Volume Fraction of Composites

Dr. Arockia Julias A

Department of Mechanical Engineering

B.S. Abdur Rahman Crescent Institute of Science & Technology
Deemed to be University u/s 3 of the UGC Act, 1956

Introduction

- Composites consist of Reinforcement and Matrix phase
- Mechanical properties of these composites depends on the volume fraction of reinforcement and matrix
- The reinforcement material can be either fiber, particle or whiskers
- Fiber weight fraction can be measured practically to compute the fiber volume fraction
- The other mechanical properties can be calculated from fiber volume fraction

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Weight Fraction

- Standard methods used for measuring weight fraction are

1. Ignition loss / Burn-off test – ASTM D2854
2. Matrix digestion – ASTM D 3171

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Weight Fraction cont….

Weight of composite , $w_c = w_f + w_m$

Weight of matrix, $w_m = w_c - w_f$

For unit weight of composite, $1 = w_f + w_m$

Where,

w_c - Weight of Composite

w_f – Weight of Fiber / Reinforcement

w_m - Weight of Matrix

Void content is assumed to be negligible

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Fiber Volume Fraction

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$$v_f = \frac{w_f/\rho_f}{(w_f/\rho_f) + (w_m/\rho_m)},$$

Where,

V_f – Volume fraction of Fiber / Reinforcement

V_m – Volume fraction of Matrix

ρ_f – Density of Fiber / Reinforcement

ρ_m – Density of matrix

V_c – Volume fraction of Composite

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Fiber Volume Fraction cont…

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Volume of composite , $v_c = v_f + v_m$

For unit volume of composite, $1 = v_f + v_m$

Volume fraction of matrix, $v_m = 1 - v_f$

Density of composite, $\rho_c = \rho_f v_f + \rho_m v_m$

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Void Fraction

Void content in a composite can be estimated by comparing the theoretical density with actual density of the composites manufactured.

Void fraction of composite, $$Vv = \frac{\rho ct - \rho ca}{\rho ct}$$

Where,

v_v – Volume fraction of void

ρ_{ct} – Theoretical density of composite

ρ_{ca} – Actual density of composite

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Tutorial 1

The following data is obtained from the burn-out test conducted in a glass-epoxy composite. Weight of empty crucible is 46.5 g. Weight of crucible and composite is 66.3 g. Weight of crucible and glass fiber is 58.6 g. Find the volume fraction of fiber and actual density of composite. Take density of glass fiber as 2.49 g/cm^3 and that of matrix as 1.1 g/cm^3.

Solution:

Weight of composite, $W_c = 66.3 - 46.5 = 19.8$ g

Weight of fiber, $W_f = 58.6 - 46.5 = 12.1$ g

Weight of matrix, $W_m = 19.8 - 12.1 = 07.1$ g

Volume fraction of fiber, $V_f = \dfrac{12.1/2.49}{12.1/2.49 + 7.7/1.1} = 0.41$

Volume fraction of matrix, $V_m = 1 - 0.41 = 0.59$

Density of composite $\rho_c = 2.49 \times 0.41 + 1.1 \times 0.59 = 1.67$ g/cm^3

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Tutorial 2

Find the fiber volume fraction and density of a composite with 45 weight percentage of fiber. Assume density of fiber as 2.4 g/cm^3 and that of matrix as 1.1 g/cm^3.

Solution:

Assume a composite sample of unit mass (1g) and compute the volume,

Weight of fiber, $W_f = 0.45$ g

Weight of matrix, $W_m = 1 - 0.45 = 0.55$ g

Volume fraction of fiber, $V_f = \frac{0.45/2.4}{0.45/2.4 + 0.55/1.1} = 0.27$ or 27%

Volume fraction of matrix, $V_m = 1 - 0.27 = 0.73$ or 73 %

Density of composite $\rho_c = 2.4 \times 0.27 + 1.1 \times 0.73 = 1.45$ g/cm^3

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Thank you

Reference: Fiber Reinforced Composites by P K Mallick