SHEET MOULDING COMPOUND (SMC)

SMC is a moulding compound made on the basis of glass-fibre reinforced unsaturated polyester resin.
The industrial application of SMC dates back to the beginnings of the sixties, when the excellent electrical characteristics of this material were used for cable distribution boxes and electrical insulation. In the beginnings of the seventies SMC conquered the automotive industry. Since the first moulding compounds based on unsaturated polyester in the 1930s and the industrial startup in the 1950s this class of materials has developed into a variety of high performance polymers for various fields of application with a broad range of tailor made performances.
The use of Sheet Moulding Compound (SMC) is a very important production process for the production of GRP parts.

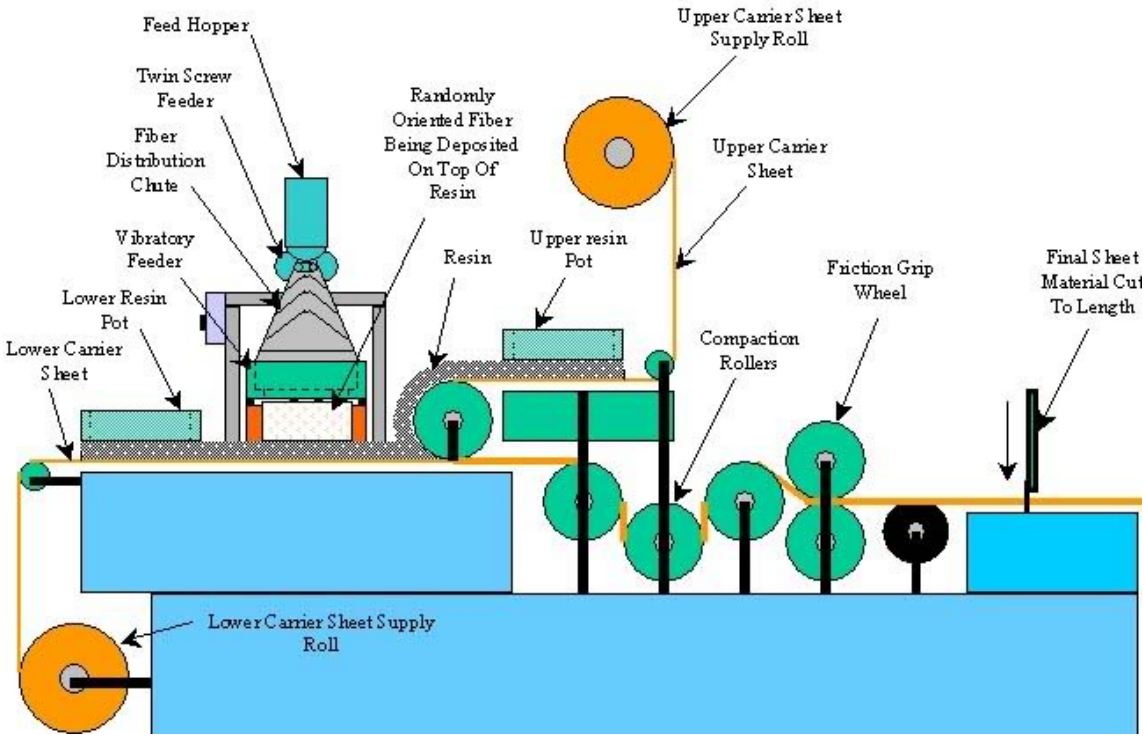
SMC is a thermoset, that means cross linking materials where the cross linking is irreversible. This is the base for the unique technical performance of these materials class.
The materials consist of the following components:

- Resin
- Shrink compensation
- Fillers
- Reinforcement
- Additives
- Curing system

} SMC Composite

A significant portion of the world's thermoset production comes in the form of SMC.

Manufacture of SMC

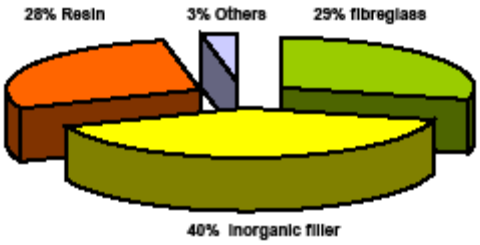


SMC is a flat sheet-like compound, produced on a continuous moving belt process. The SMC composites are made from chopped multi end rowing strand sandwiched between two layers of film, onto the resin paste (resin, shrink compensation, fillers, additives and curing agent) has already been applied. The prepreg passes through a compaction

system that ensures complete strand impregnation and makes a sheet wound into rolls. These are stored for pre maturing before moulding to allow the prepreg to thicken into a mouldable viscosity.

A typical formulation for a SMC is given below.

Raw material	Parts by weight
Unsaturated Polyester resin	60
Low profile additive	40
Peroxide	1.5
Fillers	150
Release agent	4
Magnesium oxide paste (35% MgO)	2
Glass fibres	25% on total formulation



As glass fibre reinforcement in most cases cut glass rovings are used. Calcium carbonate (chalk) is the most commonly used filler. Magnesium oxide in the formulation can react with the free acid groups of the resin. This results after a few days in an enormous increase of the viscosity of the SMC formulation. A leather-like sheet is formed, which is almost non-sticky and easy to handle. In this stage the resin is still not polymerized.
In the production of SMC the resin is premixed with all the components of the formulation to a paste. On the SMC machine first the paste is dosed on a polyamide or polyethylene film by means of a doctor blade. In the next stage glass rovings are cut to lengths of 25 – 50 mm and sprinkled on top of the resin layer. Then a second film, on which also a resin paste is applied, is put on top of the glass fibre. The whole package between the two films is then pulled through a compacting section of the machine. In this phase the glass fibre is impregnated and the compound is homogenized. At the end the SMC is rolled and stored during a few days to give the thickening reaction sufficient time. The sheet is allowed to mature for 48 hours. The ready and thickened SMC is stored and sold in the form of rolls.
Depending on the requirements for the finished product a wide variety of formulations is nowadays available. Products are made that possess high weather - or corrosion resistance, excellent surface finish or high mechanical properties.

Why SMC?

Due to the intrinsic limitations of metals as well as sky rocketing costs, many design engineers utilize thermoset composites as a metal replacement material for high-performance applications. Thermoset composites provide more strength, dimensional stability, and corrosion resistance than metals, while increasing design flexibility and manufacturing efficiency. In addition, thermoset composites, such as sheet moulding compound (SMC), offer the following benefits over traditional metals;

- **Thermal resistance**
  All thermoset polymers are known for their excellent thermal resistance. Using specific resin systems thermal resistances up to 300°C can be achieved. From technical view these materials are superior to engineering thermoplastics and especially the more economic alternative solution in comparison to high performance thermoplastics.
  The combination of cross linked polymer and high inorganic filler content by maintaining the excellent moulding

characteristics make SMC materials the first choice for applications where elevated service temperatures are required or high temperatures can occur temporarily.
For demanding engineering applications it is also crucial that the Coefficient of Thermal Expansion is close to metals and ensure excellent performances in all temperatures.

- **Fire retardancy**
  High fire retardancy is nowadays most important for many applications and markets. To achieve high flame retardancy a number of additives can be used for different polymers. SMC do not contain any halogens or other hazardous flame retardants. Still they can be formulated having excellent properties even at very low wall thicknesses.

- **Precision**
  SMC are first choice solutions for substitution of high performance metal parts where high precision is achieved through post machining. Tightest tolerances can be produced directly without post operations and ensure not only cost savings but also increased profitability.
  As a main advantage towards competing with non thermoset polymers, the possible compensation of shrinkage make even most challenging jobs feasible. For highest precision, materials with negative shrinkage (expansion) will be used.

- **Weight reduction**
  In times where fossil fuels are running out at the same time as the environmental stress must be reduced, high performance composites can contribute with components with less weight and lower energy consumption. The mechanical properties of SMC make the substitution of a wide range of metal parts not only feasible but also quite easy.

- **Electrical performance**
  Excellent electrical performances have from the beginning of the plastics era been one of the biggest advantages of thermoset materials. Additionally to the excellent electrical properties of thermosets SMC show even higher performances especially in the parameters of electrical strength, water absorption and surface resistivity.
  Contrary to the excellent isolation properties also, materials with reduced surface resistivity and elevated conductivity are available.
  SMC covers the full range of electrical requirements, isolating and conductive.

- **Class A surfaces - This quality is equivalent to “mirror-like” finish**
  Excellent surfaces for online- and offline painting as well as metalizing are a domain of especially SMC parts. The surface results from the unique technology to compensate the material shrinkage.

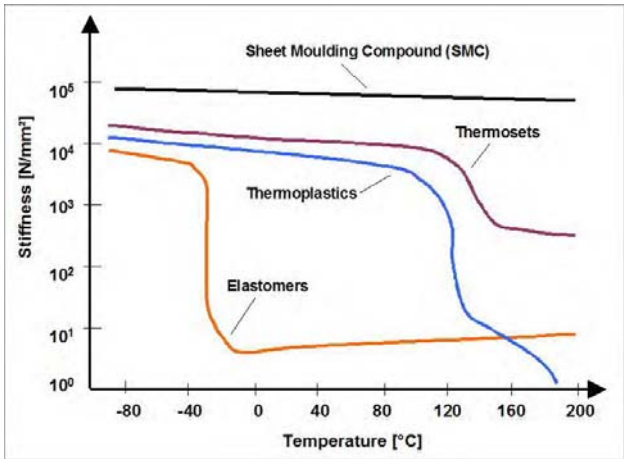
- **Low emissions**
  All interior parts in the automotive industry require low emission materials. Any hazardous or uncomfortable emissions and smell are restricted. Also the lighting system's headlamp reflectors must be free of any emissions to avoid the feared fogging which reduces the lamp's performance.

Properties

Typical structural FEA properties for SMC

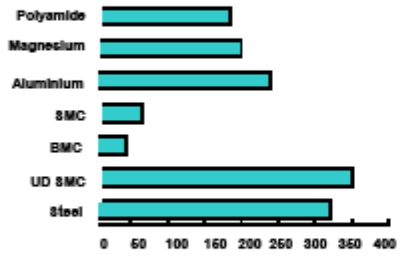
Properties	Unit	SMC- 20 – 40 % Glass Content
Coefficient of Thermal Expansion	°C	17.78
Flexural Modulus	GPa	10.34 – 13.10
Specific Gravity	g/cm³	1.6 – 2.0
Poisson’s Ratio	-	0.32 – 0.36
Shear Strength	MPa	55.17 – 82.76
Tensile Modulus	GPa	9.66 – 12.41
Young’s Modulus	GPa	11.03 – 13.79

Retention of dimensional properties: SMC compared with other polymers

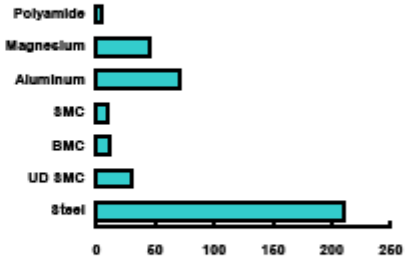


Mechanical performance of SMC/BMC versus metals and glass reinforced polyamide

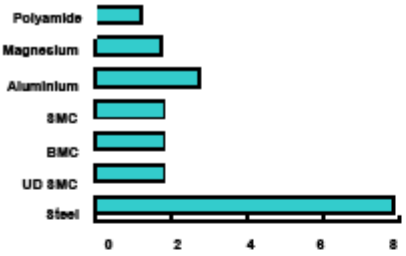
Tensile strength MPa



Young's modulus GPa

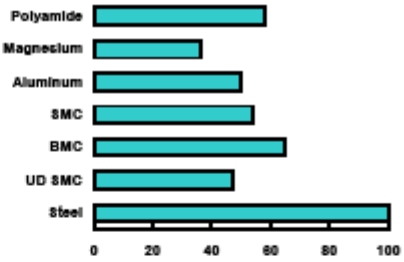


Density g/cm³

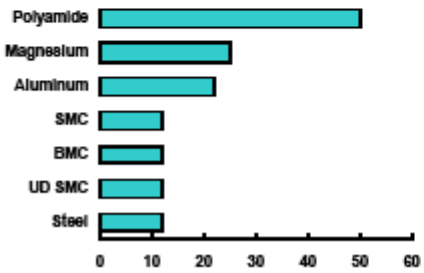


Light weight potential.

Equivalent flexural stiffness: steel is 100%



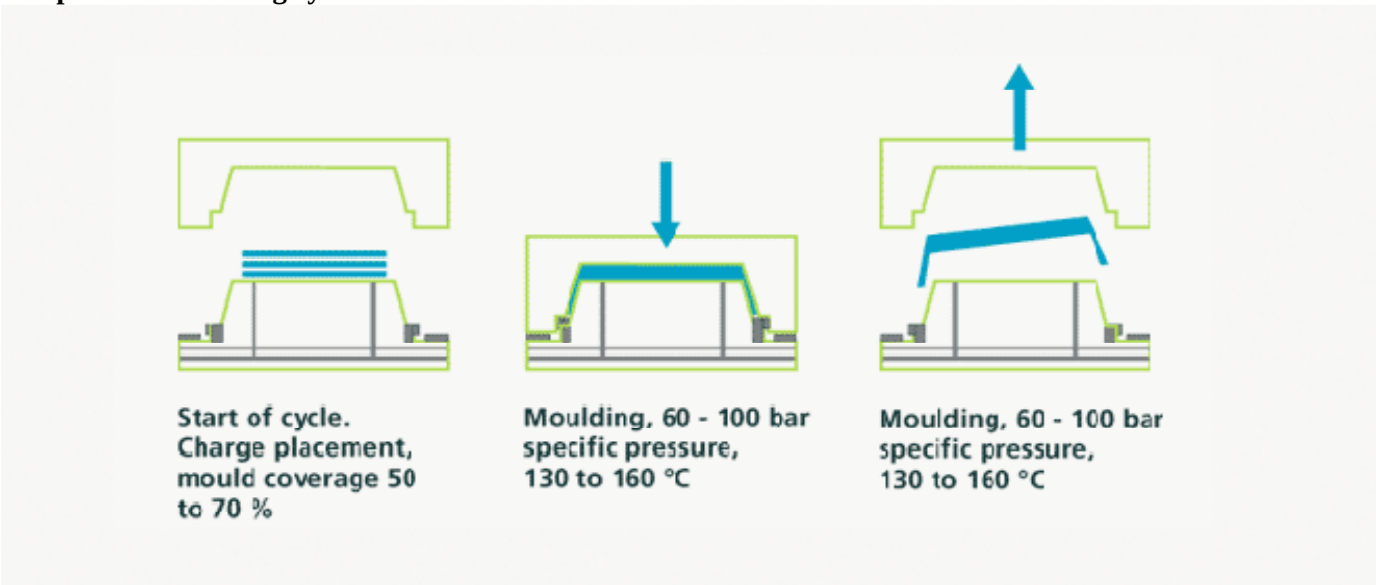
Coefficient of thermal elongation 10^{-8} m/mK



Conclusion
Naming only some of the characteristics of SMC it already proves the unique positioning as a high performance, economical - highly profitable material class with enormous potential for the future.
The ability of SMC, to tailor sew performances to specific application demands will expand the usage of these materials significant in the future.

Moulding of SMC Parts:

Moulding is made in heated steel tools at temperatures between 125°C and 170°C. It is very important to take note of the setup instructions of each specific material due to the variety of formulations. All known processes are possible as the material will be tailor made for your specific process and application.
Compression moulding cycle



Layers of SMC are placed into the heated tool. Through closing the tool the material fills the cavity and polymerizes. After complete cure the parts are released hot.
With compression moulding highest mechanical strengths can be achieved.

Applications

SMC open up a new world of possibilities with solutions and performances. Engineered Solutions for High-Performance Markets

Perhaps the best news of all is that SMC formulations continue to abound in answer to a diverse range of applications. Market penetration for SMC is gaining ground in terms of both end-use applications and global demand. Suppliers are reporting more interest in SMC from industrial, consumer, building and construction, energy generation, electrical / electronic, non-automotive transportation, and even aerospace customers.
The capabilities in customization by tailor-made formulations combined with great design freedom enable high / superior performance and cost efficient applications, matching highest demands has successfully converted many cast aluminum, zinc, iron, steel fabrication, and other custom metal fabrication parts to thermoset composite materials.

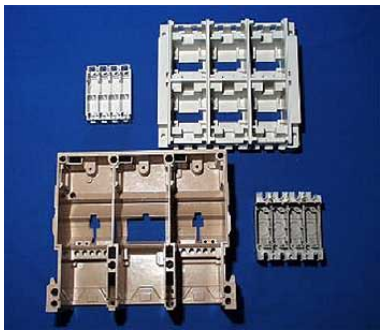
Increasing performance demands in automotive, electrical, appliance, food service, and energy industries, among others, plus the rising cost of cast metals, is prompting design engineers to consider metals conversion to alternate materials for new products. Thermoset composites have many unique properties - exceptional strength, light weight, corrosion resistance, UV resistance, electrical non-conductance, exceptional thermal properties - that make them desirable over thermoplastics and, in particular, metals, such as cast steel and aluminum.

For instance, thermoset composite materials can be used outdoors and in extreme environments, as they will not rust or corrode. And, because many components can be molded along with the part, and require no final finishing, they are often more economical from a total manufacturing standpoint. With a better strength-to-weight ratio than most metals,

thermoset composites are a reliable substitute for traditional materials. They are fast becoming the material of choice for design engineers looking to reduce cost in new high performance applications.

A brief overview about some fields of application:

- **Electrical & Electronics**



Thermoset composite materials exhibit excellent dielectric strength due to the network of cross-linked molecules that create a rigid structure, where molecules are held in place by chemical bonds. Compounds made with thermoset binders, therefore, have the ability to maintain both physical and electrical properties under mechanical loads during prolonged exposure to elevated temperatures.

Often, parts molded from plastic materials will carbonize or melt during exposure to electrical arcing or tracking. However, thermoset materials demonstrate minimal effects in these situations and have Comparative Tracking Index (CTI) values exceeding 600 volts and dielectric strengths in excess of 15 KV / mm. This, along with excellent thermal properties, makes SMC moulding compounds an ideal choice to protect sensitive electrical output devices operating in high-temperature environments.

  - Electrical connectors, shrouds, circuit breaker housings, and contact blocks
  - Motor mounts, brush cards, brush holders, and starter housings
  - Electric switchgear
  - Electrical insulator parts
  - Electrical junction boxes
  - Satellites Aerials / Dish Antennas

- **Automotive**

In the automotive and heavy truck market, designers struggle to meet many different and sometimes conflicting requirements. Parts must have the physical properties to handle the loads and environments of demanding vehicle applications. At the same time, they must be relatively light, cost effective, and manufacturable in the time allowed by tight production schedules. In some cases, they must also have a pleasing appearance that will help attract buyers and differentiate a vehicle from its competitors. Some specific applications where SMC materials are currently being used by the automotive and heavy truck industry include:

- Air deflectors and spoilers
- Frames for windows/sunroofs
- Air-intake manifolds
- Front-end grill opening panels
- Battery casings and covers
- Headlamp housings
- Bumpers and bumper beam
- Heat shields (engine, transmission)
- Cylinder head (e.g. valve, rocker, cam) covers
- Pillars (e.g. 'A' and 'C') and coverings

Thermoset composite materials are used because of their high thermal stability, low coefficient of thermal expansion (comparable to steel), excellent dimensional control, high impact strength, relatively low weight, and their receptiveness to paint. Many of these parts are used where a Class A surface finish is required, as these materials can endure the required paint and bake cycles of the automotive industry.

- **Appliances**

Appliance components must meet the most stringent durability requirements. The life span of these components may be 10 years or more, during which time they can be exposed to the adverse effects of heat, loads, impacts, electrical currents, and corrosive substances. Besides retaining physical properties during long exposure to harsh environments, components must maintain an attractive appearance. For instance, a bright white kitchen appliance must retain its color and gloss, even when exposed to high temperatures and staining substances such as food, grease, condiments, and cleaning chemicals.

A growing number of appliance designers and manufacturers are converting from pricey conventional materials to thermoset composites. Consisting of fibre reinforcement in a polymer resin, thermoset materials such as sheet moulding compound (SMC) can cost significantly less than common metal and thermoplastic alternatives. Thermoset composites can be molded in color, or can accept a variety of paint systems. Designers can also mold-in sub assemblies and smaller details to eliminate the need for final

finishing, as required by metals.
Despite their relatively low cost, thermoset materials offer top-notch performance in appliance applications. Besides excellent structural and electrical properties, thermosets are among the few uncoated plastics that provide dimensional stability along with stain and corrosion resistance.
Thermosets can also maintain their color at temperatures up to 500°F / 260°C.
Applications range from

- Oven end-panels
- Cabinets & Storage Boxes
- Kitchen Sinks
- Lids.
- Cutters, etc.
- Housings and Cooling Coil Drip Pans in HVAC products, such as room air conditioners.

- **Building & Construction**

Construction components must be durable and maintain an attractive appearance over time. For example, roofing tiles must stay strong and aesthetically pleasing during years of exposure to the worst outdoor conditions.
To meet these demanding requirements at a reasonable price, many manufacturers in the construction industry are turning to thermoset composite materials. Consisting of fibre reinforcement in a polymer resin, thermoset sheet moulding compound (SMC) provide properties such as high strength, dimensional stability, and stain and corrosion resistance at a lower cost than competing construction materials, such as metal and wood, which have experienced sharp price increases in recent years.
Thermosets feature cross-linked molecules that help the materials maintain their properties during long periods of exposure to extreme temperatures.
Besides maintaining critical physical properties under exposure to stressful conditions, many construction components must maintain an attractive appearance over time. For example, a bright white window frame must maintain its color and gloss when exposed to natural elements, drastic temperatures, and harmful cleaning supplies.
In addition to roofing tiles, construction components now made of SMC include:

- Door Skins
- Fencing
- Roofing
- Window Panels
- Water Tanks
- Dust Bins
- Basins & Bath Tubs

- **Energy**

Alternate energy applications represent a substantial opportunity for Sheet Moulding Compound (SMC) material. Solar power tiles and wind turbines are two ideal applications; both require material that can withstand extended exposure to sun and natural elements while maintaining dimensional control. In addition to providing superior material properties, molded SMC components provide exceptional cost savings due to parts consolidation.

Performance and cost considerations are spurring the use of new materials in the “small wind” energy market. Thermoset composites are ideal for compression moulding 3-4 meter turbine blades of various shapes for commercial and home use. The material is strong and durable, with a specific gravity that is well below aluminum for exceptional rigidity and vibration dampening.

Plus, they create smooth, airfoil surfaces that won't dull or fibre bloom with exposure. The hub, usually machined from solid or cast aluminum transfers stresses from the blades to the primary input shaft of the generator. Thermoset composites provide the exceptional material strength required for this application, and save manufacturers the milling and final finishing costs associated with metal production.

Applications in the mission-critical power generation market are subject to extreme environmental conditions, including exposure to heat, corrosive liquids, and UV rays. Sheet Moulding Compound (SMC) has proven to be effective materials that can withstand the test of time under harsh conditions. With their cross-linked molecules, thermosets provide excellent electrical insulation and dielectric strength even during prolonged exposure to high temperatures. Utilized in pad and portable power generators for home, farm, construction, office use, oil fields, and power substations, manufacturers are transitioning to SMC composite materials because of its key properties.

Key applications:

- Support frames for Thin Film and Rigid Silicon solar panels.
- Roof tiles for Thin Film installations.
- Housings for solar structures for heating liquids in pipe systems.
- Small Turbine Blades
- Blade Hub
- Turbine Housing
- Pad Type Or Portable Type Power Generators

- **Wastewater**

Many manufacturers in the wastewater industry have made the switch from aluminum and other metals to thermoset composite materials. Ideally suited for the unique needs of the wastewater treatment market, manufacturers and molders can request a custom-formulation of the material to fit the unique needs of each specific application. An outdoor manhole cover needs to resist deterioration from exposure to harmful UV rays and a plumbing flange must resist corrosive chemicals.

There is an economic benefit to switching to thermoset SMC for

wastewater applications as well. Products in this market are traditionally dominated by die-cast aluminum / cast iron some of which are subject to machining and welding. Moulding a single-part from SMC shortens design and production, and provides a finished product that will stand up to the harsh environments for years to come.
For components such as

- Lids
- Weir
- Plates
- Control Valves
- Plumbing Flanges
- Manhole Covers

- **Transportation**

Thermoset Sheet Moulding Compounds (SMC) meet the requirements of the Rapid Transit industry with regard to low smoke generation and low flammability ratings, making them ideal for rapid transit, suburban commuter, and light rail systems' third rail electrical applications. These composite materials offer superior electrical insulation and heat resistance, allowing them to withstand prolonged exposure to the elevated temperatures and high voltage common in transit applications.
Thermoset materials have Comparative Tracking Index (CTI) values exceeding 600 volts and dielectric strength in excess of 15 KV/mm. This, along with their excellent thermal properties, makes SMC moulding compounds an ideal choice for the insulative needs of the Rapid Transit industry.
Applications for SMC in the Rapid Transit market include:

- Train / Tram interior & body parts
- Third rail insulators
- Third rail canopies
- Contactors
- Traction motor brush holders

- **Medical Devices**

Medical applications require many special considerations that make thermoset Sheet Moulding Compound (SMC) the perfect choice over metals and thermoplastics. These applications often require a material that can stand up to harsh cleaning solvents, high-temperature sterilization, and even X-ray radiation exposure. Thermoset SMC composite materials have many material characteristics that make it ideal for medical applications, such as;

- Instrumentation covers, bases, and components
- Standard and contagious/biohazard trash cans and receptacles
- X-ray film containers
- Surgery equipment
- Dental medication systems
- Antibacterial components

- **Military & Aerospace**

Metals have a long history in the military and aerospace markets, but their shortcomings can result in discomfort, damage, and even disaster in many mission-critical land, sea, and air applications. Metals are heavy, easily dented, and highly susceptible to corrosion. And during combat operations, metals can be detected by enemy radar, with potentially deadly consequences for military personnel. So it's no surprise that many designers and manufacturers are switching from metals to thermoset composite materials. Consisting of fibre reinforcement in a polymer resin, field-tested thermoset sheet moulding compound (SMC) offer many advantages in military and aerospace applications. These include:

• **High strength-to-weight ratio.** Thermoset components are up to 35 percent lighter than steel parts of equal strength.
• **Corrosion resistance.** Unlike metals, thermosets withstand long-term exposure to water and other corrosive substances.
• **Excellent memory characteristics.** While metal panels permanently deform on impact, SMC panels deform and spring back to their original shape, which minimizes denting.
• **Radar absorption.** This property minimizes thermosets visibility to enemy radar.

Among defense manufacturers, thermosets have become popular choices for electrical applications such as switches, transformers, and circuit breakers. Conforming to Mil Specs, SMC meet the military's demanding requirements for electrical components. These include higher strength, flame retardancy, and smoke and toxicity standards than those promulgated by other industries.

In addition, SMC maintain their high strength during long-term exposure to natural elements, making them ideal for protecting sensitive military and aerospace equipment. Protective products made of thermosets include **weapon housings, tote bins, equipment cases, and ballistic barriers.** Thermosets are also used to make rifle grips and the body panels of military vehicles.

- **Lighting**

Thermoset SMC is ideal for high-intensity discharge (HID) lighting fixtures, from architectural to safety applications. The material's dielectric properties are a strong attribute for these applications, as well as its high total reflectance (TR) value. Parts consolidation also makes SMC an attractive material for lighting applications, as manufacturers are able to mold terminal blocks directly into the fixture with no secondary operations. In addition, tremendous cost savings can be realized by directly moulding reflectors with the thermoset material. SMC can be found in outdoor HID lighting, where exposure to moisture and UV are key environmental considerations. SMC is also corrosion- and stain-resistant, and offers molded-in color which, in the case of highly-reflective white coloration, can dramatically enhance the effectiveness of the fixture. For indoor HID lighting, SMC offers light weight, high TR values, and the ability to hold accurate dimensions for applications such as warehouses, stadiums, and gymnasiums. Most important, SMC is UL-approved for flame retardancy.

- **Safety & Security**

Firemen, miners, and construction workers are continuously exposed to natural elements, as well as extremely high temperatures and falling debris. For safety helmets, metals can provide some of the properties required, but their relatively heavy weight can quickly fatigue helmet wearers.

Worse, helmets made of conductive metals can actually pose a safety risk to wearers if they come into contact with electrical equipment or lines. These concerns have made thermoset composite materials a popular metals replacement material in safety and security applications. Thermoset sheet moulding compound (SMC) feature cross-linked molecules that provide excellent impact resistance at both high and low temperatures, giving thermosets a crucial edge over many thermoplastic materials. In addition to meeting demanding impact requirements, SMC also hold up well in harsh outdoor environments. They also feature good heat and flame resistance and low smoke and toxicity emissions when exposed to fire. When used in a number of other safety and security applications, thermoset SMC provide important properties that are often difficult to obtain with metals or thermoplastics. These applications include:

Lighting and communications equipment: Mounted on the helmets of firemen and miners, this equipment can often mean the difference between life and death for helmet wearers and those in need of rescue. Thermosets offer good structural rigidity at extreme temperatures. They also allow manufacturers to mold in the design details of different types of mounting equipment.

Safety and security instrument housings: These housings must comply with OSHA color codes, survive years of harsh weather exposure, and protect internal equipment from radio broadcast interference. SMC can help manufacturers meet all these requirements, making these materials a popular choice for a range of instrument housings. Thermosets offer molded-in color, corrosion and UV resistance, and built-in RFI / EMI / ESD protection or radio-transmission transparency.