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Basalt Fiber: An Ancient Material for Innovative and Modern Application

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Abstract: Basalt fiber (BF), known as "the green industrial material of the XXI-century", combines ecological safety, natural longevity and many other properties. It is not a new material, but its applications are surely innovative in many industrial and economic fields, from building and construction to energy efficiency, from automotive to aeronautic, its good mechanical and chemical performances. Hence basalt fiber has gained increasing attention as a reinforcing material especially compared to traditional glass and carbon fibers. In this context, several studies dealing with glass and carbon fiber reinforced composites consider the significance of basalt fiber as a new reinforcing material.

Key words: Basalt fiber · Reinforcing material · Glass fiber · Useful applications

INTRODUCTION

Basalt is well known as rock found in virtually every country around the world. Its main use is as a crushed rock used in construction, industrial and highway engineering. However it is not commonly known that basalt can be used in manufacturing and made into fine, superfine and ultra fine fibers. Comprised of single-ingredient raw material melt, basalt fibers are superior to other fibers in terms of thermal stability, heat and sound insulation properties, vibration resistance and durability [1].

Basalt continuous fibers offer completely new range of composite materials and products. As it is well known, basalt is the name given to a variety of volcanic rock, known principally for its resistance to high temperatures, strength and durability, widely diffused all around the world, in which SiO_2 accounts for the main part, followed by Al_2O_3, then Fe_2O_3, FeO, CaO and Only acidic type basalts satisfy the conditions for fiber preparation.

actually basalt can also be formed into a continuous fiber having unique chemical and mechanical properties, so that it is ideally suited for demanding applications requiring resistance against high temperatures, insulation properties, acid and solvent resistance, durability, mechanical strength, low water absorption, etc [2].

Basalt products have no toxic re-action with air or water, are non-combustible and explosion proof. When in contact with other chemicals they produce no chemical reactions that may damage health or the environment. Basalt replaces almost all applications of asbestos and has three times its heat insulation MgO. For this reason, basalt rocks are classified according to the SiO_2 content as alkaline (up to 42% SiO_2), mildly acidic (43 to 46% SiO_2) and acidic basalts (over 46% SiO_2)[3].

Properties. Basalt based composites can replace steel and all known reinforced plastics (1 kg of basalt reinforcement equals 9.6 kg of steel). The life of basalt fiber pipes, designed for a variety of applications, is at least 50 years without maintenance or electrical or technical protection[4].

A Short History: The French Paul Dhé was the first with the idea to extrude fibers from basalt; he was granted a U.S. patent in 1923.Around 1960, both the U.S. and the Soviet Union (USSR) began to investigate basalt fiber applications, particularly in military field. In 1970 U.S. glass companies imposed research strategies that favoured glass fiber than basalt fiber, while in Eastern Europe research was nationalized by the USSR's Defense Ministry. After the breakup of the Soviet Union in 1991, the results of Soviet research were declassified and made available for civilian applications [5].

Today, basalt fiber research, production and most marketing efforts are principally based in some of countries once part of the Soviet Union (Georgia, Ukraine,

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the same Russia) and in China. Basalt fibers together with carbon or ceramic fibers as well as various metals is the most advanced and exciting area of application, as they can develop new hybrid composite materials and technologies [6].

Basalt's special properties reduce the cost of products whilst improving their performance. More than hundred specific unique manufacturing techniques using basalt fiber materials and products have been developed and patented in Russia [7].

Properties: Basalt fibers are new unique and economic products with superior properties to similar one in present use like as glass fibers. These fibers as a basis for composites open a new page in the 21st century material science. In thermal conductivity, articles made of basalt fibers are 3 times as efficient as those made of asbestos and superior to glass and mineral fibers. The application temperature of articles made of basalt fibers markedly higher (from-2600C to 9000C)[8].

In their physical properties (strength, elasticity) basalt fibers considerably exceed mineral and glass fibers.

Due the elasticity of micro-and macrostructure, basalt fibers are vibration-resistant compared to similar products. This property is of particular importance in mechanical construction and civil engineering. For example, when buildings are erected near highways, railways and underground, whereas under vibration cushions of mineral and glass fibers experience damage and finally disintegrate, basalt slabs are vibration-resistant and, hence, more durable.

In chemical properties basalt fibers are more resistant to aggressive media i. e. acids and alkalis. Therefore pipes made of basalt fibers may be used in the chemical production for transporting hot acids, in the construction of sewerage systems, transportation of aggressive liquids and gases, loose materials, etc.

Dielectric properties of basalt-plastics, in particular volume resistance of basalt fibers are 1 to 2 orders of magnitude higher than those of fiberglass. Basalt fibers can be used in various branches of industry fully replacing cancerous asbestos and to a considerable degree glass fibers and metals.

Why is better to use a heater of basalt superfine fibers compared to fiberglass insulation?

The most effective way to reduce the loss of heat energy is good insulation. Regardless of the use of structural and technological solutions you would like to use light, durable and harmless product. These are the characteristics for different types of thermal insulation chambers (ovens, sterilizers, etc.) have a fibrous insulation materials used in conjunction with the reflective insulation (foil).

By the fibrous insulation materials, have received widespread industry should include fiberglass and more recently, such "exotic material" as basalt fiber, which is due to the introduction of modern technologies to reduce the cost of its production and quality are increasingly being used in various industries. Basalt super fiber (BSTF) is produced from natural mountain magmatic rocks gabbro bazaltovogo types: basalt, diabase, gabbro, amphibolite and esite by melting the material at a temperature of (+) 1400 -1500°C and blowing up a high-temperature (+) 1600°C with high gas flow (300-400 m / s) at discrete basic staple fibers.

Basalt fiber insulation of the super modern materials are the twenty-first century, combining ecological purity, natural durability, fire safety (incombustibility). Temperature range of application of basalt fibers ranges from (-) 260°C and (+) 900°C, while the glass of (-) 60°C to (+) 450°C, hygroscopic basalt fibers less than 1%, glass - up to 10-20%. Producing industrial glass fiber especially in the neutral composition can absorb significant amounts of moisture in the humid air. This affects their physical and technical properties and durability and eventually leads to destruction of fibers.

Basalt fibers are low is not changing over time hydroscopicity due to its chemical composition. Slow is not increasing over time hydroscopicity basalt fibers provide thermal stability characteristics in the long run. Basalt fibers have high chemical resistance and belong to the first hydrolytic class and on acid and alkali steam resistance is far superior glass fiber.

The disadvantages of glass fibers in comparison with the basalt is a low temperature of (+) 450°C and the sintering temperature (+) 600°C, thorniness threads and the allocation of fine dust by mechanical destruction of the insulation during thermal cycle loads. The strength of basalt fibers, due to the high modulus of elasticity is 35-40% higher than the strength of glass fibers - the fiber is more elastic, unarmed.

Materials of basalt fibers have much greater resource exploitation, as compared with the materials of glass fibers. Fibers from superfine basalt fiber are firmly fastened together by natural cohesion. In mineral waddling for instance and glass fibers are used for gluing and carbamid phenol-formaldehyde resin, the concentration of vapor in the air of working area should be strictly controlled.

Production Process: In many ways, basalt fiber technology production is similar to glass fiber one, but it requires less energy. This aspect, together with an easy availability of raw material all over the world, justifies the lower cost of basalt fibers compared to glass fibers. BF is extruded from basalt rocks through a melting process without the application of additives.

Quarried basalt rock is first crushed, then washed and moved into melting baths in gas-heated furnaces. Under temperature of 1460-1500°C. Here, the process is simpler than glass fiber processing because the basalt fiber has a less complex composition. Molten basalt flows from furnace through a platinum-rhodium bushing with 200, 400, 800 or more holes and the fibers can be drawn from the melt under hydrostatic pressure. Then a sizing is applied to the surface of the fibers by a sizing applicator to impart strand integrity, lubricity and resin compatibility. Finally, a winder allows to realize some large spools of continuous basalt filament.

The production process, particularly temperature levels in the furnace, is of considerable importance in relation to final mechanical properties of basalt fibrous materials (rovings, etc). Infact it has been reliably determined that low variations in chemical composition of basalt rocks have a minor effect on the level of mechanical of continuous basalt fibers while the greatest effect comes from direct molding conditions of the fibers (drawing temperature and the period of melt homogenization).

For example, for the same basalt chemical composition, a fiber drawing temperature increase of 160°C (from 1220°C to 1380°C) increased their strength from 1.3 to 2.23 GPa and modulus of elasticity from 78 to 90GPa. Great importance on final properties has also the fiber dimension: as the filament diameter increases of 3-4 µm, the strength value decreases from 2.8 to 1.8 GPa.

Chemical and Mechanical Properties: Basalt fibers are characterized by a good resistance against low and high temperatures and are superior to other fibers in terms of thermal stability, heat and sound insulation properties, ablation resistance, vibration resistance and durability.

Basalt fiber is raised, from a performance standpoint, between the carbon fiber and the glass fiber, even if among others, it has a great advantage: it is well-compatible with carbon fiber. The consequence is that high efficient hybrid materials can be manufactured by adding small (pre-determined) amount of carbon fibers to basalt fibers. The obtained thread, differing insignificantly in cost (owing to small content of expensive carbon fiber) will demonstrate considerably better elastic properties compared with basalt fiber (notice that elastic modulus of basalt fiber is around 11.000 kg/mm^2, whereas that of carbon fiber is 22.000-56.000 kg/mm^2).

However, from a properties point of view, glass fiber, in its various form and chemical composition, can be considered as the reference material for a better understanding of basalt fiber properties.

Both are inorganic but they are manufactured by different processes.

Glass fibers are produced from melted charge (composed of quartz sand, soda, limestone, fluxing agents, etc.) to obtain glass, from which fibers are obtained by blow with steam, air or at centrifuge.

Among these various properties and characteristics, basalt fiber resistance in acidic and basic environments should be highlighted especially if compared with glass fiber, for the implications that this has in common applications of this material, such as concrete reinforcement in form of chopped or bars.

Obviously, chemical resistance of basalt fibers principally depends upon their chemical composition even if it is very important to evaluate the fiber surface condition, especially in the case of surface-active media (alkali, some salt solutions and so on); the ratio of silicon, aluminum, calcium, magnesium and iron oxides is of great importance.

For instance, the presence of iron oxides imparts to basalt fibers higher chemical and heat resistance as compared with glass fibers. In particular BF have high acid resistance, which is greater than the resistance of E-glass and S-glass fibers, but is somewhat less than the resistance of specific chemically resistant zirconium glasses.

Comparative characteristics of glass, mineral and basalt fibers and materials on their basis Glass fibers are produced from melted charge (composed of quartz sand, soda, limestone, fluxing agents, etc.) to obtain glass, from which fibers are obtained by blow with steam, air or at centrifuge. From glass fiber, glass fiber mats and fabrics are obtained as commodity products.

Mineral fibers are manufactured by smelting blast furnace slags with additives (slag wool) or some mineral resources (gabbro-basalts with additives of clays, dolomite, etc.), with following blow similarly to glass fiber production; mineral wool mats and plates are obtained from mineral fiber.

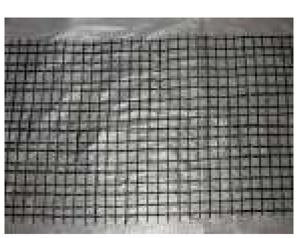
Basalt fiber is obtained from melted rocks of gabbro-basalt composition without any additives; among commercial products of basalt fiber are basalt mats, non woven web (cloth), fabrics, plates, cardboard.

Comparative characteristics of fibers

S.No	Parameter (characteristics)	Glass fiber	Mineral fiber	Basalt (BSTF)
1	Apparent density, kg/m3	12-25	25-40	15-23
2	Diameter of elementary fiber, microns	4-12	4-10	1-3
3	Length of fibers, mm	15-50	16	40-70
4	Elastic modulus, Kgf/mm2	Up to 7200	5400…8000	9100…11000
5	Thermal conductivity, W/m°C	0.038..0.042	0.04…0.047	0.031..0.034
6	Working temperature, °C	-60…+250	-180…+450	-250…+700

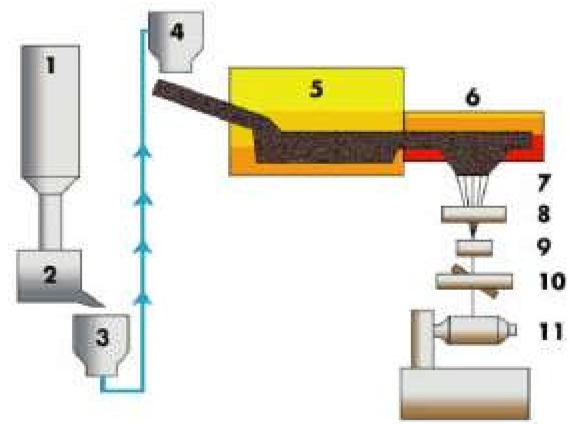
Areas of Application of Basalt Fiber:

- Aviation industry - heat and sound insulation quilt, covered with waterproofing fabric for insulation propulsion and airframe, the fuselage interior.
- Automotive - heat and sound insulation of engines, interiors of buses, mufflers, resonators, cameras utilization of CO, catalysts.
- Civil and industrial construction - internal heat and sound insulation of floors, walls, frame walls, tubes, pipes, boiler shells, tanks, chimneys, fire protection structures, etc.
- Cryogenic equipment - thermal insulation materials in the production of liquefied gases.
- Engineering - heat and sound insulation of thermal equipment, heating, hardening furnaces, heat lines, household electrical and gas appliances, medical sterilizers.
- Metallurgy - Materials for thermal insulation of various types of technological furnaces, equipment, pipelines and communications.
- Shipbuilding - heat and sound insulation of refrigeration equipment, fire insulation of partitions, decks, cabins.
- Chemical industry - heat and sound insulation of thermal equipment, drying chambers, heating mains and communications
- Energy - nuclear, thermal power stations - reactors, turbines, heating plants, boilers, heating, heat and sound insulation of thermal equipment, insulation installations, fire partitions, doors, cable penetrations, etc.



Fiber preforms

chopped fiber



Traditional Glass Fiber Production

1. Crushed stone
2. Loading station
3. Transport station
4. Bath charging station
5. Initial melt zone
6. Secondary control heat zone
7. Filament forming
8. Sizing
9. Strand formation
10. Fiber tensioning
11. winding

CONCLUSION

As a result of its characteristics and properties, basalt fiber can be really considered as the material of our future for a green and sustainable development. The basalt fiber is now being a popular choice for the material scientists and research fellows for the replacement of carbon fiber and steel due to its high rigidity and low elongation at break. Its supreme tenacity value makes it as a useful reinforcement material in the present and also for the future era to come.

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