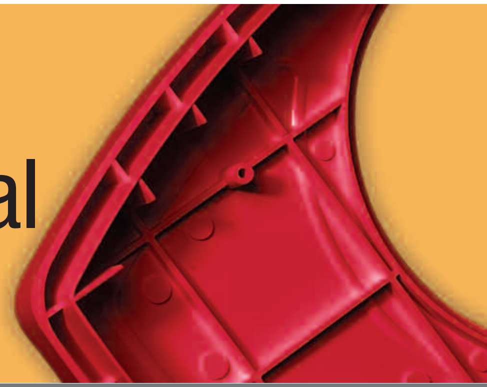
IDI Composites International
THERMOSET MOLDING COMPOUNDS



Structural Thermoset Compounds™ Meet Critical Battlefield Requirements

Larry Landis, IDI Composites International

The modern battlefield has changed dramatically since even a decade ago, with materials playing an ever increasing role in the performance and safety of American armed forces. Whether considering armaments, munitions, ground vehicles, aircraft or logistics systems, new materials and advanced chemistries can now make the critical difference in military operations.

To respond to this challenge, many of the materials that are used in modern warfare have been redesigned from the ground up for enhanced properties, such as durability, impact resistance, the ability to perform in challenging environments, and cost-effective production. For instance, the hand guard for the battle-proven M-14 infantry rifle is made of a Structural Thermoset Compound that provides excellent thermal insulation and shock-dampening, plus it is impervious to moisture, UV degradation, and chemical corrosion. In addition, it is light-weight and cost-effective to mold. The use of this one material has effectively made this weapon affordable for large production runs and has greatly enhanced the performance factors that give armed forces who carry it a distinct combat advantage.

Thermoset compounds — properties of BMC and SMC can be altered to create custom formulations. Fiber type, length, and mix proportion help determine properties such as strength and rigidity...

> Structural Thermoset Compounds

Thermoset molding compounds are one product family that has been dramatically enhanced during the past decade. Among thermosets is a relative new family of high-performance products, called Structural Thermoset SMC and Structural Thermoset BMC. They are offered in unique formulations of existing thermoset chemistries, depending on the demands of the application. The new products have the benefit of advanced resin systems coupled with high levels of fiber glass or carbon reinforcement for strength and durability. This added reinforcement provides additional strength and stiffness, while the special resin formulation protects the fibers and helps the composite achieve its overall properties.

Key properties of Structural Thermoset Compounds that specifically benefit military applications are light weight, high-strength, corrosion resistance, temperature resistance, high impact resistance, highly-repeatable volumes to scale (for joint services applications), and long life span. These properties can be changed, depending on application requirements, by varying the type and quantity of the ingredients. For example, fiber type, length, and mix proportion would alter flow, strength, and rigidity; varying resin concentration and type would affect the overall strength of the material along with its heat/corrosion resistance.

Examples of military applications for which structural thermosets are particularly well-suited include **munitions containers**, where high-value items need safe storage and transportation; **gunner seats** on armored personnel carriers, where molded-in mounting inserts provide high torque retention and excellent load bearing properties; **hand guards** for the M-16 field weapon, where thermal insulation and durability are key; **and rotary aircraft components**, where durability and light weight are critical to safe performance.

IDI BMC can be molded in a variety of colors.

> Structural Thermoset Technology

Structural Thermoset Compounds are distinguished from standard thermosets by the use of more specialized resins combined with higher levels of reinforcement (glass, carbon, aramid, etc.). This combination allows structural thermosets to satisfy unique performance requirements. The added reinforcement provides additional strength and stiffness, while the special resin formulation protects the fibers and helps the composite achieve its overall properties.

Exposure to thermal energy during the molding process for structural thermosets causes the formation of three-dimensional covalent bonds between the polymer molecules. This process, known as cross-linking, is irreversible. Therefore, cross-linked materials cannot be melted and reshaped. The term "thermoset" accurately describes this chemistry. Cross-linking creates a rigid 3D molecular structure that allows thermosets to maintain the desired physical and electrical properties during prolonged exposure to a variety of conditions such as high temperatures. This distinguishes thermosets from thermoplastics, which are generally unsuitable for high-temperature environments because they can be melted after solidification. Thermosets have the advantage of high heat distortion temperatures (HDT) and glass transition temperatures (Tg) that literally melt most thermoplastics.

Three of the most common thermoset resins are polyester, vinyl ester, and epoxy. Each of these resins has its own price and performance characteristics, so selection is based on functional and cost requirements of the application. For example, design engineers might choose vinyl ester resin for corrosion-resistant products, epoxy for high-strength applications, and polyester when good overall performance and cost are the driving factors.

As for reinforcement, many types of reinforcement fiber can be used for structural thermosets, depending on the molding

IDI SMC can be formulated with 10 – 60 percent glass content depending on the physical requirements of the application.

process and the product's strength requirements. Glass reinforcement options include chopped-strand, mat with random fiber orientation, light textile fabrics, heavy woven materials, knitted materials, and uni-directional fabrics. Carbon fiber reinforcement is used for applications that require exception strength coupled with severe weight restrictions.

> Structural Thermoset SMC and BMC

SMC is the primary format for Structural Thermoset Compounds, though some applications require BMC. SMC is a cost-effective, lower weight alternative to many metals. Standard SMC contains 10-30% reinforcement, while structural grades are typically in the 40-65% range. This reinforcement normally consists of chopped-strand glass fibers measuring 1/2-2 inches (12.7mm – 50.8mm) long. For most structural compounds, the fiber level exceeds 40%, due to the type of applications in which they are found.

Structural Thermoset SMC manufacturing is a continuous process that combines a viscous paste and glass fiber on a specialized machine that features a continuous web. Custom paste that contains the resin and special additives is poured onto a carrier film, then cut glass fibers are added, along with a second layer of film. This applied paste and glass between a top and bottom carrier film produces a thin "sandwich" that is run through a series of serpentine rollers. The serpentine action and resulting pressure allow the paste to "wet out" the fibers. SMC is packaged in continuous lengths, 12 to 60 inches wide either on rolls or soft-folded into large, flat containers for handling and thickening. For many applications, the rolls or containers hold in excess of 1,000 pounds.

The packaged SMC is matured for a specific period of time (usually 48 hours, depending on the formulation) in a controlled temperature and humidity environment before it is shipped to the customer. This maturation step is critical since the material increases in viscosity over time. Proper maturation allows the finished SMC product to easily peel from the carrier film, facilitating handling at the customer site. Because of this, it is important to tightly control the amount of water and chemical thickeners (metal oxides, metal hydroxides, isocyanates, etc.) added to the paste during manufacturing. Since maturation is an on-going chemical reaction, it is also important to know the optimum viscosity window for the best molding performance. Typically, an SMC should be molded within 30 days of manufacture unless it is stored below 75°F. Many molders of structural SMCs store their material at sub-zero Celsius temperatures to extend the product's shelf life.

Though it can be used in transfer and injection molding processes, Structural Thermoset SMC is best suited for compression molding. SMC can be molded into complex shapes in processes that generate little scrap. With its excellent surface appearance and mechanical properties, structural SMC is used as a replacement for sheet metal for heat shields, skid plates, sports equipment, high-strength electrical components, prosthetics, watercraft, and a host of structural products. Due to its ease of handling and sheet size, structural SMC is often the only choice for larger parts.

For Structural Thermoset BMC, a resin, fiber reinforcement, and several other ingredients blend to form a viscous, putty-like material. By weight, structural BMC normally includes 25-40 percent reinforcement, which usually consists of chopped-strand glass fibers measuring 1/32 -1/2 inch (.75 -12.7mm) in length. Structural BMC is suitable for compression, transfer, or injection molding. When BMC is injection molded, cycles can be as fast as 10 seconds per millimeter of part thickness. Depending on the application and specific formulation, BMC provides tight dimensional control, flame and track resistance, superior dielectric strength, corrosion and stain resistance, excellent mechanical properties, minimal shrink, and color stability. Available in numerous colors, BMC also provides surfaces receptive to powder coating, paint, and other coating processes.

> Advantages of Structural Thermoset Compounds

Structural compounds have a number of critical advantages over commonly used materials that are causing design engineers and molders to convert their product designs to high-performance SMC and BMC. By evaluating the attributes of structural thermosets early in the design process, custom formulations can be created that take advantage of key material properties for a specific application. Core advantages include:

Tensile and Flexural Strength

Structural Thermoset Compounds offer higher tensile and flexural strength per unit weight than most metals. With the high loadings of fiber, their superior strength allows them to replace many traditional materials. When compared to thermoplastics, such as polycarbonate/ABS, PPO/Nylon 6, and polycarbonate/PBT, Structural Thermoset SMC has significantly higher flexural and tensile strength. When it comes to high Modulus (Flex and Tensile), Structural Thermoset SMC usually yields much higher values than thermoplastics.

Structural Thermoset Compounds can be comprised of many different resins and reinforcement combinations. Therefore, unlike other materials, they can be custom designed to meet the strength requirements of a particular application. Unlike metals, which have equal strength in all directions, structural thermosets are anisotropic and can be custom tailored to provide extra strength in a specific

Structural Thermoset - BMC/SMC Market Applications

Markets	Applications	Defining Properties
Military & Aerospace	Military aviation, radomes Military aviation, rotary aircraft components Military aviation, ammunition cartridge handling guides Munitions Containers Weapon Components	high temperature resistance, fire retardant, high strength-to-weight ratio, design flexibility, corrosion resistance, durable, high impact resistance, excellent memory characteristics, radar absorption, light weight
Transportation	Automotive, fuel vapor canister bracket Automotive, heat shield Automotive, radiator bracket Automotive, sun roof drainage channel Automotive, body shield Automotive, leaf spring Automotive, skip plate Rail, switchgear Rail, window casing	high temperature resistance, fire retardant, high strength-to-weight ratio, dimensional stability, high impact resistance, parts consolidation, reduced tooling costs, design flexibility, paintable surfaces, dielectric strength, corrosion resistance, moisture resistance
Safety	Firemen's helmets Firefighting equipment Composite toe cap Bump cap	high temperature resistance, fire retardant, high strength-to-weight ratio, low smoke and toxicity generation, dimensional stability, high impact resistance, corrosion resistant, electrical insulation, RFI/EMI/ESD resistance, molded-in color
Medical	X-ray equipment components Prosthetics	corrosion resistance, dielectric strength, molded-in color, excellent cosmetic appearance, antimicrobial properties, high temperature resistance, fire retardant, dimensional stability, x-ray transparency or opaqueness, thermal insulation
Electrical	Switchgear	corrosion resistance, high strength, high temperature resistance, dielectric strength
Industrial	Drive equipment coupling Load bearings Springs Valve bodies Circular saws	corrosion resistance, high strength-to-weight ratio, high temperature resistance, dielectric strength, dimensional control, UV stability, non-sparking
Alternative Energy	Solar, power tiles Wind, turbine blades Fuel cell, bipolar plates, end panels	corrosion resistance, UV stability, high temperature resistance, high tensile strength, dielectric strength, high strength-to-weight ratio, consolidation of parts, paintable surface or molded-in color, design flexibility, fire retardant, low specific gravity, structural rigidity, moisture resistant
Marine	Out drive Gimbal housing Gimbal rings and cowlings Power boat seat shells Personal watercraft longerons (internal stringers)	corrosion resistance, high strength-to-weight ratio, low water absorption

Some common market applications for IDI BMC & SMC.

Thermoset compounds — exceptional strength, light weight, and corrosion resistance make thermoset compounds the ideal material for conversion from metals...

direction. If a thermoset part has to resist bending in one direction, most of the fiber can be oriented at 90 degrees to the bending force to produce a stiff structure in the desired direction. Thanks to their molecular structure, thermosets maintain excellent strength and other physical properties during prolonged exposure to extreme temperatures.

By contrast, when metals and thermoplastics are exposed to high temperatures, they may bend under the weight of applied loads. In addition, thermoplastics become brittle at low temperatures. Some highly engineered thermoplastics offer physical properties close to those of structural thermosets, but these materials are very expensive and cannot replace Structural Thermoset SMC in many applications.

Dimensional Stability

Besides strength, the cross-linked molecules in Structural Thermoset Compounds provide dimensional stability in high-temperature environments. A thermoset part is far less susceptible to relaxation or creep failure than one made of thermoplastic. The ability to increase fiber content reduces structural variations and makes thermosets ideal for low shrink applications. The dimensional difference between structural thermosets and thermoplastics can be seen during tensile and flexural tests at elevated temperatures. In these tests, thermoplastics may stretch several inches, while structural thermosets stretch just thousandths of an inch. In addition, tensile loads applied in high-temperature environments causes molded holes in thermoplastic parts to elongate over time. Under the same circumstances, however, holes in a thermoset part retain their original shape.

A structural thermoset has a shrinkage range from 0.2 percent down to zero and, if needed, a thermoset material can expand to be larger than the tool after cooling. Minimal shrinkage helps to ensure close tolerances in molded parts, which often eliminates the need for secondary operations, such as drilling or machining. For many applications, structural thermosets mimic the coefficient of linear thermal expansion (CLTE) of metals, allowing for many types of materials to work together with thermosets in a single application.

Corrosion Resistance

Unlike common metals, Structural Thermoset SMC won't rust or corrode when used outdoors or in harsh environments. The material provides long-term resistance to both chemicals and extreme temperatures. A good example of this can be found in chemical manufacturing plants where thermoset ductwork has been in service for more than 25 years. Thermoset compounds have also seen long service life in underground chemical storage systems. The corrosion resistant properties of structural SMC make it ideal for applications that are subject to strict sanitary requirements. Frequent exposure to harsh cleaning chemicals will not corrode the material, promoting sanitary operation.

In contrast, thermoplastics can be weakened by corrosive substances and environments. And metals are notoriously susceptible to corrosion caused by water and common chemicals. Metals used in corrosive environments must first be coated, or must be an expensive corrosion-resistant alloy.

UV Resistance

Constant and prolonged exposure to ultraviolet (UV) radiation from direct sunlight can cause a number of problems for common materials. These include pigmentation fading, discoloration, and uneven coloration, as well as chalking (a scaly white surface) and reduced material strength. With Structural Thermoset Compounds, the right choice of resin, filler, glass, and pigment reduces material degradation. Most of the sun's damaging energy occurs at wavelengths between 370 nm down to the exact solar cut-off of 295 nm. With the proper formulation technology, a thermoset compound can now perform at levels much higher than previous generations.

Cost-effective Alternative

Structural Thermoset Compounds have a very long life span. Many thermoset structures built in the 1950s are still in use. In addition, structural thermosets feature low maintenance requirements. They also reduce manufacturing costs by enabling part consolidation and virtually eliminating final finishing and coloring.

In metal manufacturing, complex designs may require multi-piece parts. The pieces of such a part are made in a series of progressive dies or costly stamping stations, and then assembled to create the final product. But by using Structural Thermoset SMC or BMC, complex parts can be made as a single piece in a single step. A simpler process translates into faster, more efficient production, with fewer secondary operations, fewer errors, and lower costs. At the end of the manufacturing process, parts made from Structural Thermoset Compounds are essentially ready to ship to the customer. They require very little final finishing, if any, and benefit from molded-in color and an attractive, durable surface.

Design flexibility

Structural Thermoset Compounds give designers more freedom than they have with metals. Normal thermoset molding processes allow for complex shapes and intricate details that are impractical or even impossible to produce from metals. And unlike metals, thermosets allow for a wide range of material combinations. Various resin and reinforcement options can be tried to give unique properties to certain products. In some cases, structural thermosets can be molded on the most basic of systems for R&D and prototyping purposes.

> Summary

To respond to the changing requirements of the modern battlefield, many of the materials that are used in modern warfare have been redesigned from the ground up for enhanced properties, such as durability, impact resistance, the ability to perform in challenging environments, and cost-effective production. Thermoset molding compounds are one product family that has been dramatically enhanced during the past decade. Among thermosets is a relative new family of high-performance products, called Structural Thermoset Compounds. Examples of military applications for which structural thermosets are particularly well-suited include munitions containers, gunner seats on armored personnel carriers, shoulder stocks for the M-16 field weapon, and rotary aircraft components. Advantages of Structural Thermoset Compounds include exceptional tensile and flexural strength, dimensional stability, corrosion resistance, UV resistance, design flexibility, and lower cost.

A leading supplier of Structural Thermoset SMC and BMC is IDI Composites International, headquartered in Indianapolis, IN USA. Through its extensive R&D capabilities and global sourcing, IDI designs and manufactures the latest in high-performance thermoset materials for the most demanding battlefield applications. IDI products for Military & Aerospace markets are made in the USA.

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Larry Landis is Director of Technology and Quality at IDI Composites International and has more than 20 years of experience developing and testing molding compounds. He is the principal chemist for IDI's new line of Structural Thermoset Compounds.

With **more than 35 years** of leadership experience, IDI works closely with customers to identify the optimal thermoset molding compound for each application....

IDI Composites International
THERMOSET MOLDING COMPOUNDS

About IDI Composites International

IDI Composites International (IDI) is the premier global formulator and manufacturer of thermoset molding compounds for custom molders and OEMs. The company provides customized polyester/vinylester-based bulk molding compounds (BMC), sheet molding compounds (SMC), and continuous impregnated compounds (CIC) for the world's most demanding markets, including automotive/truck, electrical, food service, alternative energy, and appliance. IDI also offers a new line of high performance Structural Thermoset Compounds™ (STC) that are manufactured in both sheet and bulk formats for the most demanding applications in markets such as Military/Aerospace, Transportation, and Industrial.

IDI Composites International global headquarters in Noblesville, Indiana USA

Headquartered in a 120,000 square foot facility in Noblesville, IN (USA), IDI has a strong presence in the international thermoset composites market. To support a growing customer base worldwide, the company operates multiple wholly owned manufacturing facilities in Europe, Asia, and The Americas. For more information, please visit www.idicomposites.com.

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