A Winning Formula

Sports products are capitalizing on tailored materials and specialty processes to enhance performance and athletic skills

By Pat Toensmeier

When the Winter Olympics begin in South Korea next month, eyes will be on the elite athletes. Their equipment, however, will be unnoticed by all but a select group of product developers who are increasingly turning to advanced polymers, compounds, and reinforcements, as well as enhanced process technologies intended to expand the design envelope of sports accessories.

Growing demand for sports products is ramping up pressure for product designs that deliver consistently high performance and reliability, ease of use, affordability, and safety.

Safety is especially important in contact sports. A recent Yale University report asserts that if contact sports in the U.S. could be made non-contact—think flag football—there would be 651,500 fewer injuries every year among male college and high school athletes.

A growing concern in contact sports is CTE—chronic traumatic encephalopathy—a degenerative neurological disease

Strong, light materials enhance the properties and performance of sports products and help improve players' skills.
Courtesy of the National Hockey League

caused by repetitive head trauma, notably in football players. A study in the *Journal of American Medicine* of 202 randomly donated brains of deceased football players found that 91 percent of the college players suffered from CTE, as did 99 percent of the professional players. The problem is serious enough that the NFL will provide $1 billion per year for 65 years to treat former players.

Left: **Salomon specifies Dupont's Hytrel RS elastomer for the collar of its Ghost Rider ski boot.**
Courtesy of Salomon

Above: RTP Co. worked with Werner Kayak to develop a paddle blade molded of recycled carbon-fiber-reinforced polymer from Boeing.
Courtesy of RTP Co.

Developers are thus seeking ways to improve products. The plastics industry is providing its expertise with specialty formulations and applying lessons learned in other industries to sports products. Notable trends that are influencing plastics in sports include:

- Lightweighting and part consolidation: Engineered polymers, compounds, and innovative reinforcements allow the replacement of metal and conventional plastics in many products and the elimination of unnecessary weight. Reductions of only a few grams make a difference, observers say.
- Growing use of renewables: Sustainability is an issue among sporting goods manufacturers. Resin producers are supplying biocompatible materials for use in place of petrochemical-based plastics where feasible or as a part of blends.
- Innovative process technologies: A number of companies have developed hybrid, multilayer, and other fabrication techniques that significantly improve the properties of plastic parts.
- Cross-market experience: Examples of plastics and composites in other markets are studied by sports manufacturers and resin suppliers for the benefits they can provide in sports.

These trends will lead to higher-performing applications and ultimately to enhanced results by athletes. Following are representative examples of developments in sports plastics.

Eco-Friendly Play

The availability of sustainable materials is getting a boost from resin producers. Wilmington, Del.-based DuPont USA, for one, offers grades of renewably sourced (RS) formulations derived from biomass. Examples include:

- Hytrel RS, a TPE that DuPont says has the performance and processing characteristics of conventional Hytrel copolyester elastomer. Hytrel RS grades comprise 35 to 65 percent renewable polyether glycol sourced from non-food biomass. The glycol replaces a petrochemical version in conventional Hytrel.
- Zytel RS polyamide, grades of which incorporate nylon 610 or nylon 1010. The material is based on sebacic acid from castor oil, and has loadings of 20 to 100 percent. DuPont reports that Zytel RS provides the stiffness, toughness, and chemical and hydrolysis resistance of conventional Zytel polyamide.
- Sorona EP, a polytrimethylene terephthalate with 20 to 37 percent content of Susterra, a propane diol made from corn sugar. DuPont says Sorona EP has the strength, stiffness and molding characteristics of polybutylene terephthalate.

Among applications for Hytrel RS is the Ghost Rider ski boot collar from Salomon. The grade isn't new, but its ongoing use demonstrates the grade's ability to withstand the cold and snow of skiing while maintaining the flexibility and impact resistance it was selected for over polyurethane. The collar securely fits the boot to a skier and protects the lower leg. It is flexible enough to reliably transfer movement from the leg to the ski. Salomon specified the grade to promote renewable material in its boot.

"Renewably sourced materials are important in sports equipment but still in the embryonic stage," says Hok Hoh Wong, global marketing leader for industrial, consumer, electronics, and medical at DuPont.

The supplier's experience in part design and "long history of work with sporting goods" position it to assist companies in using RS materials without compromising performance or incurring cost penalties.

Performance Engineering

Fiber reinforcements significantly enhance the performance of a thermoplastic. One example is carbon fiber, which offers strength, stiffness, and light weight to sports products. Also important is long glass fiber (0.4 to 0.9 in.), the durability of which maintains the structural integrity of products and resists damage from repeated use in high-stress applications.

Among the specialists in reinforced compounds is RTP Co. of Winona, Minn.

"We create carbon fiber compounds in a variety of formulations for a multitude of industries, with each application having its own unique requirements," says Eric Lee, general manager of structural products.

RTP supplies four compound types—carbon fiber and glass reinforced—for critical performance and safety needs. These are:

- Carbon-fiber-reinforced compounds, which are also economical when compared with special metals and glass-fiber grades;
- Ultra-performance compounds with among the highest strength and stiffness values in the market;
- Very-long-fiber compounds, which are engineered for durability and can be molded into complex shapes without loss of structural properties; and
- Impact-modified compounds for parts with relatively low structural requirements but which require durability and impact resistance.

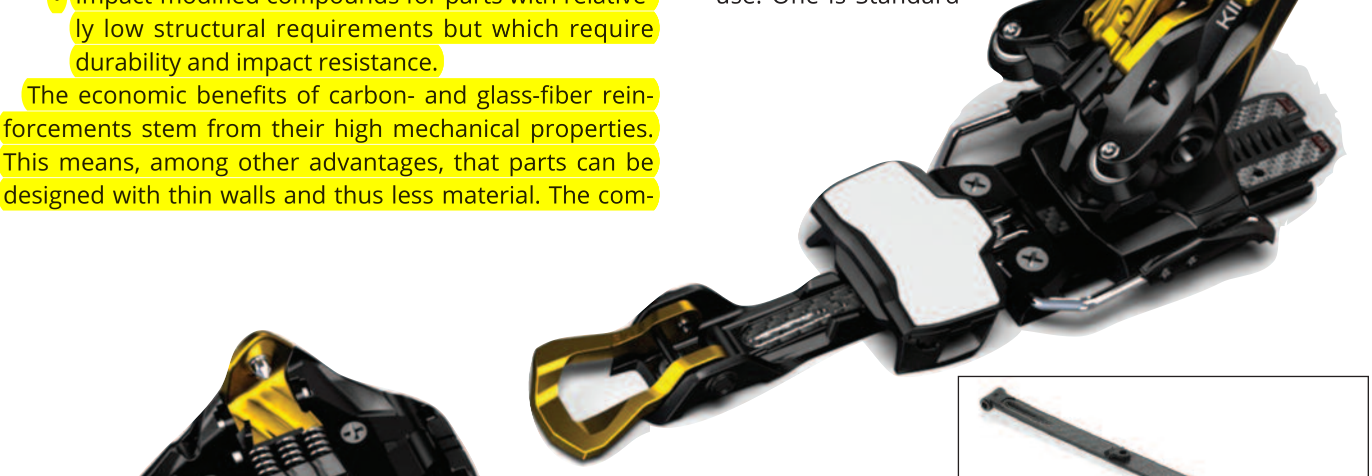
The economic benefits of carbon- and glass-fiber reinforcements stem from their high mechanical properties. This means, among other advantages, that parts can be designed with thin walls and thus less material. The compounds are also injection molded, which simplifies and effectively automates manufacturing, and from a design perspective enhances part consolidation.

RTP compounds are in many sports products. One notable application makes use of carbon-fiber-reinforced polymer recyclate from the Boeing 787 Dreamliner aircraft production. KASO Plastics, Inc. of Vancouver, Wash., molds the part, a kayak paddle blade, for Werner Kayak Paddles. RTP sourced the recyclate from the Aircraft Fleet Recycling Association, and worked with KASO to develop strength, rigidity and other properties—including aesthetics—in the part.

The reclaimed compound proved "easier to process [than virgin material], and the system cost between the recycled-content carbon fiber compound and virgin alternatives is insignificant," says Tim Bailey, engineering manager at KASO.

One emerging "miracle material" could radically affect the performance and design of products. Graphene, an inert carbon allotrope in the form of a two-dimensional, atomic-scale hexagonal lattice, substantially increases mechanical, electrical and thermal properties with loadings of a fraction of 1 percent by weight. This is because the material is only 1 atom thick.

A handful of companies produce graphene for commercial use. One is Standard



Marker Völkl's innovative Kingpin ski binder incorporates a multifunctional polyamide stringer under the heel that is made on KraussMaffei's FiberForm hybrid machine. Courtesy of KraussMaffei

The glass-reinforced Marker Völkl stringer controls three binder movements. Courtesy of KraussMaffei

Graphene of Pusan, South Korea. Kim Gunsoo, chief technology officer, says that carbon fiber reinforcement is one focus of Standard's work. Adding a fraction of 1 percent of graphene improves fiber strength by almost 25 percent compared with untreated fiber, he says.

The MAG baseball, shown in its wireless charger, contains a sensor that records pitch velocity and other data.
Courtesy of Mizuno Corp.

Standard is experimenting with applications it hopes to see commercial this year. One such is an ice hockey stick, which is being tested by teams in Sweden. Baek Choi, director of global business, says the mechanical and tensile strength of the epoxy stick increases by double and triple digits with graphene.

He did not release data due to a non-disclosure agreement with the stick manufacturer. The high surface area of graphene usually means loadings of 0.01 to 0.1 wt% are all that are needed to boost properties. He notes that each team testing the sticks typically breaks two regular sticks a day during practices. The graphene-reinforced sticks last two weeks on average before breaking.

"The use of graphene will completely change the design of sports equipment," Baek adds. "Significant improvements in mechanical and tensile strength will enable extreme lightweighting and break the limitation of [conventional] design. Less material will be needed, and this will maximize a player's performance."

Process Specialization

Innovations in materials and processing come from many sources. Piper Plastics Corp. of Chandler, Ariz., specializes in

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This detailed brace for a drone pilot's headgear, fabricated with KyronMAX polymers from Piper Plastics, replaces a heavier aluminum part. Courtesy of Piper Plastics Corp.

molding, machining, compounding, and materials development. The company offers reinforced polymers called KyronMAX, which apply carbon fiber technology to produce high-strength components in conventional injection molding and a proprietary high-pressure molding process.

Targets include metal replacement. Dave Wilkinson, materials engineering manager, says the materials and high-pressure process yield near-net-shape parts that are 15 to 20 percent stronger than extruded shapes and 50 percent stronger than compression molded shapes. The KyronMAX polymers meet and sometimes exceed the mechanical properties of metals.

The materials and fabrication techniques "let us mold shapes that no one has thought of," Wilkinson says. As a result, when company engineers sit with customers, the question they ask, "What's Utopia for you?" indicates that Piper can meet most development needs, he adds.

The materials come in three series: S, for strong; ES, stronger; and XS, strongest.

Injection moldable S grades are commercial and include polypropylene, polyamide, polyphenylene sulfide, polyetherimide, polyphthalamide (PPA) and polyetheretherketone (PEEK). The grades have 10 to 40 percent loadings of short carbon fiber that Wilkinson says outperform long carbon fiber reinforcements. He credits this to a technique for fiber placement that Piper developed. As a result, a 15 percent loading is stronger than a 30 to 40 percent loading of glass.

ES series grades are primarily PEEK and PPA compounds, for injection molding on conventional machines and the company's special high-pressure machines.

XS grades, some of which will be commercial in 2018, are also based on PEEK and PPA, and will be fabricated on Piper's high-pressure machine.

Metal replacement targets for the three series range from aluminum, cast iron and magnesium to steel, stainless steel, and titanium.

Wilkinson says sports manufacturers are evaluating KyronMAX compounds. Citing confidentiality agreements, he declines to identify them, but believes that "as more companies understand our capabilities," they will specify the materials.

Injection machine makers are adding specialty systems to enhance product design. Among these suppliers is KraussMaffei, whose automated CX 300 FiberForm hybrid machine combines thermoforming and injection molding to produce rigid polyamide parts with weight savings of up to 20 percent versus conventional molding.

The ability to thermoform a sheet in-mold with the system and then injection mold parts allows designers to insert features such as ribs, shaped openings, or reinforced edges that enhance rigidity in parts. A primary target of the process is metal replacement.

Helmets for football and other sports could eventually contain sensors that transmit data about potentially harmful hits. Courtesy of Riddell

The 3,000-kN (337-ton) machine forms a composite sheet in a mold with as much as 60 percent long-glass-fiber reinforcement. The sheet is then insert molded into parts.

FiberForm, used in automotive for seat pans, backrests, instrument panel side supports and semi-structural parts, is getting attention from sports manufacturers. One notable application is the Kingpin touring ski binder from Marker Völkl. This includes a multifunctional stringer made with FiberForm that fits under the binder heel. The glass-reinforced polyamide stringer allows skiers to adjust the binding to boot length, and to toggle the binding between ascent (heel is free) and descent modes (heel is locked).

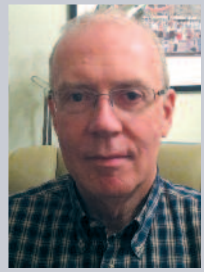
Playing 'Smart'

One application that's bound to grow is the use of sensors to create "smart plastics" that transmit data from competitive use. Some observers, for example, believe football and other helmets will eventually be equipped with impact sensors that alert coaches and doctors to potential concussions.

Sensors are appearing in basketballs and soccer balls, primarily to record motion and improve players' skills. Manufacturer Mizuno Corp. of Japan developed a smart baseball that pitchers use to improve their throws. The MAQ baseball contains sensors that record velocity, ball rotations and rotational axis. The ball has a rechargeable magnetic sensor in its core that is held in place by silicone gel within a polycarbonate capsule. The sensor is powered by a lithium battery, which uses a wireless charger.

The MAQ ball is not for hitting. It reportedly withstands 3,000 pitches at up to 80 mph. The ball carries a hefty price—$320—and should be commercial this spring.

ABOUT THE AUTHOR



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