

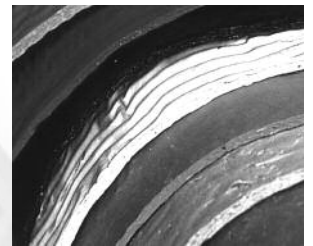


**Composites
International**
THERMOSET MOLDING COMPOUNDS

> the composite advantage: why designers choose thermoset materials

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Due to the intrinsic limitations of metals and thermoplastics, many designers turn to high performance thermoset composites. Thermoset composites provide more strength, dimensional stability, and corrosion resistance than other commonly used materials, while also increasing design flexibility and manufacturing efficiency. In addition, thermoset composites utilize strong molecular bonds that help the materials maintain excellent properties during prolonged exposure to extreme chemical and temperature profiles.



This paper takes an in-depth look at thermoset composites and why they are the optimal material for many applications. After covering the basics of composite compounds, the paper details thermosets and the specific characteristics of two predominant thermoset formulations: bulk molding compound (BMC) and sheet molding compound (SMC). The paper includes an examination of the key properties of BMC/SMC that are causing design engineers and molders to convert their product designs from metal and thermoplastic alternatives. These advantages are highlighted in a discussion of current and potential uses for BMC and SMC. The paper also explains how certain additives imbue thermosets with special properties that allow them to meet specific needs that are not addressed by competitive materials, such as metals and engineered thermoplastics.

Thermoset composites — exceptional strength, light weight, corrosion resistant, UV resistant, electrically non-conductive, exceptional thermal properties...

> composite basics

Composite materials consist of fiber reinforcement in a polymer resin. The fiber provides strength and stiffness, while the resin protects the fibers and gives the material its shape. Composite reinforcement is typically fiberglass, but high-strength fibers such as aramid and carbon are used to meet demanding performance requirements.

The properties of a composite can be changed by varying the type and quantity of its ingredients. Fiber type, length, and mix proportion help determine properties such as strength and rigidity. In addition, resin characteristics can be changed to provide the desired processability, durability, and heat and corrosion resistance.

Exposure to thermal energy causes the formation of three-dimensional covalent bonds between the polymer molecules. This process, known as cross-linking, is irreversible. This means that cross-linked materials cannot be melted and reshaped (see Figure 1).

Since crosslinking permanently solidifies the materials, they are known as thermosets. Crosslinking creates a rigid molecular structure that allows thermosets to maintain acceptable physical and electrical properties during prolonged exposure to high temperatures. This distinguishes thermosets from thermoplastics, which are generally unsuitable for high-temperature environments because they can be melted again after solidification.

Three of the most common thermoset resins are polyester, vinylester, and epoxy. Other resins such as silicone, phenolic, and polyurethane are also used for certain applications. Each of these resins has its own price and performance characteristics, so selection is based on the functional and cost requirements of the application.

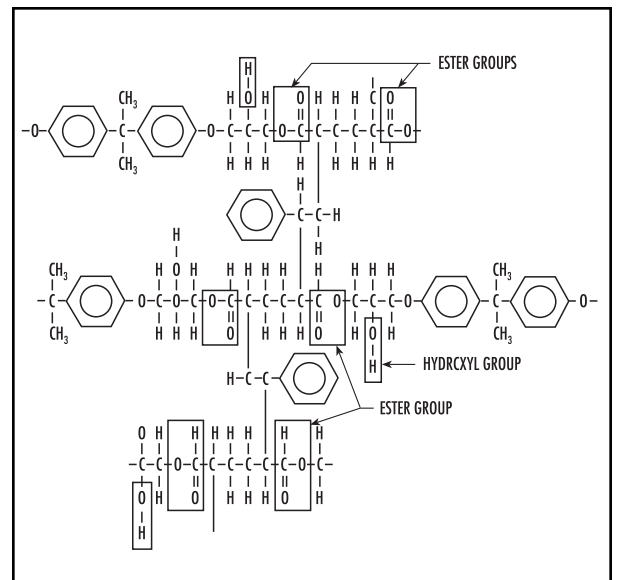


Figure 1. Illustration of cross-linked covalent bonds

For instance, composite users might choose vinylester 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 glass fiber can be used in thermosets, depending on the molding 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 unidirectional fabrics.

> bmc and smc

A significant portion of the world's thermoset production comes in the form of BMC and SMC. In BMC, a resin, fiber reinforcement, and several other ingredients blend to form a viscous, putty-like material (see Figure 2). By weight, BMC normally includes 5-25 percent reinforcement, which typically consists of chopped-strand glass fibers measuring 1/32-1/2 inch (.75-12.7mm) in length.

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, BMC variations can provide 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 technologies.

SMC, while similar in chemistry to BMC, is manufactured by a much different process. SMC is produced in sheets that can be handled more easily for many applications, and typically offers much higher mechanical strength than its thermoset counterpart (see Figure 3). SMC normally includes 10-65 percent reinforcement, consisting of chopped-strand glass fibers measuring 1/2-2 inch (12.7mm – 50.8mm) long.

SMC manufacturing is a continuous process that combines a viscous paste and glass fiber on a specialized machine. The paste and glass are put together between a top and bottom layer, producing 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 glass fibers. Finally, the SMC sheet is matured for a specific time (typically 2 days) before it is shipped to the customer. The maturation step is critical since the material increases in viscosity over time. This allows for easy peeling of the product from the carrier film and handling at the customer site.

Though it can be used in transfer and injection molding processes, 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 that top those of BMC, SMC is used for automotive body panels, high-strength electrical components, equipment cabinets, watercraft, and a variety of structural parts. Due to its ease of handling and sheet size, SMC is often the only choice for larger parts. SMC sheets are typically 12 to 60 inches wide and can be put in boxes that hold more than 1,000 lbs.



Figure 2. IDI BMC can be molded in a variety of colors



Figure 3. IDI SMC can be formulated with 10 – 60% glass content depending on the physical requirements of the application

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> converting to thermoset composites

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

Strength

BMC and SMC offer higher strength per unit weight than most metals (see Figure 4). In addition, SMC has significantly higher flexural strength than thermoplastics such as polycarbonate/ABS, PPO/Nylon 6, and polycarbonate/PBT.

SMC Properties Comparison Table			
PROPERTY	SMC R25 25% Glass Reinforced	SMC R50 50% Glass Reinforced	Steel SAE 1006
Tensile Strength MPa	65-90 (9.4-13.0)	124-204 (18-29.6)	330.7 (47.9)
Tensile Modulus GPa (psi x 10 E06)	10-12.5 (1.2-1.8)	12.2-19.1 (1.8-2.8)	206.7 (30.0)
Flexural Strength MPa (psi x 10 E03)	155-200 (22.4-29.0)	380 (36.0-55.1)	n/a
Flexural Modulus GPa (psi x 10 E06)	8.5-14.0 (1.2-2.0)	11.6-16.4 (1.7-2.4)	n/a
Specific Gravity	1.8-2.0	1.85-2.15	7.86
Coefficient of Expansion m/m c x 10 E06 (in/in F x 10 E06)	12-14 (6.7-7.8)	13-17 (7.2-9.5)	12.1 (6.7)

Figure 4. Flexural and tensile strength of thermosets and metals

Thermoset composites can be made of many different resin and reinforcement combinations. Therefore, unlike other materials, they can be custom designed to meet the strength requirements of a particular application. The formulator can increase the size or amount of reinforcement or change the base chemistry to increase mechanical strength.

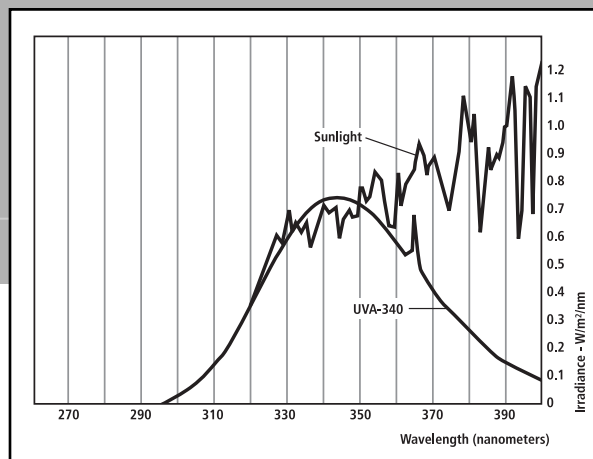
Unlike metals, which have equal strength in all directions, thermosets are anisotropic and can be custom tailored to provide extra strength in a specific direction. If a thermoset part has to resist bending in one direction, most of the fiber can be oriented at 90 degrees to the bending force to produce a stiff structure in the desired direction. Thanks to their cross-linked molecules that result from strong covalent bonds, thermosets maintain excellent strength and other physical properties during prolonged exposure to high and low temperatures.

By contrast, metals and thermoplastics that are heated to high temperatures may bend under the weight of applied loads. In addition, thermoplastics become brittle at low temperatures. Some high-end engineered thermoplastics offer physical properties close to those of thermosets, but these materials are far more expensive and cannot replace BMC and SMC in many applications.

Dimensional stability

Besides strength, the cross-linked molecules in BMC and SMC provide dimensional stability at elevated temperatures. In high-temperature environments, a thermoset part is far less susceptible to relaxation or creep failure than one made of thermoplastic. The difference can be seen during tensile tests at elevated temperatures. In these tests, thermoplastics may stretch several inches, while thermoset composites 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 thermoset composites retain their original shape.

Figure 5. The deterioration of durable materials exposed outdoors is primarily caused by the short wavelength UV portion of sunlight.



Thermosets also shrink significantly less than thermoplastics. Thermoset shrinkage ranges from 0.2 percent down to zero or even negative expansion values. 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 thermoset composites mimic the coefficient of linear thermal expansion (CLTE) of metals, allowing for many types of materials to work together in an application.

Corrosion resistance

Thermoplastics can be weakened by corrosive substances and environments. In addition, metals are notoriously susceptible to corrosion caused by exposure to water and common chemicals. Those who choose metals for applications in corrosive environments must coat them or use expensive corrosion-resistant alloys.

Unlike common metals, BMC and SMC won't rust or corrode when used outdoors or in harsh environments. The materials provide long-term resistance to both chemicals and extreme temperatures. A good example of this can be found in some chemical manufacturing plants, where thermoset ductwork has been in service for more than 25 years despite continuous exposure to corrosive chemicals. Thermosets have also seen long service life in underground chemical storage systems. The corrosion resistant properties of BMC and 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.

UV stability

Constant and prolonged exposure to ultraviolet (UV) radiation from direct sunlight can cause a number of problems for thermoplastic parts. These include fading pigmentation, discoloration, and uneven coloration, as well as chalking (a scaly white surface) and reduced material strength.

The right choice of resin, filler, glass, and pigment to prevent material degradation are combined and then tested in a QLAB UV chamber to simulate outdoor exposure (see Figure 5). Most of the sun's damaging energy occurs at wavelengths between 370 nm down to the exact solar cut-off of 295 nm. The decision can then be made on the best materials package for the application.

Cost-effective alternatives

Thermoset composite structures have very long life spans. Many composite structures built in the 1950s are still in use. In addition, composite materials feature low maintenance requirements.

Composites cut actual manufacturing costs by enabling part consolidation. 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, then assembled to create the final product. But by using SMC or BMC, complex parts can be made as a single piece in a single step. A simpler process translates into faster and less expensive production, with fewer secondary operations.

Design flexibility

Thermoset composites give designers more freedom than they have when working with metals. Normal composite molding processes allow for the creation of complex shapes and intricate details that are impractical or even impossible to produce from metals. And unlike metals, composites enable the use of a wide range of material combinations. Various resin and reinforcement options can be combined to give unique properties to specific products.

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> applications

The advantages of thermoset composites make them attractive alternatives to metals and thermoplastics in a wide variety of industries. At present, the main markets for BMC and SMC are automotive and heavy truck, appliance, and electrical. Other established markets include lighting, food service, energy, and transit.

Automotive and Heavy Truck

A large and growing number of exterior automotive components are now made of thermoset composites. BMC and SMC are also gaining popularity among designers of interior vehicle components. The reasons include:



Figure 6. Heavy truck valve cover molded with IDI SMC

- **Weight:** SMC components are typically 25-35 percent lighter than steel parts of equal strength.
- **Dimensional stability:** SMC has a low CLTE and holds up well to engine heat and scorching summer temperatures, making it suitable for vehicle hoods, deck lids, and roof panels.
- **Surface finish:** SMC body panels offer excellent surface quality, and are as paintable as traditional steel panels.
- **Memory:** While metal panels permanently deform on impact, SMC panels deform and spring back to their original shape.
- **Cycle time:** By reducing the number of parts in finished assemblies, thermosets shorten design and production time.

Appliance

Appliance components have stringent durability requirements. The life span of these components may be 10 years or more, during which time they may be exposed to heat, loads, impacts, and corrosive substances. Besides retaining critical physical properties during long lives in harsh environments, many appliance components must maintain an attractive appearance.

Cost effective BMC provides dimensional stability and stain and corrosion resistance, while also maintaining its color at temperatures up to 450°F. Major appliance makers specify BMC for kitchen components such as fry pan covers, griddle surrounds, and oven end-panels. Outside of the kitchen, BMC/SMC compounds are used to make housings, vent strips, control panels, water tank panels, steam iron skirts, cooling-coil drip pans, and outdoor grill side shelves and handles.

Electrical

Parts molded from thermoplastic materials will often carbonize or melt during exposure to electrical arcing or tracking. But thermosets hold up well during these processes, undergoing no significant changes. Thermosets offer comparative tracking index values in excess of 600 volts and dielectric strength of over 15 kilovolts per millimeter. In the electrical industry, BMC and SMC are used to make parts with track resistance greater than 600 minutes and arc resistance greater than 180 seconds.



Figure 7. Electrical enclosures molded with IDI SMC

Lighting Fixtures

BMC and SMC are used in HID-type lighting fixtures because they can withstand the high temperatures in these fixtures. Conventional polished-metal HID assemblies include separate terminal blocks that are individually fabricated. Thermosets make the process easier for manufacturers, who can mold composite terminal blocks directly into HID lighting fixtures with no secondary operations. The materials are moldable to net shape due to zero shrink. In addition, they provide the highest flame retardance values and excellent resistance to deterioration caused by UV and other natural elements.

Commercial Food Service

BMC and SMC are suitable for commercial kitchen equipment because of their ability to withstand heat and exposure to corrosive food ingredients and cleaning solutions. In addition, thermoset parts can be molded-in color, so they don't have to be painted like their metal counterparts. By converting to a single-mold thermoset BMC and SMC design, manufacturers are able to provide their customers with a product void of difficult to clean metal attachment areas, such as welds or bolts, promoting sanitary operation. Typical food-service applications for BMC and SMC materials include fryers, steamers, meat cutters, and food-holding cabinets.

Figure 8. Berkel Company commercial meat slicer featuring components molded with IDI BMC. Converting to BMC contributed to a 40% parts reduction compared to the previous all-metal slicer.



Alternative Energy

Each year, the fuel cell industry will use large quantities of thermoset materials to make bipolar plates. Thermosets provide heat and corrosion resistance without the shrink or excessive stress that might compromise a thin thermoplastic part. BMC and SMC

are also suitable for solar power tiles and wind turbines. These applications require materials that won't warp or deteriorate during long-term exposure to the sun and other natural elements.

Transit

Smoke toxicity can be deadly in the confined areas of subway systems. Transit requirements prohibit the use of materials that emit hazardous chemicals when they burn. Banned materials include many thermoplastics, which can be highly flammable and emit toxic fumes. Unlike these materials, BMC and SMC can provide high flame resistance that meets UL94-5V requirements (see Figure 9). In addition, thermosets offer smoke toxicity levels that make them acceptable for use in confined transit applications. Many transit systems are powered by a live "third rail," a high-voltage bar alongside the track. With their high dielectric strength, thermosets are widely used to make third-rail insulators and canopies.

Technical Data and Testing Procedures		
PROPERTIES	ASTM METHOD	VALUES
Flame Propagation Index, is	E162	4
Flame Resistance	D229	
Ignition Time – seconds		147
Burn Time – seconds		43
Smoke Generation	E662	
Flaming Ds @ 90 seconds		0
Flaming Ds @ 240 seconds		5
Non-Flaming Ds @ 90 seconds		0
Non-Flaming Ds @ 240 seconds		3
Toxicity in Flaming Mode (MIL-M14G)		None
Inclined Plane Tracking	D2303	Did Not Track
Resistance after 1,000 Hrs. in Weather-O-Meter, Minutes @ 2,500 Volts	G-23, D1499	@600 +
ARC Resistance after 1,000 Hrs. in Weather-O-Meter, Volts/MIL	G23, D1499	
Impact Strength – Izod Notched Ft. - Lb./In.	D256	14
Compressive Strength – PSI	D695	26,000

Figure 9. Flammability ratings for thermoset BMC, including flame resistance and smoke toxicity levels

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



> conclusion

Thermoset composites can improve the design, manufacture, and performance of a wide variety of products, causing many design engineers and molders to convert their product designs to BMC and SMC. Consisting of fiber-reinforced polymer resin with cross-linked molecules, thermosets like BMC and SMC offer a number of advantages over metals and thermoplastics, including higher strength per unit weight, better dimensional stability and corrosion resistance, greater design flexibility, and lower costs. Because the properties of a composite can be altered by varying the type and quantity of its ingredients, custom formulations can be created specifically tailored to the needs of an application. Firmly established in a number of industries, BMC and SMC are finding their way into new applications as more designers discover the benefits of these highly capable and cost-effective materials.



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