Performance by Design
HexWeb™ EM
HexWeb™ EM was developed as a counter measure material to meet FMVSS 201U head impact protection regulations where low crush strengths are required and space is a constraint. Other interior applications include head rests, knee bolsters, and side impact protection.
Towflex®
Hexcel's TowFlex® Continuous Fiber Reinforced Thermoplastic materials are used for the award-winning BMW M3 bumper. An E-glass/nylon construction meets performance demands, manufacturing cost restrictions and recycling requirements.
Modipur®
Hexcel's Modipur® polyurethane foam and HexWeb® honeycomb reinforcements, provide durable yet lightweight solutions for spoilers.
HexLite®
Hexlite® sandwich panels are lightweight, yet strong and durable. Automotive Tonneau cover, cargo cover, or floor designs integrate Hexlite® panels as a stiffener and weight-saving component supplied with bonded inserts for fastening.
HexPly®
Leafsprings manufactured from HexPly® prepregs weigh up to 60% less than their steel counterparts. Composite leafsprings also have greater energy absorption and fatigue resistance than metal versions.
Hexcel Composites offers technical support to help provide valuable solutions for demanding automotive applications.
We are a proven supplier to the automotive industry, and manufacture a wide range of high performance composite materials in both Europe and the USA.
For the latest information on Hexcel Composites products, visit our website at www.hexcelcomposites.com
or call 1-248-344-8688 (USA)
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automotive@hexcel.com
HEXCEL Composites

Reinforced Plastics, Nov. 2002 p39

SMC updates T-Bird's look

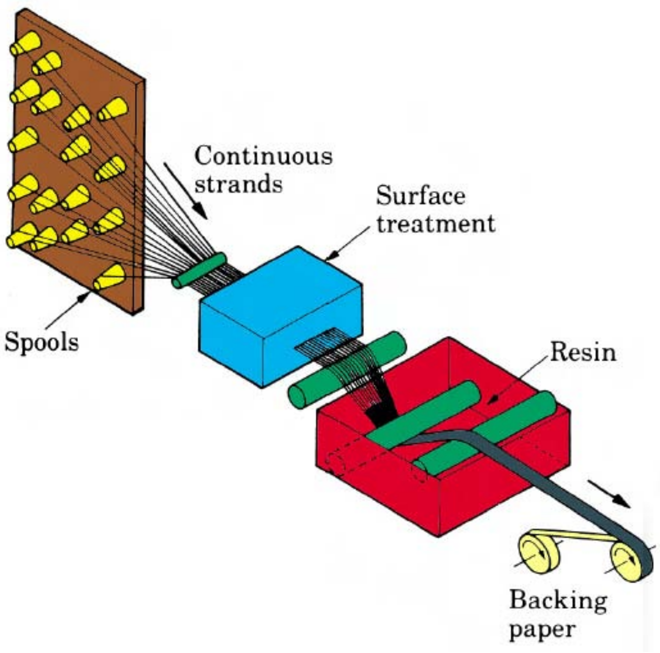
Sheet moulding compound (SMC) is a composite material, typically consisting of chopped glass fibre dispersed in a thermoset polymer matrix (often an unsaturated polyester resin), combined with various additives and fillers. The components are processed to make a continuous sheet of material which can then be cut into blanks and processed in a press under pressure and temperature to produce shaped, cured parts. The ability to press-mould medium-to-large sized components has attracted the automotive industry, where it is used to produce Class A parts such as door panels, hoods (bonnets), fenders (wings), and trunk (boot) lids. ('Class A' is the automotive industry's terminology for the surface quality required for body panels.)

The Automotive Composites Alliance (ACA), based in Rochester, Michigan, USA, forecasts a 44% increase in production of reinforced thermoset composites for the automotive and heavy truck industries over the next few years to reach nearly 500 million lbs (226 800 tonnes) by 2005. Much of this growth will result from SMC components used in the development of new models. One current example is Ford's 2002 Thunderbird, where 60% of the exterior body panels are made of thermoset composites. The hood, front fenders, grille opening reinforcement, decklid and removeable top and CHMSL panel located between the trunk lid are made from SMC. Budd supplies the body panels, Venture Industries the removeable top, and Meridian Automotive the CHMSL. The roof module integrates the SMC inner and outer panels, headliner, package shelf, framework for the car's distinctive porthole windows, and all seals, hatches and hinges.

Tooling costs for the new T-Bird are reported to have be cut by around 50% by choosing SMC for most of the key exterior panels. It also gave styling advantages, such as the integral scoops in the hood, which were not possible with steel. First-year prodution is expected to reach 30 000 units.

Ford's 2002 T-Bird makes an impact with the help of SMC. (Picture © Wieck Media Services Inc.)

"Prepreg" Composite Tape



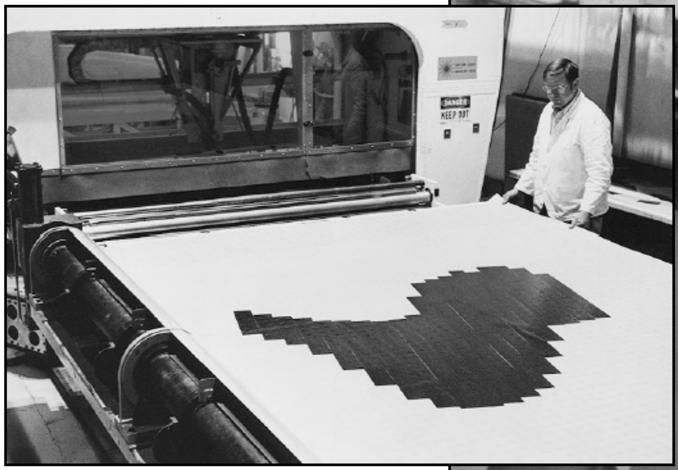
(a)

(b)

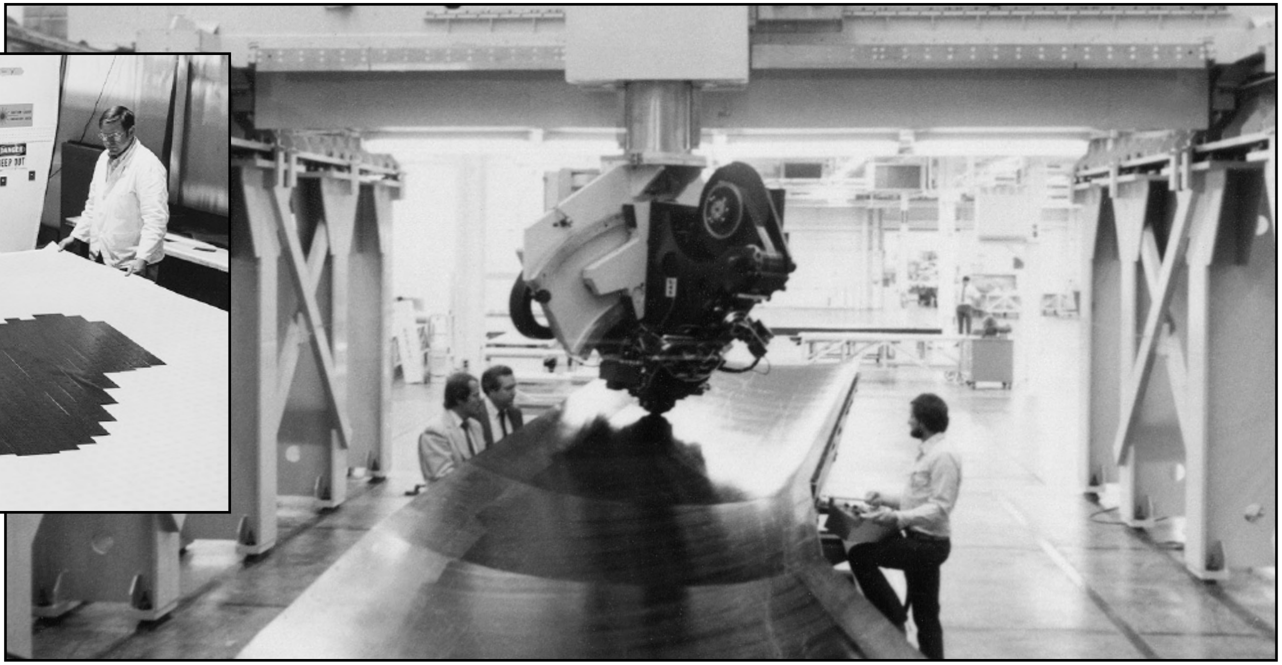
Figure 18.17 (a) Manufacturing process for polymer-matrix composite. Source: T.W. Chou, R.L. McCullough, and R.B. Pipes. (b) Boron-epoxy prepreg tape. Source: Avco Specialty Materials/Textron.

S. Kalpakijan and S.R. Schmid, *Manufacturing Engineering and Technology*, 4th edition, Prentice Hall, Upper Saddle River, NJ, 2001.

"Prepreg" Tape Layup



(a)



(b)

Figure 18.18 (a) Single-ply layup of boron-epoxy tape for the horizontal stabilizer for F-14 fighter aircraft. Source: Grumman Aircraft Corporation. (b) A 10 axis computer-numerical-controlled tape-laying system. This machine is capable of laying up 75 mm and 150 mm (3 in. and 6 in.) wide tapes, on contours of up to ±30° and at speeds of up to 0.5 m/s (1.7 ft/s). Source: Courtesy of The Ingersoll Milling Machine Co.

S. Kalpakijan and S.R. Schmid, *Manufacturing Engineering and Technology*, 4th edition, Prentice Hall, Upper Saddle River, NJ, 2001.

Halpin-Tsai Equations

Halpin-Tsai equations are interpolations of the exact solutions (numerical methods).

Their utility lies in adaptability for various fiber geometries & arrangements.

$$E_{11} \cong E_f V_f + E_m V_m \qquad \text{(H-T 1)}$$

p = composite moduli, E_{22}, G_{22}, G_{23}, ν_{23}

$$\nu_{12} \cong \nu_f V_f + \nu_m V_m \qquad \text{(H-T 2)}$$

p_f = corresponding fiber moduli, E_f, G_f, ν_f

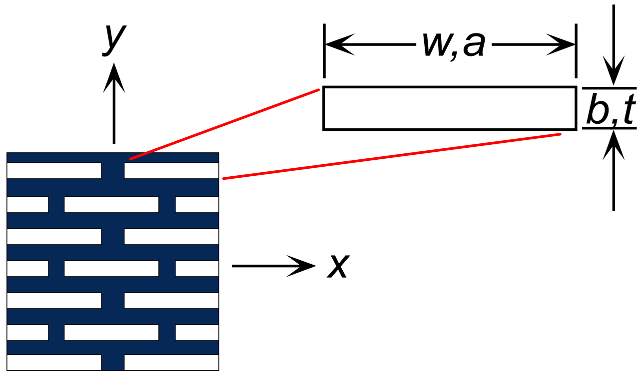
$$\frac{p}{p_m} = \frac{1+\zeta\eta V_f}{1-\eta V_f} \qquad \text{(H-T 3)}$$

p_m = corresponding matrix moduli, E_m, G_m, ν_m

$$\eta = \frac{\left(p_f / p_m - 1\right)}{\left(p_f / p_m + \zeta\right)} \qquad \text{(H-T 4)}$$

$\zeta = f$(reinforcement dependence on boundary conditions – fiber geometry and arrangement)

RVEs – See book chapter by Halpin, e.g.:



Halpin-Tsai Equations

(a) particulate reinforcement

$$\zeta_E = \zeta_{E_{22}} = 2 + 40 \cdot V_f^{10} \qquad E/E_m \rightarrow \text{(H-T 3)}$$

$$\zeta_G = \zeta_{G_{12}} = 1 + 40 \cdot V_f^{10} \qquad G/G_m \rightarrow \text{(H-T 3)}$$

(b) voids or a foam $p/p_m \rightarrow 0 \quad \therefore \quad \eta_E = 1/\zeta_E$ and $\eta_G = 1/\zeta_G$

$$\zeta_E = 2a/b \qquad E/E_m \rightarrow \text{(H-T 3)}$$

$$log(\zeta_G) = \sqrt{3} log(a/b) \qquad G/G_m \rightarrow \text{(H-T 3)}$$

(c) oriented continuous fibers $\qquad E_{11} \rightarrow$ (H-T 1)

$$\zeta_{E_{22}} = 2 + 40 \cdot V_f^{10} \qquad E_{22}/E_m \rightarrow \text{(H-T 3)}$$

$$\zeta_{G_{12}} = 1 + 40 \cdot V_f^{10} \qquad G_{12}/G_m \rightarrow \text{(H-T 3)}$$

$$\zeta_{G_{23}} \cong \frac{1}{4 - 3\nu_m} \qquad G_{23}/G_m \rightarrow \text{(H-T 3)}$$

$$\nu_{23} \cong 1 - (E_{22}/G_{23}) \qquad \nu_{12} \rightarrow \text{(H-T 2)}$$

Halpin-Tsai Equations

(d) oriented discontinuous fibers

Let L/d = longitudinal aspect ratio = length/diameter (or thickness)

$\zeta_{E_{11}} = 2(L/d) + 40 \cdot V_f^{10}$ $\quad E_{11}/E_m \rightarrow$ (H-T 3)

$\zeta_{E_{22}} = 2 + 40 \cdot V_f^{10}$ $\quad E_{22}/E_m \rightarrow$ (H-T 3)

$\zeta_{G_{12}} = 1 + 40 \cdot V_f^{10}$ $\quad G_{12}/G_m \rightarrow$ (H-T 3)

$\zeta_{G_{23}} \cong \dfrac{1}{4 - 3\nu_m}$ $\quad G_{23}/G_m \rightarrow$ (H-T 3)

$\nu_{23} \cong 1 - (E_{22}/G_{23})$ $\quad \nu_{12} \rightarrow$ (H-T 2)

Halpin-Tsai Equations

(e) oriented continuous ribbon or lamellar shaped reinforcement

Let w/t = transverse aspect ratio = width/thickness

$E_{11} \rightarrow$ (H-T 1) $\nu_{12} \rightarrow$ (H-T 2)

$$\zeta_{E_{22}} = 2\left(w/t\right) + 40 \cdot V_f^{10}$$ $E_{22}/E_m \rightarrow$ (H-T 3)

$$\zeta_{E_{33}} = 2 + 40 \cdot V_f^{10}$$ $E_{33}/E_m \rightarrow$ (H-T 3)

$$\zeta_{G_{12}} = \left(w/t\right)^{1.73} + 40 \cdot V_f^{10}$$ $G_{12}/G_m \rightarrow$ (H-T 3)

$$\zeta_{G_{23}} \cong 2 + 40 \cdot V_f^{10}$$ $G_{23}/G_m \rightarrow$ (H-T 3)

$$\nu_{23} \cong \left(\frac{V_f}{\nu_f} + \frac{\left(1 - V_f\right)}{\nu_f}\right)^{-1}$$

(f) oriented, discontinuous ribbon or lamellar shaped reinforcement (e.g., plate)

$$\zeta_{E_{11}} = 2\left(L/t\right) + 40 \cdot V_f^{10}$$ $E_{11}/E_m \rightarrow$ (H-T 3)

$$\zeta_{E_{22}} = 2\left(w/t\right) + 40 \cdot V_f^{10}$$ $E_{22}/E_m \rightarrow$ (H-T 3)

$$\xi_{G_{12}} = \left[\left(L + w\right)/2t\right]^{1.73} + 40 \cdot V_f^{10}$$ $G_{12}/G_m \rightarrow$ (H-T 3)