Sheet molding compound, SMC, polyester matrix

Description

Image

Caption

SMC cycle shed. © ACT, McMaster University

The material

Lay-up and filament winding methods of shaping composites are far too slow and labor-intensive to compete with steel pressings for car body panels and other enclosures. Sheet molding compounds (SMCs) and dough (or bulk) molding compounds (DMCs or BMCs) overcome this by allowing molding in a single operation between heated dies. To make SMC, polyester resin containing thickening agents and cheap particulates like calcium carbonate or silica dust is mixed with chopped fibers -- usually glass -- to form a sheet. The fibers lie more or less parallel to the plane of the sheet, but are randomly oriented in-plane, with a volume fraction between 15% and 40%. DMC is made in a similar way, but the mix has a higher concentration of filler and a lower volume fraction of chopped fiber (10% to 25%), which are randomly oriented in 3-dimensions. This makes a "pre-preg" with leather or dough-like consistency. When SMC sheet is pressed between hot dies it polymerizes, giving a strong, stiff sheet molding. DMC is molded in closed, heated dies to make more complex shapes: door handles, shaped levers, parts for washing machines and the like.

Compositional summary

(OOC-C6H4-COO-C6H10)n + CaCO3 or SiO2 filler + 15 to 40% chopped glass

General properties

Density		1.8e3	-	2e3	kg/m^3
Price	*	3.29	-	3.85	USD/kg
Date first used		1962			

Mechanical properties

Young's modulus		9	-	14	GPa
Shear modulus	*	3.6	-	6	GPa
Bulk modulus	*	10	-	13	GPa
Poisson's ratio		0.33	-	0.35	
Yield strength (elastic limit)		50	-	90	MPa
Tensile strength		60	-	100	MPa
Compressive strength		240	-	310	MPa

Elongation	2.5	-	3.2	% strain
Hardness - Vickers	* 15	-	25	HV
Fatigue strength at 10^7 cycles	* 20	-	36	MPa
Fracture toughness	* 5	-	13	MPa.m^0.5
Mechanical loss coefficient (tan delta)	* 0.005	-	0.008	

Thermal properties

Glass temperature	147	-	197	°C
Maximum service temperature	180	-	220	°C
Minimum service temperature	-80			°C
Thermal conductor or insulator?	Good insulator			
Thermal conductivity	0.27	-	0.5	W/m.°C
Specific heat capacity	1.05e3	-	1.09e3	J/kg.°C
Thermal expansion coefficient	18	-	33	µstrain/°C

Electrical properties

Electrical conductor or insulator?	Good insulator			
Electrical resistivity	1e18	-	1e19	µohm.cm
Dielectric constant (relative permittivity)	4.25	-	5.1	
Dissipation factor (dielectric loss tangent)	0.003	-	0.0095	
Dielectric strength (dielectric breakdown)	10	-	18	1000000 V/m

Optical properties

Transparency	Translucent

Processability

Moldability	4	-	5
Machinability	3	-	4

Durability: water and aqueous solutions

Water (fresh)	Excellent
Water (salt)	Excellent
Soils, acidic (peat)	Limited use
Soils, alkaline (clay)	Unacceptable
Wine	Acceptable

Durability: acids

Acetic acid (10%)	Limited use
Acetic acid (glacial)	Unacceptable
Citric acid (10%)	Excellent
Hydrochloric acid (10%)	Excellent
Hydrochloric acid (36%)	

	Excellent
Hydrofluoric acid (40%)	Unacceptable
Nitric acid (10%)	Excellent
Nitric acid (70%)	Unacceptable
Phosphoric acid (10%)	Excellent
Phosphoric acid (85%)	Excellent
Sulfuric acid (10%)	Excellent
Sulfuric acid (70%)	Excellent

Durability: alkalis

Sodium hydroxide (10%)	Unacceptable
Sodium hydroxide (60%)	Unacceptable

Durability: fuels, oils and solvents

Amyl acetate	Limited use
Benzene	Unacceptable
Carbon tetrachloride	Excellent
Chloroform	Unacceptable
Crude oil	Acceptable
Diesel oil	Excellent
Lubricating oil	Excellent
Silicone fluids	Excellent
Toluene	Limited use
Turpentine	Excellent
Vegetable oils (general)	Acceptable
White spirit	Limited use

Durability: alcohols, aldehydes, ketones

Acetaldehyde	Limited use
Acetone	Limited use
Ethyl alcohol (ethanol)	Limited use
Ethylene glycol	Excellent
Formaldehyde (40%)	Excellent
Glycerol	Excellent
Methyl alcohol (methanol)	Limited use

Durability: halogens and gases

Chlorine gas (dry)	Excellent
Fluorine (gas)	Unacceptable
O2 (oxygen gas)	Unacceptable
Sulfur dioxide (gas)	Excellent

Durability: built environments

Industrial atmosphere	Excellent
Rural atmosphere	Excellent
Marine atmosphere	Excellent
UV radiation (sunlight)	Good

Durability: flammability

Flammability	Highly flammable

Durability: thermal environments

Tolerance to cryogenic temperatures	Unacceptable
Tolerance up to 150 C (302 F)	Excellent
Tolerance up to 250 C (482 F)	Unacceptable
Tolerance up to 450 C (842 F)	Unacceptable
Tolerance up to 850 C (1562 F)	Unacceptable
Tolerance above 850 C (1562 F)	Unacceptable

Primary material production: energy, CO2 and water

Embodied energy, primary production		109	-	121	MJ/kg
CO2 footprint, primary production		7.69	-	8.49	kg/kg
Water usage	*	89	-	280	l/kg

Material processing: energy

Compression molding energy	*	3.33	-	3.68	MJ/kg

Material processing: CO2 footprint

Compression molding CO2	*	0.266	-	0.294	kg/kg

Material recycling: energy, CO2 and recycle fraction

Recycle		✘			
Recycle fraction in current supply		0.5	-	1	%
Downcycle		✔			
Combust for energy recovery		✔			
Heat of combustion (net)	*	14	-	14.7	MJ/kg
Combustion CO2	*	1.24	-	1.31	kg/kg
Landfill		✔			
Biodegrade		✘			
Toxicity rating		Non-toxic			
A renewable resource?		✘			

Environmental notes

Fiber composites cannot be recycled.

Supporting information

Design guidelines

The chopped fiber reinforcement makes SMC and DMC moldings stiffer, stronger and more abrasion resistant than straight resin castings or moldings. They are relatively cheap, but competitive with steel and aluminum pressings only when batch sizes are small ("small" means batch volumes below about 10,000) or the part itself is small. The in-mold curing time limits the rate at which parts can be molded -- the thicker the section, the longer this time becomes (because of the low thermal conductivity of the resin), and the greater the processing cost.

Technical notes

Considerably flow takes place when SMCs are molded. Flow leads to fiber alignment, something that can be exploited to improve part performance. The degree of alignment varies from place to place in the molding, something that is important to know if properties are to be predicted. Approximate estimates for the elastic constants of SMC parts, neglecting alignment, are Young's modulus = Fiber modulus x volume fraction /3Shear modulus = Fiber modulus x volume fraction /8Poisson’s ratio = 1/3These are useful for first estimates but not adequate for detailed design.

Typical uses

Sheet pressings of all types, competing with steel and aluminum sheet. Car body panels; enclosures; luggage and packing cases.

Tradenames

Celanex; Eastar; Flomat; Hytrel; Plenco; Polyrite; Premiglas; Premix; Rynite; Synolite; Valox; Vybrex

Links

Reference

ProcessUniverse

Producers