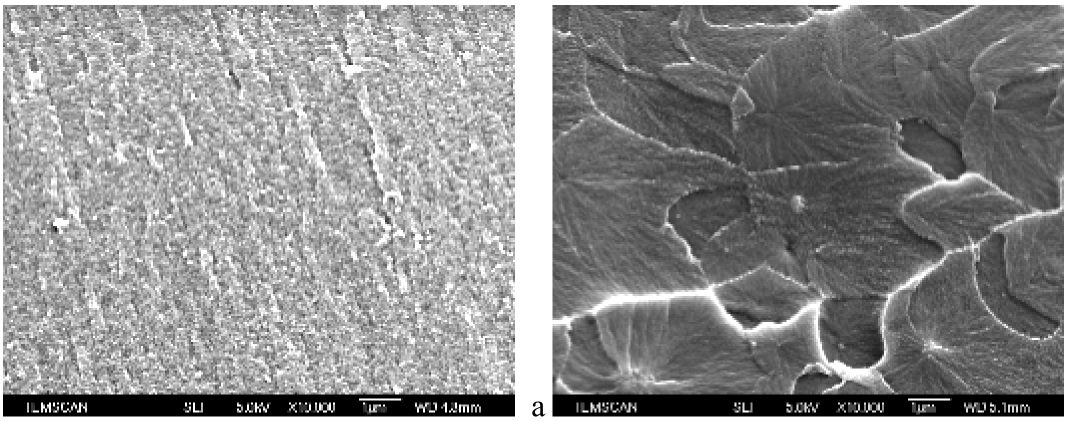
Fig.2 Probes of basalt fiber reinforcement after crossbending test: a) BPA 5,5; b) BPA 7,5.

RESULTS

Continuous basalt fibre, concrete paving meshes and composite reinforcements are considered by many specialists as one of the most prominent composite materials which possess the unique combination of advantages and at the same time much more cost-effective compared to other high performance fibres. Authorities in Russia and many other countries strongly support promotion of this product into industrial applications.

The new nanomodified binding agent on base of the theoretical modelling and experimental research has been developed (Bardakhanov, 2012). The agent has a higher strength and flow properties so it is possible to build reinforcement by winding and pooltrusion. Table 1 shows generalized results of experimental testing of basalt composite reinforcements. The micristructure of binding agents are shown in Fig.1. Research results to increasing the after aging strength of composite by 46% and tension strength by 32%.

The results from the tensile tests are shown in Fig. 3. The load-displacement curve has two different regions. The first region is nonlinear and evolves to an approximately linear region. Table 1 shows the results for the stiffness parameters E_I and E_{II}.



a b

Fig.3 Binding agent microstructure, ×10000: a) “pure”; b) nanopowder modified.

Table 1 Generalized test results of basalt composite reinforcements

Characteristics	Standard requirements	Reinforcement composite mark				
		SPA 5,5	SPA 7,5	BPA 5,5	BPA 7,5	BPA 5,5-T
Elasticity, *E*, GPa	50	52,9	54,5	58,3	57,1	58,7
Breaking strength, $\sigma_{в}$, MPa	1500	1668	1835	1536	1812	1495
Ultimate strain, ε	0,0317	0,0315	0,0337	0,0264	0,0318	0,0256
Crossbending strength before accelerated aging, σ_{n0}, MPa	1585	1887	2100	1648	2210	1639
Crossbending strength after accelerated aging, σ_{n}, MPa	1205	1265	1682	927	1023	1358
Tensile breaking strength, σ_{t}, MPa	905	921	1155	1014	1036	1091
Across fiber shear strength, τ_{sh}, MPa	165	231	229	231	276	939
Fiber chip strength, τ_{ch}, MPa	35	49,7	64,7	50,7	49,8	49,7
Phase change temperature (heat endurance), T_{t}, °	70	85,2	87,0	88,7	83,3	86,9
Vitrification temperature, T_{v}, °	93	105,7	117,6	114,2	108,5	109,7
α-transient temperature, T_{α}, °	-	98,8	107,0	105,0	99,7	101,5

The transport support is one of the urgent problem for the Northeast of Russia. It is connected to necessity of solution of the safety problem up to official standard level. There are series of specific factors for the cold climate region, as the seasonal and daily temperature drops, long period of very low negative temperature up to -60 ºC and other, that should be taken into account, so already known solutions for other Russian and most of the world regions are not suitable. It is in fully concerned for the materials and testing methods for the low climate temperatures, for the damage accumulation diagnostics and resource exhaustion for structures and machinery.

One of the actual problem for Yakutia is the high-level risk for the potential accident objects, higher crashworthiness and high-level of flood danger in spring period, melting of the frozen rock and permafrost soil, never so dangerous as for transport objects, and some other specific conditions.

Another big problem is the necessity of renewal of the old overage engineering equipment and machine park and potential accident objects that exploited in the North conditions. The solution of this problem makes the specific terms concerning the testing and production of the cold-resistance materials, new production technologies, repairs and restoration of structures and machines in northern design, modern models of the mining equipment and transport, off-line life-support systems, design and experimental testing and manufacturing application of residual lifetime estimation methods and health monitoring systems for potential accident projects in cold climate regions, including the natural gas and oil pipelines and tanks.

CONCLUSION

This study shows that there is important to take into account the possibility of new materials for the energy and transport design in cold regions, including sustainable and safety development. The strength of basalt composite materials could be raised by nanomodification for widely application like in wind turbine, transmission towers (piles) for eletric grid nets.

The strategy of defining and the metrics of project efficiency growth factor has been validated on the base of modern methodology base for regional energetic program requirements, with the mathematical methods and modelling bundled software for economy and fuel-energy complex forecasting of countries and regions, and large investment projects (Petrov, et al., 2010; Krugman and Obstfeld, 2003; WEO, 2007).

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