

Reinforced thermosets offer unique benefits in electrical engineering

Dr.-Ing. Klaus Ahlborn, Stratinor Composites

The European plastics industry was founded on thermosets, but nowadays thermoplastics are often considered the preferred material for electrical engineering applications. This overlooks the fact that glass-fibre reinforced thermosets, in particular, offer a unique range of beneficial properties. SMC and BMC (sheet and bulk moulding compounds) based on unsaturated polyesters are attractively priced alternatives that are easily processed by compression or injection moulding. These composites are characterised by excellent insulating properties, high temperature resistance while retaining dimensional accuracy and the ability to withstand long-term stresses and loadings. They also offer environmental benefits in terms of their low smoke and low toxicity flame retardancy and their suitability for recycling.

SMC is primarily used in hot press moulding for the production of large, relatively flat mouldings, while BMC is mainly used to produce smaller and more complex components by means of injection moulding. Both types of material are a composition of E-glass fibres (E = suitable for electrical engineering), mineral fillers and thermosetting unsaturated polyester (UP) resin. This resin is competitively priced and is renowned for its good temperature resistance. Due to the 'ceramic' nature of SMC and BMC, they offer many beneficial properties [1]

- insulating properties
- heat resistance
- low tendency to creep
- high endurance strength
- environmentally friendly
- flame resistance
- low volume shrinkage
- coefficient of expansion similar to that of metals
- suitability for recycling.

Natural Insulators

Thermoset compounds are very good insulators. According to IEC 60093:1980-01 [2], the specific volume resistance is between $10^{12} \Omega\text{cm}$ and $10^{14} \Omega\text{cm}$. For flameproof applications, the specific internal insulation resistance is reduced to $<10^6 \Omega\text{cm}$ by the addition of conductive fillers. The dielectric dissipation factor $\tan \delta$ according to IEC 60250:1969-01 [3] is 0.01 and is relatively stable across a wide range of temperatures and frequencies. The relative dielectric constant ϵ_r is low (4), at a test frequency of 1 MHz. The electrical strength according to IEC 60243 [VDE 0303 Part 21]: 1999-03 [4, 5] is 17 kV/mm to 19 kV/mm. The excellent tracking resistance of CTI 600 (comparative tracking index) according to IEC 60112 (VDE 0303 Part 1): 1984-06 is much better than that of engineering thermoplastics [6-8].

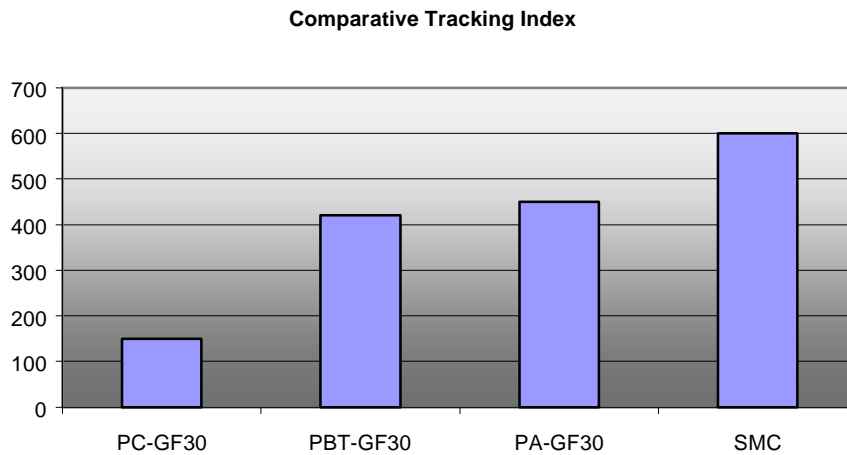


Figure 1: Comparative tracking index of SMC in CTI according to IEC 60112 (VDE 0303 Part 1) [6-8] compared to the engineering thermoplastics polycarbonate (PC), polybutylene terephthalate (PBT) and polyamide (PA), each with 30 % by weight of chopped strands (GF-30) in accordance with [9]

The above overview of the electrical engineering properties demonstrates that SMC and BMC are ideal for the insulation of electrical currents. However, when in component production, good electrical engineering properties are not the only requirement. Another critical requirement is the price of the material. Figure 2 shows the cost benefits of SMC compared to engineering thermoplastics on the basis of the volume prices (price per kilo and density) in accordance with [10].

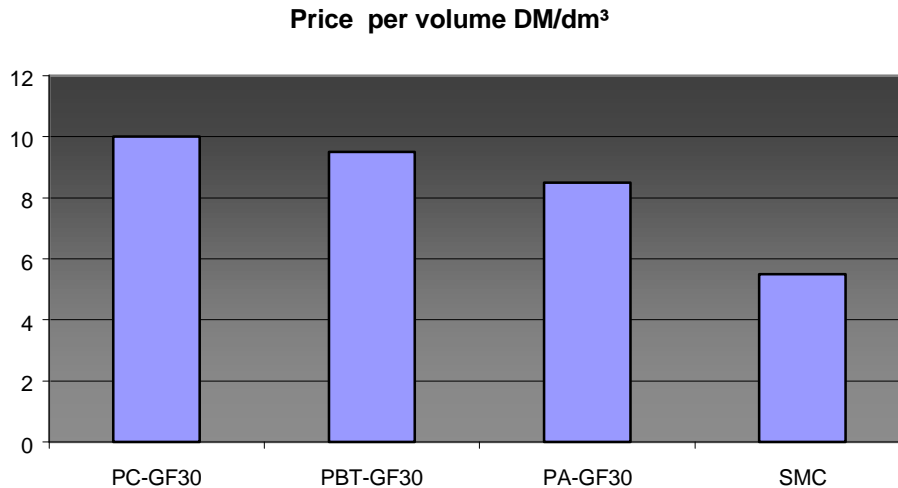


Figure 2: Volume price of SMC compared to polycarbonate (PC), polybutylene terephthalate (PBT) and polyamide (PA), each with 30 % by weight of chopped strands (GF-30) in accordance with [10]. The volume price is calculated from the product of the price per kilo and density and hence takes into account the differences in density when comparing materials.

Other requirements, mainly mechanical, are relative to the type of application. For example, temperature resistance is important, and SMC compounds have been successfully used for cable distribution cabinets in outdoor applications. SMC is extremely resistant to weathering and low temperatures – even down to -40°C [1]. A further benefit for housings is dimensional stability. SMC can resist the heat generated by the current flow and the resistance to continuous mechanical stress.

The increasingly complex and compact design of the circuit breakers (**Figure 3**) requires ever-higher levels of dimensional stability. **Figure 4** compares the dimensional stability of SMC with that of engineering thermoplastics in accordance with DIN EN ISO 75-3:1996-03, procedure A [13, 14]. This test determines the temperature at which a predefined load can withstand flexural stress within the required deformation parameters. The long glass fibres and the crosslinked molecular structure of the UP resin matrix enables SMC and BMC compounds to withstand forces at temperatures of more than 200°C .

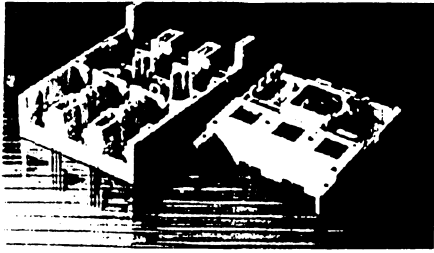


Figure 3: BMC circuit breaker housing at Moeller, Bonn [11] made by Mitras Composites Systems [12] using injection-compression moulding

Heat Resistance Temperature °C

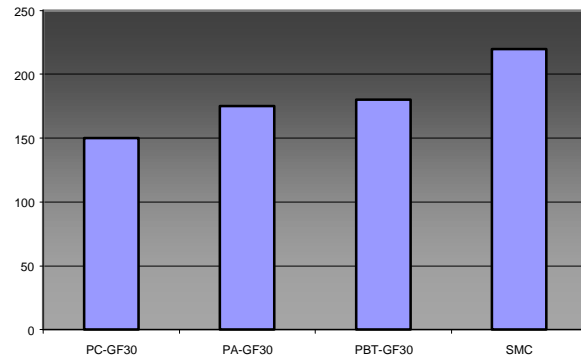


Figure 4: Heat resistance temperature in accordance with DIN EN ISO 75-3 procedure A [13, 14] of SMC compared to that of polycarbonate (PC), polyamide (PA) and polybutylene terephthalate (PBT) each with 30 % by weight of chopped strands (GF-30) in accordance with [15, 16]

SMC creep is as low as that of metal alloys

Creep tests also demonstrate superior response under continuous mechanical stress. In this case, a test piece is subjected to a constant tensile stress and the resulting elongation is plotted over time. The lower the onset of the tendency to creep, the longer a screwed connection will be able to withstand the force applied to close the housing. As the comparison of creep elongation in **Figure 5** shows, on exposure to a mechanical stress of 10 MPa for 1000 hrs, SMC exhibits minimal creep behaviour, similar to aluminium alloys. Thermoplastics, on the other hand, undergo three to seven times more creep elongation.

Another type of continuous stress takes the form of mechanical vibrations. These may be generated by electric motors or cyclic current flows. This vibrating stress results in the gradual destruction of the material and in a degradation of properties. The longer the material is exposed to the vibrating stress, the more the strength is reduced. As the comparison of the tensile stress test in **Figure 6** shows, the continuous glass fibres and the crosslinking of the unsaturated polyester resin, give the SMC improved resistance when exposed to vibrating stresses.

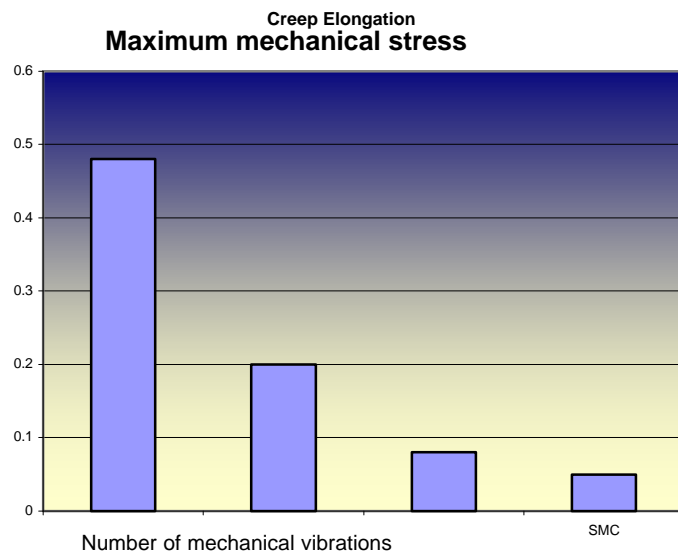


Figure 5: Creep elongation of SMC after 1000 h tensile stress at 10 MPa compared to polyvinyl chloride (PVC), polyamide (PA with 30 % by weight of chopped strands GF-30) and an aluminium alloy (AISI10Mg)

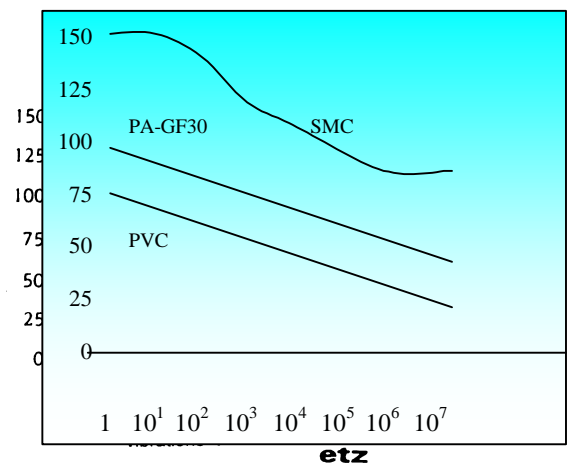


Figure 6: Endurance strength of SMC under tensile fatigue stress compared to polyamide (PA with 30 % by weight of chopped strands GF-30) and polyvinyl chloride (PVC) with a fracture probability of 50 % and a stress ratio of min amplitude to max amplitude of $R = 0.1$

Maximum fire protection – and environmentally friendly

Statistics produced by the Berlin Fire Brigade, show that electricity is the second most frequent fire ignition source. In 31 % of all cases, a synthetic material is the first to be ignited [17]. Consequently, the plastics chosen for the insulation of electrical currents should be as difficult to ignite as possible and must not help to propagate the fire. To achieve this, thermoplastics are often treated with halogenated flame retardants. The EU intends to prohibit the use of several brominated flame retardants by 2007 in a Directive on the restriction of hazardous materials in electrical equipment [18, 19]. These flame retardants also have the disadvantage that they create a large amount of smoke, and it is smoke that tends to be the main cause of damage and fatalities in fire situations. The fumes not only hinder fire fighting, they are also suffocating for humans and corrosive, thus causing extensive damage to machines and equipment.

Naturally occurring mineral fillers are an environmentally preferable alternative. However, they cannot be added to viscous thermoplastic melts in sufficient quantities and are rarely able to withstand the high processing temperatures used with thermoplastics. On the other hand, low-viscosity UP resins may be filled with naturally occurring aluminium trihydroxide, for example, and thus provide excellent protection against ignition and flame propagation. SMC/BMC can therefore easily meet the requirements in the above-mentioned EU Directive.

Probably the most common test in the world used to evaluate the fire behaviour of plastics is the determination of the oxygen index in accordance with DIN EN ISO 4589: 1999-09 [20]. In this test, a plastic sample section is ignited and examined to determine the oxygen/nitrogen mixture at which the flame continues to burn. An oxygen content of 21 % represents normal atmospheric conditions. Therefore, the more difficult to ignite the plastic is, the higher the oxygen concentration has to be set. As **Figure 7** shows, SMC has a limiting oxygen index of > 90 % which represents excellent flame resistance.

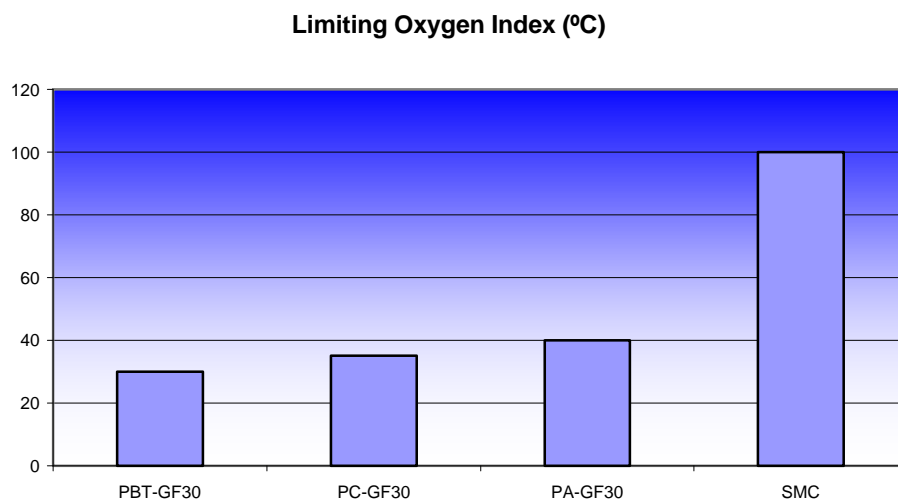


Figure 7: Limiting oxygen index in accordance with DIN EN ISO 4589 [20] of SMC compared to polyamide (PA), polybutylene terephthalate (PBT) and polycarbonate (PC) each with 30 % by weight chopped strands (GF-30) for evaluating fire behaviour in accordance with [21]

Functional integration by the embedment of metals

Composites such as SMC/BMC enable the conductivity of metals to be combined with the insulating capabilities of plastics. Obstacles to achieving this kind of compatible connection, are frequently the high moulding shrinkage of the plastics and the differences in the coefficients of thermal expansion. Both these factors mean that high forces are established in the plastic, when combined with metals, and these could result in the cracking or tearing of the plastics. Such problems are not encountered with SMC and BMC materials. The moulding shrinkage may be compensated to values of around zero and at 1.6×10^{-5} m/m to 2.3×10^{-5} m/m, and the coefficient of linear expansion is in the same range as that of normal metal alloys. By reducing the number of components and integrating numerous functions in one component, it is therefore possible to embed current-carrying copper conductors - for example - in SMC or BMC, as shown in **Figure 8**, using the example as a base module for disconnection switchgear.

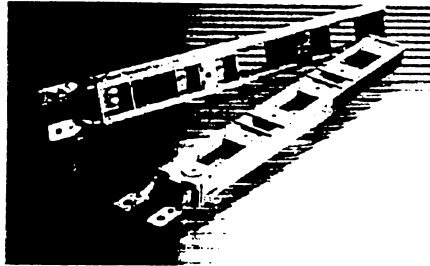


Figure 8. Base module of disconnection switchgear made by Pfisterer, Stuttgart [22] with embedded copper conductors, produced by injection moulding

Direct recycling in the form of particle recycling

SMC and BMC are often underestimated when it comes to recycling. Since the crosslinking – the factor that gives them their excellent heat performance - means they cannot be re-melted, they are often considered to be unsuitable for material recycling. In reality, the method of particle recycling, in use since the early nineties, enables these materials to be directly recycled in the same application without any deterioration of properties. The method is based on the comminution of the parts by grinding and milling [23]. This commercially proven process also permits the recycling of paint finishes and enables embedded metal components to be separated without difficulty.

SMC/BMC – ideal materials for electrical engineering

In summary, the combination of favourable semi-finished product costs, good electrical insulation properties, the ability to withstand continuous mechanical stress (particularly in heat), and high functional integration, enable SMC and BMC to compete very favourably with engineering thermoplastics (**Figure 9**). Frequently underestimated by electrical component designers, these materials offer economical and high performance solutions to complex electrical engineering challenges. More intricate and compact designs, constantly increasing material requirements and cost constraints, will make the use of SMC and BMC even more compelling in the future. For these reasons, many OEMs are already collaborating closely with manufacturers in the further development of these important materials.

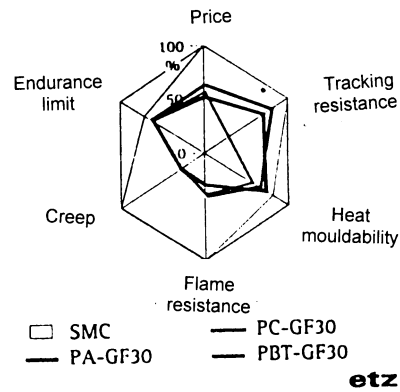


Figure 9: Overview of the properties of SMC compared to those of engineering thermoplastics; here the pre-defined property values were each standardised at the maximum values achieved by engineering plastics

Please note:

The references for the literature have been translated into English, for better comprehension.

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About the European Alliance for SMC

The European Alliance for SMC is a cooperation of leading international manufacturers of SMC/BMC parts and semi-finished products as well as raw materials suppliers. The objective of the SMC Alliance is to make people more aware of the applicational and processing advantages of SMC compared to other materials. Further information may be obtained from: European Alliance for SMC, c/o AVK-TV, Am Hauptbahnhof 10, 60329 Frankfurt am Main: +49/69250922, email: smc-alliance@t-online.de Web site: www.smc-alliance.com

Author contact:

Dr.-Ing. Klaus Ahlborn is Director Subcontracting Customers & Development at Stratinator Composites Systems SAS, Limoges, France. Direct line +33 5 55 31 84 56 : www.stratinor.fr