Basalt Fibers: Alternative To Glass?

High-temperature performance and superior strength properties may make this late-comer a better choice in some applications.
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Source: Kamenny VekThree bobbins of continuous-filament basalt roving, ready for transport to a customer.

A hard, dense volcanic rock that can be found in most countries across the globe, basalt is an igneous rock, which means it began in a molten state. For many years, basalt has been used in casting processes to make tiles and slabs for architectural applications. Additionally, cast basalt liners for steel tubing exhibit very high abrasion resistance in industrial applications. In crushed form, basalt also finds use as aggregate in concrete.

More recently, continuous fibers extruded from naturally fire-resistant basalt have been investigated as a replacement for asbestos fibers, in almost all of its applications. In the last decade, basalt has emerged as a contender in the fiber reinforcement of composites. Proponents of this late-comer claim their products offer performance similar to S-2 glass fibers at a price point between S-2 glass and E-glass, and may offer manufacturers a less-expensive alternative to carbon fiber for products in which the latter represents over-engineering.

IDEAS AND IDEOLOGIES

Paul Dhé from Paris, France, 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 former Soviet Union (USSR) began to investigate basalt fiber applications, particularly in military hardware, such as missiles.

In the northwestern U.S., where large basalt formations are concentrated, Prof. R.V. Subramanian of Washington State University (Pullman, Wash.) conducted research that correlated the chemical composition of basalt with the conditions for extrudability and physio-chemical characteristics of the resulting fiber. Owens Corning and several other glass companies conducted independent research programs, which resulted in several U.S. patents. Around 1970, however, U.S. glass companies abandoned basalt fiber research for strategies that favored their core product. The result was a better glass fiber including successful development of S-2 glass fiber by Owens Corning.

During the same period, research in Eastern Europe, which had been carried out in the 1950s by independent groups in Moscow, Prague and other locales, was nationalized by the USSR's Defense Ministry and concentrated in Kyiv, Ukraine, where technology was subsequently developed in closed institutes and factories. After the breakup of the Soviet Union in 1991, the results of Soviet research were declassified and made available for civilian applications.

Today, basalt fiber research, production and most marketing efforts are based in countries once aligned with the Soviet bloc. Companies currently involved in production and marketing include Kamenny Vek (Dubna, Russia), Technobasalt (Kyiv, Ukraine), Hengdian Group Shanghai Russia & Gold Basalt Fibre Co. (Shanghai, China), and OJSC Research Institute Glassplastics and Fiber (Bucha, Ukraine). Basaltex, a division of Masureel Holding (Wevelgem, Belgium), and Sudaglass Fiber Technology Inc. (Houston, Texas) convert basalt fiber into woven and nonwoven reinforcement forms for the European and North American markets, respectively.

LIKE, BUT UNLIKE

Basalt fiber is produced in a continuous process similar in many respects to that used to make glass fibers. Quarried basalt rock is first crushed, then washed and loaded into a bin attached to feeders that move the material into melting baths in gas-heated furnaces. Here, the process is actually simpler than glass fiber processing because the basalt fiber has a less complex composition. Glass is typically 50 percent silica sand in combination with oxides of boron, aluminum and/or several other minerals — materials that must be fed independently into a metering system before entering the furnace. Unlike glass, basalt fibers feature no secondary materials. The process requires only a single feed line to carry crushed basalt rock into the melt furnace. On the other hand, basalt fiber manufacturers have less direct control over the purity and consistency of the raw basalt stone. While basalt and glass are both silicates, molten glass, when cooled, forms a noncrystalline solid. Basalt, however, has a crystalline structure that varies based on the specific conditions during the lava flow at each geographical location. Basalt combines three silicate minerals — plagioclase, pyroxene and olivine. Plagioclase describes a number of triclinic feldspars that consist of sodium and calcium silicates. Pyroxenes are a group of crystalline silicates that contain any two of three metallic oxides, magnesium, iron or calcium. Olivine is a silicate that combines magnesium and iron — $(Mg, Fe)_2SiO_4$. This potential for compositional variety means that the mineral levels and chemical makeup of basalt formations can differ significantly from location to location. Moreover, the rate of cooling, when the original flow reached the earth's surface, also influenced the crystal structure. Basaltex R&D director Jean-Marie Nolf notes, therefore, that despite its ready availability from mines and open-air quarries around the world, only a few dozen locations contain basalt that has been analyzed and qualified as suitable for manufacture of continuous thin filaments. Ihor Markuts, sales and marketing director for Technobasalt, maintains that basalt formations in the Ukraine are particularly well suited to fiber processing. Dr. Boris Mislavsky, director of marketing and development for Kamenny Vek, agrees. His company currently gets all of its raw material from western Ukraine. While the company has a backup mine located in Russia, with a chemical composition close to its main source, it prefers to mine material from a single source. "All our materials come from the same quarry," he explains.

ROCK TO FIBER

As crushed basalt enters the furnace, the material is liquefied at a temperature of 1500°C/2732°F (glass melt point varies between 1400°C and 1600°C). Unlike glass, which is transparent, the opaque basalt absorbs rather than transmits infrared energy. Therefore it is more difficult for the overhead gas burners used in conventional glass furnaces to uniformly heat the entire basalt mix. With overhead gas, the melting basalt must be held in the reservoir for extended periods of time — up to several hours — to ensure a homogenous temperature. Basalt producers have employed several strategies to promote uniform heating, including the immersion of electrodes in the bath. But Ihor Markuts, sales and marketing director for Technobasalt, notes that his company prefers gas heating to electric, for quality reasons, despite increased manufacturing costs. Finally, a two-stage heating scheme is employed, featuring separate zones equipped with independently controlled heating systems. Only the temperature control system in the furnace outlet zone, which feeds the extrusion bushings, requires great precision, so a less sophisticated control system may be used in the initial heating zone.

Like glass filaments, basalt filaments are formed by platinum-rhodium bushings. As they cool, a sizing agent is applied and the filaments are moved to speed-controlled fiber stretching equipment and then on winding equipment, where the fiber is spooled.

Because the basalt filament is more abrasive than glass, the expensive bushings once needed more frequent refurbishing. As bushings wear, their cylindrical holes wear unevenly, degrading process control. Without timely maintenance, the out-of-round apertures form filaments with an unacceptably wide diameter range, producing a roving with unpredictable breaking loads, explains Nolf. While glass fiber bushings last six months or more before they need to be melted, reformed and redrilled, a bushing used for basalt fiber production previously lasted anywhere from three to five months. Kamenny Vek, however, reports that process control efforts have extended bushing life to a similar six-month cycle.

FIBER VS. FIBER

On balance, these differences in processing and maintenance lead to overall operating costs that exceed those for processing E-glass fiber, but basalt fiber proponents say that their product clearly outperforms E-glass in composites. In chopped mat, roving and unidirectional fabric forms, basalt fibers exhibit a higher breaking load and higher Young's modulus (a measure of the stiffness of a given material) than E-glass. In a study of basalt fibers and E-glass fibers, conducted by Professor Ignaas Verpoest at the Composites Dept. of the University of Leuven in Belgium, unidirectional prepregs were produced by impregnating E-glass and basalt roving with epoxy and winding each on a mandrel, and then compacting the laminate until complete cure was achieved. Samples of 135-mm by 15-mm (5.3-inches by 0.6-inch) were cut and measured for thickness. The pieces were then subjected to a three-point bending test (ISO 178) and the ILSS test (ISO 14130) to test strength and stiffness. Verpoest reports that each sample had a fiber volume fraction of 40 percent, but the basalt/epoxy sample's strength tested 13.7 percent higher than that of the E-glass sample and exhibited 17.5 percent greater stiffness, although the basalt sample was 3.6 percent heavier than the E-glass sample.

Additionally, basalt fibers are naturally resistant to ultraviolet (UV) and high-energy electromagnetic radiation, maintain their properties in cold temperatures, and provides better acid resistance. Reportedly, basalt also is superior in the realm of worker safety and air quality as well. Markuts points out that since basalt is the product of volcanic activity, the fiberization process is more environmentally safe than that of glass fiber. The "greenhouse" gases that might otherwise be released during fiber processing, he says, were vented millions of years ago during the magma eruption. Further, basalt is 100 percent inert, that is, it has no toxic reaction with air or water, and is noncombustible and explosion proof.

FIBER TO FABRIC

Once producers mastered fiber manufacture, they faced additional challenges as the product was converted to useful reinforcement forms. Basaltex, for example, found early on that woven basalt fabrics straight from a weaver's loom were fragile and easily damaged when handled, exhibiting broken fibers when sharply folded or bent, and were irritating to the skin. In order to make the product more stable, Basaltex developed a proprietary silane-based sizing that facilitates the post-manufacture processing. The coating doesn't generate toxic smoke when heated and does not degrade the fiber's fire-resistance properties. Mislavsky observes that a significant factor in initially poor fabric performance was fiber damage that occurred during the fiberization process. He maintains that, today, a combination of sizing and refined production techniques minimizes damage and enables basalt fiber manufacturers to produce strong fibers that can be braided and woven without inhibiting desired performance.

While basalt fiber is still not widely used, it is slowly making its way into the hand of consumers. At price points that vary between S-glass ($5/lb to $7/lb) and E-glass ($0.75/lb to $1.25/lb), basalt fibers have properties akin to S-glass. A common use is in the fire protection sector because of its high melt-point. Fire-blocking tests performed by Basaltex placed its basalt fabric in front of a Bunsen burner, placing the yellow tip of the flame in direct contact with the fabric. The yellow tip reaches temperatures of 1100°C to 1200°C (2012°F to 2192°F) and causes the fabric to become red hot, similar to a metal fabric. When exposed to the flame, basalt fiber maintains its physical integrity for extended periods of times, but the company found that a fabric made of E-glass with the same density can be pierced by the flame in a matter of seconds.

It's burn resistance has earned basalt fiber a role as an asbestos replacement in friction applications, such as composite brake pads, because it does not soften at elevated temperatures and won't deposit on its counterpart (either the disc or brake drum) in the braking system. Continuous basalt fibers also are in use as reinforcement in other conventional composite structures. According to Nolf, basalt fibers wet easily and therefore enable fast resin impregnation, making them suitable for resin transfer molding, infusion molding and pultrusion. "All the products that are made of glass can be made of basalt," Markuts claims.

PROTOTYPE TO PRODUCTION

Mislavsky says that Kammeny Vek currently has several customers using its standard reinforcement products. One company of note is glass fiber manufacturer Ahlstrom (Helsinki, Finland), which is supplying biaxial basalt fabrics for testing in wind turbine blade laminates. "The wind blade business is driven by stiffness," Mislavsky says. Basalt fiber laminates have a 15 percent higher modulus and 25 percent higher tensile strength over E-glass, making its use in some zones of the wind blades ideal. Project engineers use a computerized system to calculate the advantages and disadvantages of different materials and sizings. Prototypes are undergoing a series of tests, and Mislavsky expects the blades to be certified by Germanisher Lloyd later this year.

OEMs are beginning to investigate basalt fiber products for consumer goods as well. Gitzo SA (Nogent Le Phaye, France), which sells professional tripods and heads, recently debuted its basalt tripods and monopods. The company offers several different models to suit the needs of almost any photographer. Gitzo entered composites manufacture with its carbon fiber tripods, and now uses its fiber-reinforced tube fabricating experience to make basalt versions. The company chose basalt fiber because it offers a strong composite at less cost than carbon. Basalt tripod legs are roughly 20 percent lighter than aluminum legs and better at damping vibration.

Lib Technologies (Seattle, Wash.) currently sells two different snowboard models that incorporate a basalt fabric instead of the traditional fiberglass used on many of its models. The boards, manufactured by Mervin Manufacturing (Seattle, Wash.), are part of the company's *Dark* and *Phoenix* series and are made with a product the company calls Golden Fleece Basalt, from an unidentified supplier. The boards contain a proprietary wooden core with a basalt fiber lining on each side that results in lighter, stiffer snowboards. Mervin Manufacturing also produced a snowboard for QuikSilver using Basaltex products. The board was on exhibit in the Basaltex booth at the 2005 JEC Composites Show.

In the automotive industry, Azdel Inc. (Southfield, Mich.), a 50/50 joint venture of GE Advanced Materials (Pittsfield, Mass.) and glass-fiber producer PPG Industries (Pittsburgh, Pa.), developed VolcaLite, a thermoformable thermoplastic composite that combines polypropylene (PP) and long chopped basalt fiber. The company claims that the basalt/PP system offers acoustic absorption properties, low coefficient of thermal expansion (CTE), and a high strength-to-weight ratio, providing good ductility. It is initially targeted for auto headliners, which can be made 50 percent thinner than conventional systems, says the company.

Technical Fibre Products Ltd. (Kendal, Cumbria, U.K. and New York, N.Y.) has taken chopped basalt fibers and made gossamer nonwoven veils. The company is running trials of the product in laminated and thermoformed automotive components. Johns Manville Europe (Bad Homburg, Germany) also has produced wet-layed basalt veils.

Basalt fiber is becoming a contender in infrastructure applications as well. Although the company no longer produces its own fiber, Sudaglass (Houston, Texas) produces several products from basalt fiber, including concrete reinforcement rods. Pultruded from unidirectional basalt fiber, the rods are reportedly 89 percent lighter than steel reinforcement rods, have the same coefficient of thermal expansion as concrete and are less susceptible to degradation in an alkaline environment. The company claims that that 1 ton of basalt rods can provide reinforcement equal to 4 tons of steel rods.

As commercialization continues, consistent fiber supply also looks promising. Kamenny Vek, for example, is looking to launch a second furnace later this year and hopes to turn out 30,000 metric tonnes (66 million lb) per annum by 2009, Mislavsky says.