

## Technical

# Non-plastic fiber cord reinforcement for tires

By **Chris Stevens**  
NGF Europe Ltd.

and **Jason Martin**  
NGF Canada Ltd.

The common reinforcing cord fiber materials for tires are steel and thermoplastic polymer fibers. Fifty years ago glass cord was used for tire reinforcement.

This paper presents the advances in cord technology, high strength glass fibers, carbon fiber and carbon, plus glass hybrid cords that are now available. Presentation also is made of particulate

### TECHNICAL NOTEBOOK

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linear and planar fillers that are available and could provide anisotropic dynamic tire properties.

#### Glass cords

In 1967, Goodyear launched their Polyglas tire, reinforced with glass cords. The tire used two plies of polyester cords plus two belt plies of glass cord. At this time the tire was good for traction, skid control, low squirm and gave double the mileage of the previous best-selling Goodyear tires.

A glass cord is produced from a bundle of glass fibers coated with a small amount of adhesive, or "size," often a silane. The fibers are passed through a bath containing rubber latex and crosslinker (commonly resorcinol-formaldehyde resin).

With glass impregnation, every fiber is coated in latex (RFL). This is different to the thermoplastic polymer cords of today, which consist of large diameter bundles of fibers, which when passed through the dip only allows penetration

### Executive summary

The common cord materials for reinforcement of car tires are steel for the main belting. Plastic fiber cords of polyester, nylon and rayon tend to be used for carcass and cap plies.

This paper will present alternative cords made from rubber-impregnated glass fiber, aramid fiber and carbon fiber.

The history of these cords will be reviewed and brought up to date with modern materials and techniques. This will include the properties of high tensile strength glass and improved cord plying processes for extended fatigue performance.

These have the potential to allow significant light-weighting of the tires by replacement of the steel. Novel constructions involving two-material cords (such as glass wrapped carbon hybrid cords) allow significant flex fatigue life to be obtained.

of the latex into the surface layers of the fiber bundle.

The advantages of coating every fiber are that the latex acts as protection against fiber-to-fiber abrasion during fatigue. Also, when high local stresses arise, the latex allows mechanical transmission within the cord to maximize load sharing between the fibers. Typically the cord will contain 20 percent latex and 80 percent glass fiber.

A typical glass cord for tires will consist of 1,600 filaments of E glass, each 10  $\mu$  in diameter. The linear density of the glass is 330 g/km (tex). To this is added about 70 g/km of RFL, which is cross-linked into a matrix around and between the fibers.

The RFL has been chosen for very good adhesion to tire compounds—especially NR, BR and SBR. The strand would then be twisted into a cord, with the twisting providing flex fatigue resistance by angling the fibers across the tensile and bending strains. This cord is 0.5 mm in diameter, with a linear modulus of about 20 GPa, but a bending modulus of only 50 MPa.

This cord, or two strands twisted together, is still used in high volume for lightweight low heat build-up tires today. The linear stiffness available will double if two strands are twisted together, so that the reinforcing stiffness can be chosen in balance with the cord diameter:

This means that the tire designer can consider comparing glass cord reinforcement versus steel at the same diameter, same strength, same weight or same modulus by choosing different cord constructions (Fig. 1).

#### New cords

##### High tensile strength glass (HTS)

Improvements to the standard tire cords are available by using thinner bundles of fibers. The fatigue life increases when using 200 fiber bundles.

Even higher improvements are available when changing to high tensile strength glass, with a change of chemical formulation of the glass. K glass and U glass (also known as S2) as 7  $\mu$  filaments will typically have fatigue lifetimes in excess of  $5 \times 10^8$  cycles, the equivalent of about a million km in a car tire.

The much thinner strands of 200 fibers have a diameter of about 0.2 mm. Plying multiple strands together provides a much

### The author

Chris Stevens has spent his whole career in the polymer industry, trying to understand the interaction of chemical changes upon physical properties.

He currently is technical director for NGF Europe Ltd., where he is responsible for research and development of rubber-impregnated glass cords used for car timing belts, car tires and reinforcing sponge profile seals.



Stevens

Stevens gained his doctorate at Bath University in fracture mechanics, degradation studies and finite element stress analysis of O-ring seals.

He previously worked for Philips, looking at polymers for electrical and electronic components, and for safety of polymers in nuclear power. Stevens also ran a technical service rubber laboratory for a carbon black company, and was in charge of the design team at Monsanto Rubber Instruments.

finer balance of stiffness and diameter than the larger 0.5 mm strands.

#### Carbon

Carbon fibers are attractive for their high modulus and light weight. The density of carbon fiber is 25 percent lighter than glass fiber: 1.8 versus 2.5 g/cm<sup>3</sup>, providing significant advantages over thermoplastic and glass fibers for tire light-weighting.

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Fig. 1. E glass cord stiffness: Different constructions.

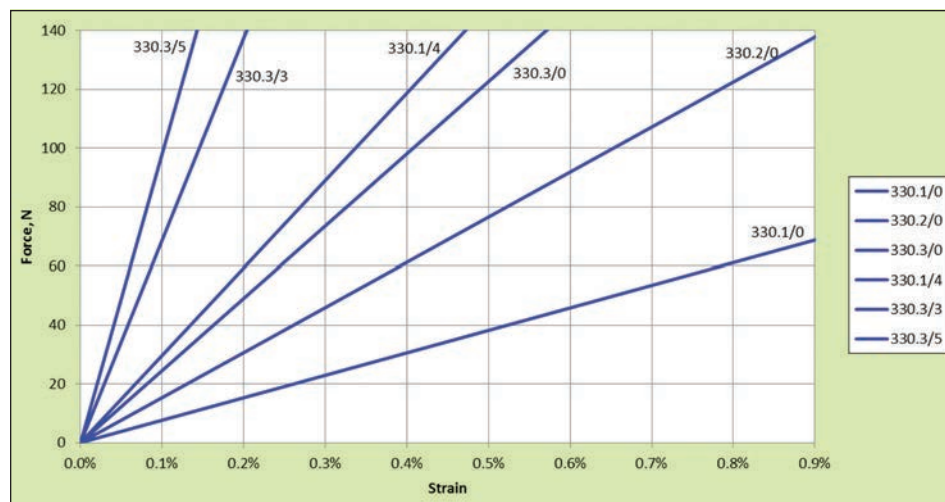


Fig. 2. Typical tensile curves for 1.05 mm cords.

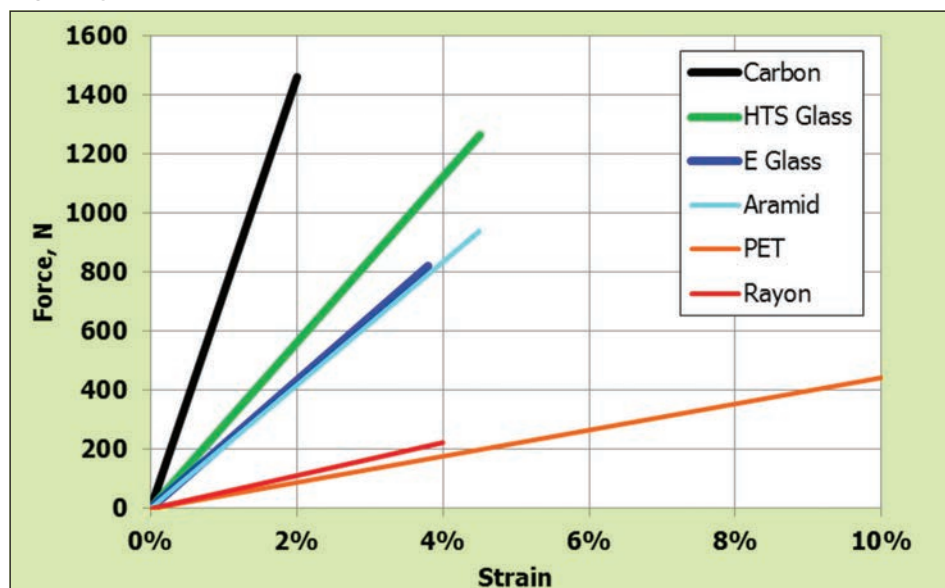
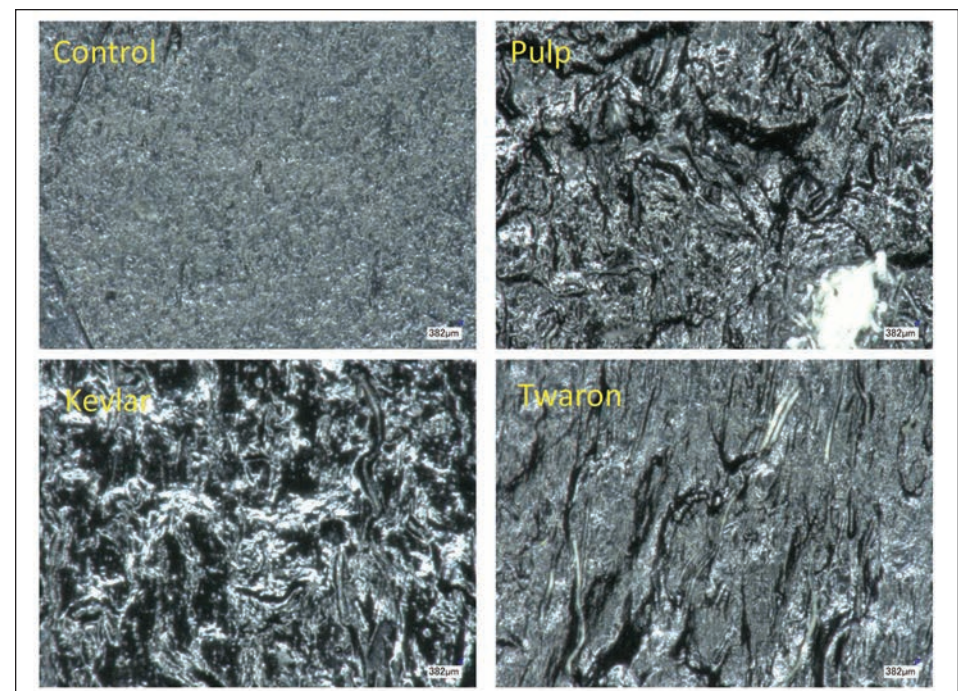


Table 1. Comparative properties.

The tensile properties of a typical 1.05 mm cord of different materials are compared:

	Polyester	Rayon	E glass	Aramid	U glass	Carbon
Modulus, GPa	5	6	25	25	33	80-85
Force to break, N	4-500	2-250	8-850	~900	12-1300	14-1500
Strain to break	10%	4%	3.8%	4.5%	4.5%	2%

Fig. 3. Microscope images of 10 phr of aramid in CR compound. The Kevlar and Twaron additions were of RFL-treated fibers.



# Fiber

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Cords are produced in a similar manner—impregnating with latex, cross-linking and twisting. The twisting means that the bending strains in the filaments are about a tenth of those predicted for the bending of a solid body.

This allows the carbon fiber cords to have a significant fatigue life, despite having a limited extensibility, as the breaking strain is only 2 percent. The carbon fiber has been found to have excellent linear tensile fatigue life. (Fig. 2)

## Hybrid

The tire industry is quite familiar with the concept of hybrid fibers, where different fibers are twisted together. This is performed at the fiber level, rather than at the bundle scale. NGF technology allows materials to be positioned within a cord. For example, a core 0.7 mm of im-

pregnated carbon fiber cord can be surrounded by a 0.2 mm sheath of impregnated glass fiber strands to make a hybrid cord of 1.1 mm diameter.

This has the advantage of separating the position and functions of the fibers. The carbon fibers are in the center of the cord. This allows the high modulus to carry the linear tensile loads in the cord. Being in the center of the cord allows the bending strains to be kept low.

The glass strands are at the outside of the cord, where the higher bending strains can be accommodated by the more extendible glass. FE stress analysis has shown that in tension and bending, the hybrid cord runs at lower internal stress than both a glass cord and a carbon cord.

## Particulate fillers

*Rubber impregnated chopped aramid strands:*

Aramid fibers can be used for reinforcement of rubber tires and other compounds. These can be treated and chopped, or pulped to give a loose wide-ranging struc-

ture. The disadvantage with pulped aramid fiber is that it is hard to disperse uniformly through the compound.

NGF Canada has impregnated every fiber within bundles of aramid fibers with BR-SBR latex. These have been chopped and the ease of mixing and compound properties compared with pulped aramid. Loadings of 5, 10 and 15 phr of aramid (both Kevlar and Twaron) have been added to a CR compound.

The uniformity of dispersion of the aramid fibers are shown in the microscope photos in Fig. 3.

The chopped strands were observed to give comparable reinforcement to the aramid pulp. The results for strain to break and stress to break are shown in Fig. 4. At 5 phr the pulped aramid was more reinforcing than the chopped impregnated strands. At 10 phr the reinforcement was similar for the chopped impregnated strands and the pulp.

## Linear particles

It is possible to take a finished impregnated bundle of fibers and to chop them into 6 mm lengths. These bundles of 1,600 filaments coated with latex are dispersed during mixing into separate 10  $\mu$  glass fibers. The latex coating provides very good adhesion and compatibility between the fiber and the rubber matrix. These rubber impregnated chopped strands can be chopped to different lengths—not the final length, as some length breakdown occurs during mixing.

These relatively long length particles have proved to be good for chipping and chunking resistance of off-road tires.

The chopped strands are available in glass, carbon and also now with aramid fibers. The latex will provide good mechanical coupling between the aramid fibers and the rubber matrix. Data on the new latex coated aramid chopped fibers was being gathered at the time of publication to examine the properties of chopped linear aramid as an alternative to pulped aramid.

## Planar particles

NGF has a range of planar glass particles of large area with small thickness. A typical particle would be 300  $\mu$  across but only 2  $\mu$  thick. Although micro-particles, the aspect ratio is superior to the more expensive nano-particles.

Silane treatments are effective at providing mechanical coupling between the planar particles and rubber compounds. The high aspect ratio has been demonstrated to be very effective at dropping permeation at loadings of 15 phr.

## Anisotropy

These linear and planar particles offer new possibilities for changing the orientation of dynamic properties. During calendaring, the linear particles are aligned in the direction of flow, along the rubber sheet. Similarly, planar particles are aligned parallel to the plane of the rubber sheet.

The properties of the rubber will be quite different along the particles versus properties across the particles. Laboratory studies have shown that there also are differences in dynamic viscoelastic properties according to the direction of testing. This means that the rolling resistance of the tire can be optimized only for the one orientation required, leaving other orientations to provide grip and traction. (Figs. 5 and 6)

For the rubber impregnated chopped aramid strands, these aligned during milling. The tensile properties were measured in the direction of the fibers (“x”) and across the direction of the fibers (“y”) (Fig. 7).

The difference in tensile strength between the x and y directions indicated alignment of the fibers in the direction of milling. The pulp aramid was anisotropic, showing some alignment. At 10 phr the tensile strength of the chopped impregnated aramid fibers were similar to the pulped aramid. At 15 phr this effect was increased considerably; there was almost a 100 percent difference in tensile strength between testing along the fibers and across the fibers.

## Conclusions

Alternative cord to plastic and steel materials now include E glass, high strength glass, carbon fiber and structural hybrid cords—with carbon fiber in the center of the cord, surrounded by a sheath of glass fibers.

Rubber impregnated aramid cord can be chopped as a reinforcing filler. The reinforcing power of chopped impregnated aramid was comparable to pulped aramid. The impregnated strands had an advantage in being more easily dispersed through the compound than the pulped aramid.

Both pulped and chopped strands aligned in the direction of milling. At 15 phr there was double the tensile strength in the direction of the fibers in comparison with the direction across the fibers. This anisotropy will extend to the viscoelastic properties, which means that tire compounds can be designed for different properties in different directions.

Fig. 4. Tensile break properties.

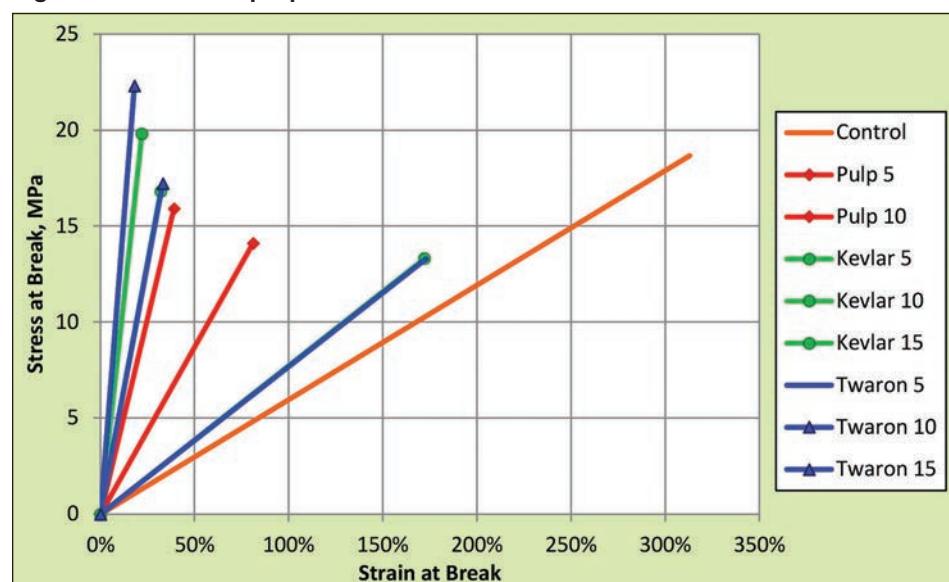


Fig. 5. Different orientations of linear rubber impregnated chopped strands can provide anisotropic dynamic properties.

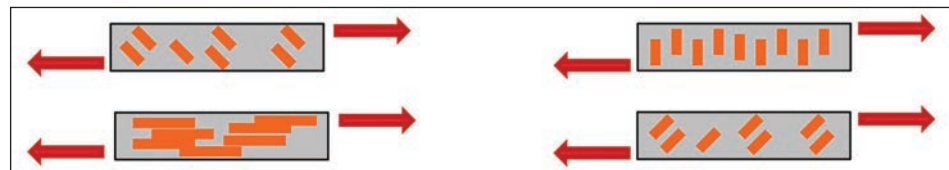


Fig. 6. Different orientations of planar glass particles strands can provide anisotropic dynamic properties.

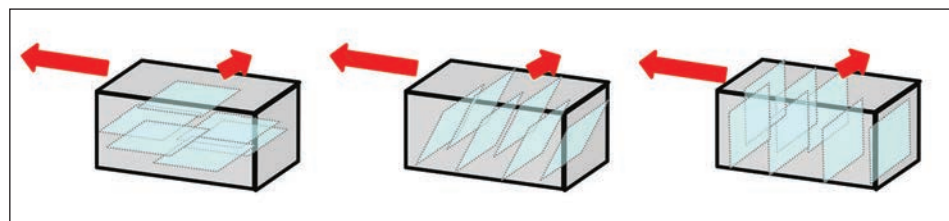
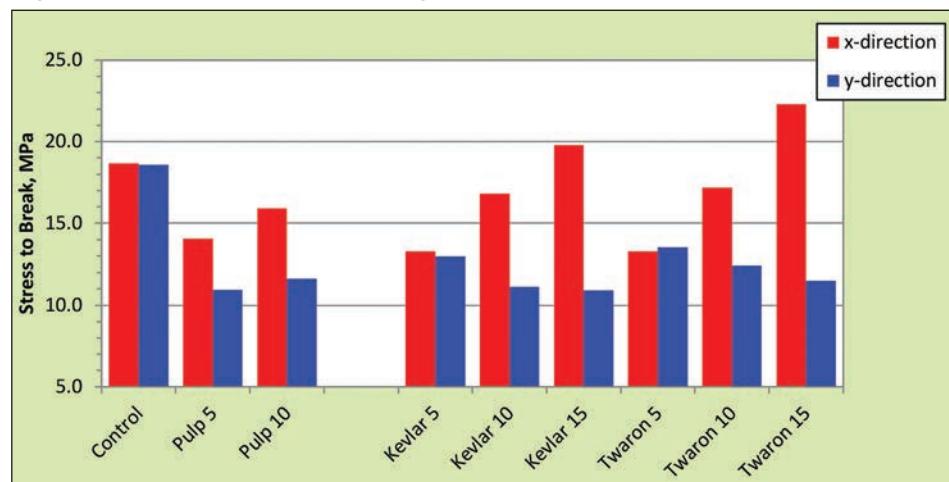


Fig. 7. CR compounds tensile strength vs. orientation.



# Evonik expands in Arkansas

By Frank Esposito  
Plastics News

OSCEOLA, Ark.—Evonik Industries A.G. is bringing more compounding capacity to the U.S.

Officials with Evonik said that it is planning an additional line for manufacturing Acrylite-brand acrylic molding compounds at its plant in Osceola, nearly doubling its capacity of specialty molding compounds.

Construction of the new compounding line will start in early 2018. Completion and startup is scheduled for early 2019.

Siamak Djafarian, Evonik molding compounds product line head, said expanding compounding capacity in Osceola “is the next logical step in our efforts to implement our global strategy for specialty molding compounds.”

He added that Evonik is the only

acrylic maker in the world that has fully integrated MMA and PMMA production networks with downstream compounding in the Americas, Europe, and Asia.

The firm said demand for acrylic compounds is on the rise in the U.S., as well as the growing Mexican and South American markets, especially for construction, lighting and automotive applications.

The expansion continues a busy pace for Evonik. In the second half of 2017, the firm signed an agreement to acquire the high-concentrates additive compounding business of 3M Co., completed its \$630 million purchase of the silica business unit of Huber Engineered Materials and announced plans to start up a new production plant for specialty copolyesters at a facility currently under construction in Witten, Germany.