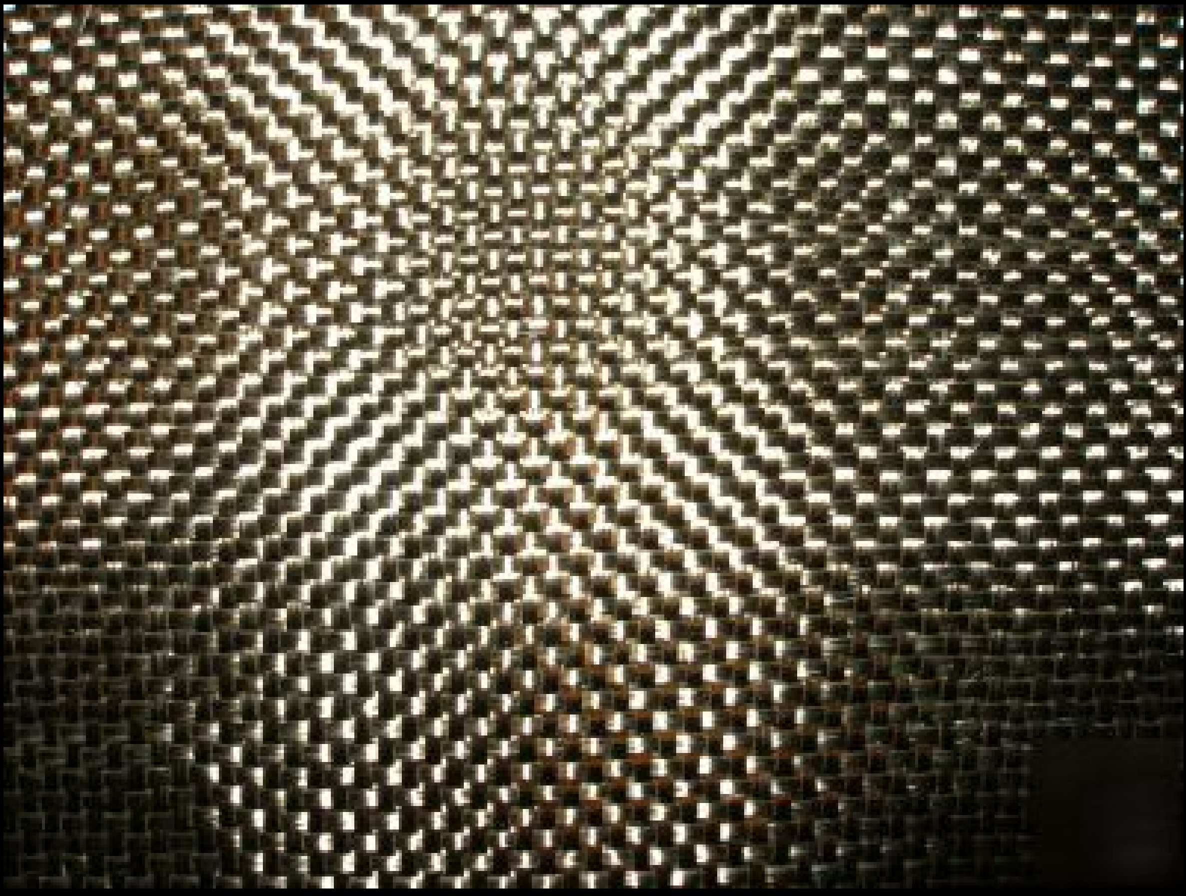
Basalt Fiber



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Abstract

The nature is constantly providing various resources for making textile materials for variety of applications. Though many textile fibers in the nature are available in the fibrous form itself, nature also offers raw materials that can be modified and formed into a filament in a way similar to the melt and solution spinning of other textile fibres. Basalt fiber is a material made from extremely fine fibers of basalt, which is composed of the minerals plagioclase, pyroxene, and olivine. It is similar to carbon fiber and fiberglass, having better physicomechanical properties than fiberglass, but being significantly cheaper than carbon fiber. It is used as a fireproof textile in the aerospace and automotive industries and can also be used as a composite to produce products such as camera tripods. Basalt fibre offers an alternative to carbon and glass in the filament winding of compressed natural gas cylinders. Basalt-based materials are environmentally friendly and are non-hazardous.

Key words

Basalt continuous filaments; Magma; Composites; Melting; Crystallization

Introduction

Basalt originates from volcanic magma and flood volcanoes, a very hot fluid or semi fluid material under the earth's crust, solidified in the open air. Basalt is a common term used for a variety of volcanic rocks, which are gray, dark in color, formed from the molten lava after solidification [1-4] .Basalt rock-beds with a thickness of as high as 200 m have been found in the East Asian countries.

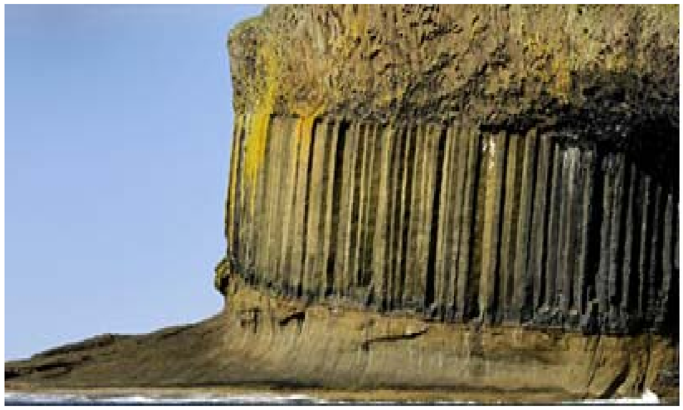

Fig.1: Sources of Basalt Fibre

Spinning of Basalt Fibre

Though basalt stones are available in different compositions, only certain compositions and characteristics can be used for making the continuous filaments with a dia range of 9 to 24 microns. Compounds present in the basalt rock may vary, especially the SiO2 content depending on their nature and origin. Basalt rocks with SiO2 content about 46% (acid basalt) are suitable for fibre production.

Table – 1: Chemical Composition of Basalt Rock

Chemical	%
SiO_2	52.8
Al_2O_3	17.5
Fe_2O_3	10.3
MgO	4.63
CaO	8.59
Na_2O	3.34
K_2O	1.46
TiO_2	1.38
P_2O_5	0.28
MnO	0.16
Cr_2O_3	0.06

Basalt continuous filaments (BCF) are made from the basalt rocks in a single step process melting and extrusion process. Technological process of manufacturing basalt filament consists of melt preparation, fibre drawing (extrusion), fibre formation, application of lubricants and finally winding [16]. Basalt fibers are currently manufactured by heating the basalt and extruding the molten liquid through a die in the shape of the fibers (Figure 1). Crushed rock materials are charged into the bath-type melting furnace by a dozing charger, which is heated using air-gas mixture. Crushed rocks are converted into melt under temperature of 1430°C - 1450°C in furnace bath. Molten basalt flows from furnace through feeder channel and the feeder window communicates with recuperator. The feeder has a window with a flange connected with slot-type bushing and is heated by furnace waste gases. The melt flows through the platinum rhodium bushing with 200 holes (500 is possible), which is heated electrically. The fibers are drawn from the melt under hydrostatic pressure and subsequently cooled to get hardened filaments. A sizing liquid with components to impart strand integrity, lubricity, and resin compatibility is applied and then filaments are collected together to form a 'strand' and forwarded to the take up device to be wound on to a forming tube. The forming package is often referred to as 'forming cake'. The dried cakes are ready for further processing. [14]

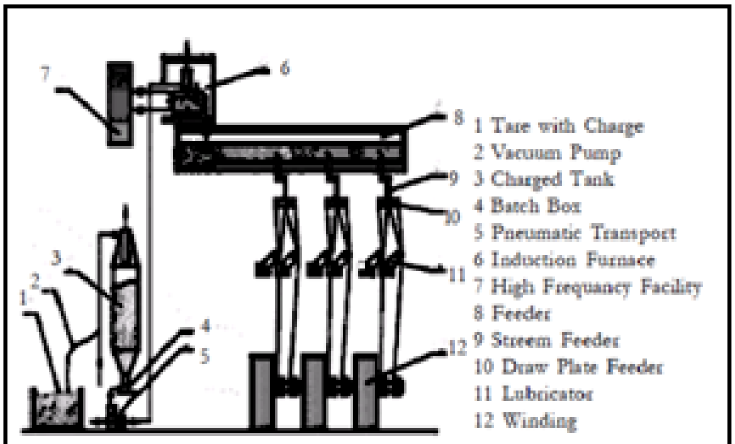

Fig. 2: Spinning of Basalt Fibre

Basalt twisted yarn is produced by twisting the basalt roving. Twist provides additional integrity to the yarn before it is subjected to weaving. Basalt Cut Fibre is produced from continuous basalt filament, chopped to a specific fiber length in a dry cutting process [5].The moisture content of the final material lies in the range of less than 1% and with sizing add on levels ranging from 1.0% - 2.0%.The very high melting temperature of basalt rocks makes the process more complicated than that is normally used in the case of glass. Molten basalt is non-homogeneous in nature, which leads to non-uniform temperature distribution during production stage. This requires a very precise temperature maintenance and control system at multiple stages [11].

The main problem that is frequently encountered during the manufacture of basalt fibers is the gradual crystallization of various structural parts like plagioclase, magnetite, and pyroxene. This arises mainly because of difference in the crystallization temperature (Tc) of the different components, which varies from 720oC - 1010oC (magnetite Tc - 720oC, pyroxene Tc - 830oC and plagioclase Tc - 1010oC).Fresh basalt fibers are practically amorphous when the rapidly quenched, due to the action high temperature these fibers develop the ability to crystallize partially. A slow cooling of these fibers leads to more or complete crystallization to form an assembly of minerals. [3] Fig. no.2

Basalt fibre (BF) can be blended with polypropylene/polyamide (PP/PA) by homogenization of the components in a twin-screw extruder followed by injection molding [10]. In order to determine their static and dynamic

Table 2: Physical Properties of Basalt Fibre

Property	Value
Density, g/cc	1.95 - 2.75
Tensile Strength, Mpa	1200 – 4840
Compressive Strength, Mpa	420
Bending Strength, Mpa	800
Elastic Modulus, Gpa	89
Elongation at Break, %	3.15
Moisture at 65% RH, %	<0.1
Max Application Temperature, 0C	982
Sustained Operating Temperature, 0C	820
Min Operating Temperature, 0C	-260
Melting Point, 0C	1450
Thermal Conductivity, W/m K	0.031 - 0.038
Glow Loss, %	1.9 - 2.0
Sound Absorption Coefficient	0.9 - 0.99
Loss Angle Tangent Frequency, MHz	0.005
Relative Dielectric Permeability, MHz	2.2
Limiting oxygen index (LOI)	>70

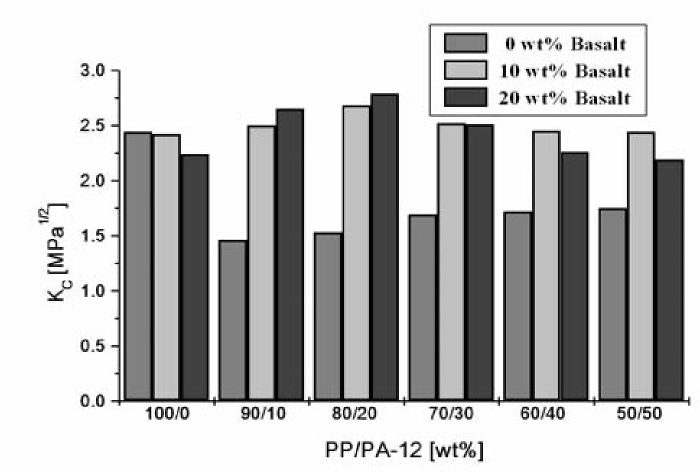

Fig. 3(a) : Critical fracture toughness of basalt fibre reinforced PP/PA blends, static

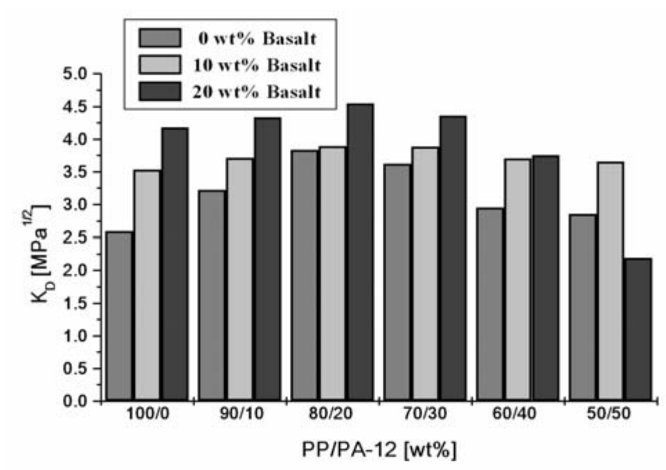

Fig. 3(b): Critical fracture toughness of basalt fibre reinforced PP/PA blends, dynamic

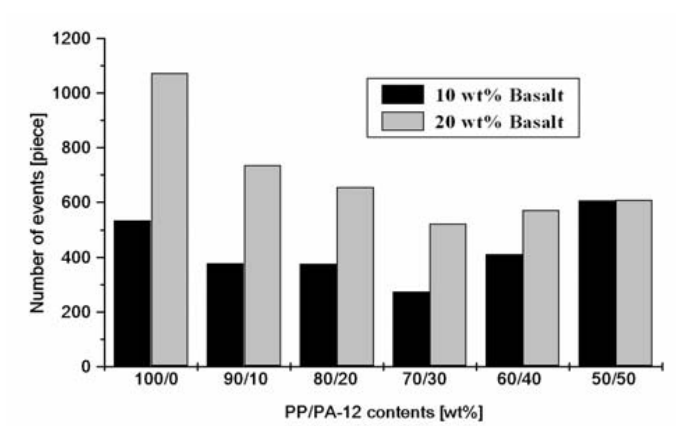

Fig. 4: Cumulative number of events in basalt fibre reinforced PP/PA blends.

mechanical properties tests have been performed on composites with different PA (0, 10, 20, 30, 40, and 50 wt %) and basalt fibre (0, 10, and 20 wt %) contents [14].Composite properties such as tensile and flexural strength, stiffness and fracture toughness have been calculated. It has been realized that the composite structure is very sensitive to the ratio of PA content. In case of small PA content (10–20 wt %), PA and basalt fibre have been experienced to form a kind of random network structure inside the PP matrix. This way could be improving the mechanical properties of the composite despite the relatively short fibre length. These results have been supported by acoustic emission (AE) tests and scanning electron (SEM) micrographs [14]. Fig. No.:-3(a) and 3(b). ***It*** shows that the fibre content influences the values of the critical stress intensity factor considerably both in case of static (*Fig. 3a*) and dynamic (*Fig. 3b*) loading.

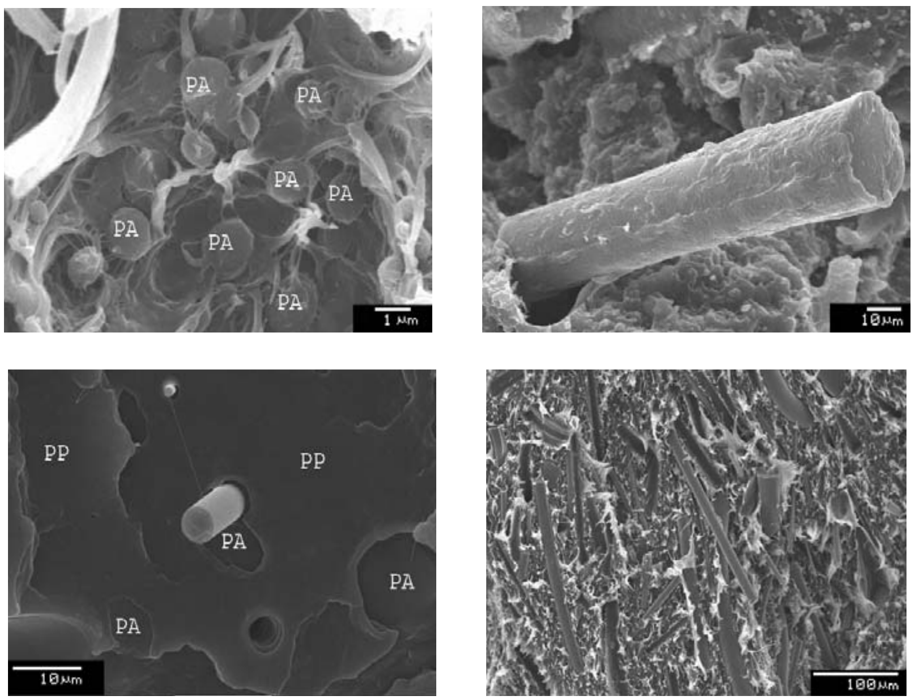

Fig.5. SEM pictures taken of the fracture surface of SEN-T specimens cut out from the basalt fibre reinforced PP/PA matrix composites with and without fibers type 40wt% PA(a), 10 wt% PA and 10 wt% fibre (b) 40 wt% PA and 20 wt% fibre (c), and 50 wt% PA and 20 wt% fibre (d) [14].

Fig.4 shows the number of detected events as a function of PA and basalt content. The most events can be seen in case of composites with 100% PP content both in case of composites with 10% and 20% basalt content, while the fewest events were detected in case of composites with 30% PA content. The results show well that when fibers separate or pull out from PP there are more events when failure occurs concerning PA/basalt. In case of the 30% PA content a few events are resulted by the PP/PA interfacial separation, which involves great plastic deformation, hence does not induce acoustic signals, as an opposite to fibre/matrix failure where friction induces a large number of events.

Applications

Basalt Products have wide prospect of application in various industries.

- **Machinery construction**

  Composite materials, constructional materials, constructions suitable for environment with strong vibrations & alternating load, grids for reinforcement of cutting wheels, sound-proof materials, heat insulation of thermal equipment, filters for cleaning of waste gases from dust and industrial drains.

- **Motor-car construction**

  Used in a wide range of products for automotive industry: heat isolation material for manufacturing of automobile mufflers, panels, screens, plastics, reinforcing material for shoes & disks, constructional plastics, nonflammable composite materials, cords for automobile tire covers, chopped strand for reinforcing plastic, etc. Also used for production of fuel tanks, LPG & compressed NG cylinders. Anticorrosive, with great dispatch and wears proof coverings of the bottoms of cars.

- **Shipbuilding**

  Seawater proof composite materials & products, heat & sound isolation for ship installations & equipment, heat-insulated plates for ship hulls & engine compartments, constructional materials. In construction of small ships – for construction of ship hulls & additional structures, as well as corrosion-proof, reinforced paint & varnish coverings of ship hulls & additional structures.

- **Carriage building**

  Composite constructional materials & products, heat & sound isolation, reinforcement of constructional plastics, nonflammable composite materials, electro-isolating materials, stable paint & varnish coverings.

- **Aviation industry and rocket production**

  Heat and sound isolation linen for motor & hull, constructional composite & high-temperature materials.

- **Power**

  Heat insulation of thermal equipment for steam boilers, turbines, heating mains; high-voltage.

- **Atomic engineering**

  Nonflammable heat isolation & constructional materials, fire-prevention doors, cable corridors, radioactive protection materials.

- **Electronic industry**

  Reinforcing material for production of plates, electro-insulation materials, construction material for cases for electronic equipment.

- **Chemical industry**

  Production of chemically proof materials & products: pipes, tanks for aggressive liquids, acids, alkalis, chemical fertilizers, pesticides, poisonous substances. Chemically proof covering for tanks, pipelines, metal constructions, Ferro-concrete constructions. Filters for cleaning from dust & industrial drains, high-temperature filters.

- **Petrochemical industry**

  Chemically & wear proof coverings of tanks, pipelines, oil pipelines; nonflammable coverings & composite materials; fire-proof composite materials; oil pipes.

- **Metallurgy**

  Thermo-insulation materials for thermal equipment, furnaces, recuperators, pipelines, communications; filters made from CBF for filtration of metals melt during molding; filters for clearing of waste gases from dust at ore-mining & processing plants; filters for sewage treatment.

- **Cryogenic technologies & equipment**

  Thermo-insulation materials for production of squeezed gases liquid oxygen, nitrogen, etc.

- **Fire-proof materials** [17]

- **Building materials**

  Building constructional and facing plastics; reinforcing plaster grids; warmed panels for construction of prefabricated houses, floors, dropped ceilings, fireproof walls, fire-resistant doors, building plastics.

  Basalt-plastic reinforcement for bridges, tunnels, railway sleepers, metro, construction materials. Reinforcement for asphalt-concrete coverings of roads, runways of airports.

Waterproof rolled and sheet materials, roofing materials. Hydraulic engineering construction, including reinforcing materials for construction of dams, irrigation materials.

- **Port constructions, sea platforms**

  Reinforcing and constructional materials made from basalt-plastics; paint & varnish proof coverings of bridges & tunnels; main construction projects; waterproof coverings for Ferro-concrete installations; nonflammable and heat-resistant paints & varnish coverings.

- **Ceramics & porcelain**

  Thermo-insulation of furnaces & equipment during production of ceramic & porcelain products, bricks & ceramic tiles.

- **Agriculture**

  Grids for strengthening soil; tanks for storage and transportation of liquid chemical fertilizers and pesticides; material for hydroponics for cultivation of bacterial cultures, sprouts of plants, etc

- **Municipal services**

  Materials for cleaning installations; big pipes for water supply & sewage; Filters for air clearing & liquid environments, municipal drains, cleaning installations, etc. Basalt fiber is the main material used for filtration of emissions & drains, and at the moment it does not have any real alternative.

- **Home appliances**

  Sanitary products, thermo insulation of gas and electric ovens, stoves, etc.

Conclusion

So, in the coming years basalt fiber has a great role to play in the field of composites. Basalt fibers are used in a wide range of application areas such as the chemical, construction and marine sectors, not to mention the offshore, wind power, transport and aerospace industries. This is due to their superior properties: not only do they boast good mechanical and chemical resistance, but also excellent thermal, electric and acoustic insulation properties.

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