ESTIMATIONS OF COMPOSITE MATERIALS PROPERTIES

Composite materials may be either **isotropic** or **anisotropic**, which is determined by the Structure of composites.

Isotropic material is a material, properties of which do not depend on a direction of measuring.

Anisotropic material is a material, properties of which along a particular axis or parallel to a particular plane are different from the properties measured along other directions.

Rule of Mixtures

Rule of Mixtures is a method of approach to approximate estimation of composite material properties, based on an assumption that a composite property is the volume weighed average of the phases (matrix and dispersed phase) properties.

According to Rule of Mixtures properties of composite materials are estimated as follows:

- **Density**
- **Coefficient of Thermal Expansion**
- **Modulus of Elasticity**
- **Shear modulus**
- **Poisson's ratio**
- **Tensile strength**

Density

$d_c = d_m*V_m + d_f*V_f$
Where

d_c, d_m, d_f – densities of the composite, matrix and dispersed phase respectively;
V_m, V_f – volume fraction of the matrix and dispersed phase respectively.

Coefficient of Thermal Expansion

- Coefficient of Thermal Expansion (**CTE**) in longitudinal direction (along the fibers)

$\alpha_{cl} = (\alpha_m*E_m*V_m + \alpha_f*E_f*V_f)/(_m*V_m + E_f*V_f)$
Where

α_{cl}, α_m, α_f – **CTE** of composite in longitudinal direction, matrix and dispersed phase (fiber) respectively;
E_m, E_f – modulus of elasticity of matrix and dispersed phase (fiber) respectively.

- Coefficient of Thermal Expansion (**CTE**) in transverse direction (perpendicular to the fibers)

$\boldsymbol{\alpha_{ct} = (1+\mu_m)\ \alpha_m *V_m + \alpha_f * V_f}$

Where

μ_m – Poisson's ratio of matrix.

Poisson's ratio is the ratio of transverse contraction strain to longitudinal extension strain in the direction of applied force.

Modulus of Elasticity

Long align fibers

- Modulus of Elasticity in longitudinal direction (E_{cl})

$\boldsymbol{E_{cl} = E_m*V_m + E_f*V_f}$

- Modulus of Elasticity in transverse direction (E_{ct})

$\boldsymbol{1/E_{ct} = V_m/E_m + V_f/E_f}$

Short fibers

$\boldsymbol{E_{cl} = \eta_0\eta_L V_f\ E_f + V_m E_m}$

$\boldsymbol{\eta_L = 1 - 2/\beta L*\tanh(\beta L /2)}$

$\boldsymbol{\beta = [8\ G_m/(E_f D^2 \ln(2R/D))]^{1/2}}$

where:

E_f – modulus of elasticity of fiber material;
E_m – modulus of elasticity of matrix material;
G_m - shear modulus of matrix material;
η_L – length correction factor;
L – fibers length;
D – fibers diameter;
2R – distance between fibers;
η_0 - fiber orientation distribution factor.
η_0 = 0.0 align fibers in transverse direction
η_0 = 1/5 random orientation in any direction (3D)
η_0 = 3/8 random orientation in plane (2D)
η_0 = 1/2 biaxial parallel to the fibers
η_0 = 1.0 unidirectional parallel to the fibers

Shear modulus

$$G_{ct} = G_f G_m/(V_f G_m + V_m G_f)$$

Where:

G_f – shear modulus of elasticity of fiber material;
G_m – shear modulus of elasticity of matrix material;

Poisson's ratio

$$\mu_{12} = v_f \mu_f + V_m \mu_m$$

Where:

μ_f – Poisson's ratio of fiber material;
μ_m – Poisson's ratio of matrix material;

Tensile Strength

⊡ Tensile strength of long-fiber reinforced composite in longitudinal direction

$$\sigma_c = \sigma_m * V_m + \sigma_f * V_f$$

Where

σ_c, **σ_m**, **σ_f** – tensile strength of the composite, matrix and dispersed phase (fiber) respectively.

⊡ Tensile strength of short-fiber composite in longitudinal direction

(fiber length is less than critical value **L_c**)

$$L_c = \sigma_f * d/\tau_c$$

Where

d – diameter of the fiber;
τ_c –shear strength of the bond between the matrix and dispersed phase (fiber).

$$\sigma_c = \sigma_m * V_m + \sigma_f * V_f * (1 – L_c/2L)$$

Where

L – length of the fiber

⊡ Tensile strength of short-fiber composite in longitudinal direction

(fiber length is greater than critical value **L_c**)

$$\sigma_c = \sigma_m * V_m + L * \tau_c * V_f/d$$

Source : http://www.substech.com/dokuwiki/doku.php?id=estimations_of_composite_materials_properties