Composite materials

① $PS = \frac{K}{MC} - tw$

PS: particle size; MC: mesh count; tw: wire thickness

$K = 25.4$ if mm

$K = 1$ if inches.

② Surface Area → $\frac{A}{V} = \frac{K_s}{D}$

A: area of shape. V: volume of shape

K_s: shape factor, for sphere = 6

D: diameter of sphere.

↳ equals > 6 if not sphere.

Sphere:

$A = \pi D^2$

$V = \frac{\pi}{6} D^3$

Cylinder:

$A = \frac{\pi}{2} D^2 + \pi D L$

$V = \frac{\pi}{4} D^2 L$.

Cube:

$A = 6s^2$

$V = s^3$

Disk: (↳ height.)

$A = 2\pi r(h + r)$

$V = \pi r^2 h$.

③ PF + porosity = 1

PF: packing factor.

$PF = \frac{\text{bulk } \rho}{\text{true } \rho}$

④ $F = A_p P_c$

F: force required. A_p: projected area. P_c: compaction pressure.

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Properties of Ceramics

Yield strength

$$K_{Ic} = Y \sigma (\pi a)^{0.5}$$

K_{Ic}: Strain fracture toughness

Y: dimensionless parameter

σ: bending moment

a: if external crack we take a = crack length; if internal crack we take $a = \frac{1}{2}$ crack length.

$$\sigma = \frac{MC}{I}$$

C: distance from center to outer

I: circle: $\frac{\pi R^4}{4}$; rectangle: $\frac{bd^3}{12}$

distance between support points

$$\Delta y = FL^3 / 48EI$$

how much fracture.

P: volume fraction porosity

$$E = E_0 (1 - 1.9P + 0.9P^2)$$

E_0: elasticity of non-porous material

$$\sigma_{fs} = \sigma_0 \exp(-nP)$$

σ_0: const., n: const.

Composite Materials.

① Elastic Modulus upper and lower limits: (particle composites).

elastic modulus — volume fraction

$$E_c(u) = E_m V_m + E_p V_p \qquad V_m + V_p = 1$$

E_c: composite; E_m: matrix; E_p: particle.

$$E_c(l) = \frac{E_m E_p}{V_m E_p + V_p E_m}$$

② Specific Stiffness $= \frac{E_c}{SG_c}$ — specific gravity

$$SG_c = SG_m \times V_m + SG_p \times V_p$$

specific gravity. elastic modulus

③ $L_c = \frac{\sigma_f^* \, d}{2\tau_c}$

ultimate tensile strength. fiber diameter.

critical length in fibers.

fiber-matrix strength or shear yield strength.

L should be $> L_c$.

④ $F_c = F_m + F_f$ — fibers

$\sigma = \frac{F}{A}$

$\sigma_c \times A_c = \sigma_m \times A_m + \sigma_f \times A_f$ ← in fiber alignment.

$\div A_c$

$\sigma_c = \sigma_m \frac{A_m}{A_c} + \sigma_f \times \frac{A_f}{A_c}$

because: $\frac{V_c}{A_c} = L, \frac{V_m}{A_m} = L, \frac{V_f}{A_f} = L$ — equal lengths

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

stress strain

$\sigma_c/\epsilon_c = (\sigma_m/\epsilon_m) \times V_m + (\sigma_f/\epsilon_f) \times V_f$

$\epsilon_c = \epsilon_m = \epsilon_f$ iso strain

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⑤ Elastic modulus (fiber - composites).

$$E_{c(l)} = \epsilon_m V_m + \epsilon_f V_f$$

matrix — fiber.

$V_m = 1 - V_f$ والعكس

continuous and aligned fiberous composite elastic modulus.

longitudinal loading

⑥ $\frac{F_f}{F_m} = \frac{E_f V_f}{\epsilon_m V_m}$.

$F_m = 1 - F_f$ والعكس

ratio of load carried by fiber to matrix.

perpindicular to fiber alignment

⑦ iso stress $\sigma_c = \sigma_m = \sigma_f$

strain $\epsilon_c = \epsilon_m \times V_m + \epsilon_f V_f$

strain $\epsilon = \frac{\sigma}{E}$ elastic modulus.

$$\frac{\sigma}{E_{ct}} = \frac{\sigma}{E_m} \times V_m + \frac{\sigma}{E_f} \times V_f$$

E_{ct} elastic modulus in transverse direction.

transverse loading

$$\frac{1}{E_{c(t)}} = \frac{V_m}{E_m} + \frac{V_f}{E_f}$$

or

$$E_{ct} = \frac{E_m E_f}{V_m E_f + V_f E_m}$$

$V_m = 1 - V_f$ والعكس.

(8) $\sigma_{cl}^{*} = \sigma_m'(1-V_f) + \sigma_f^{*} V_f$

continuous and aligned fiber composite stress.

σ_m' stress in matrix (at fiber failure)

σ_f^{*} fiber tensile strength.

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(9) $\sigma_{cd}^{*} = \sigma_f^{*} V_f \left(1 - \frac{L_c}{2L}\right) + \sigma_m'(1-V_f)$ when $L > L_c$

discontinuous and aligned fiber composite stress

fiber-matrix bond strength, shear yield strength

$\sigma_{cd'}^{*} = \frac{L\tau_c}{d} V_f + \sigma_m'(1-V_f)$

discontinuous and aligned fiber composite stress

d fiber diameter

when $L < L_c$

(10) $E_{cd} = \underbrace{K}_{\text{efficiency parameter}} E_f V_f + \epsilon_m V_m$ < 1 (efficiency)

elastic ~~efficiency~~ ~~parameter~~ modulus.

discontinuous and aligned fiber composite.

E_f modulus of elasticity fiber

ϵ_m matrix