Department Of Aerospace Engineering

Aerospace Structural Mechanics
Group C Experimental Verification of Rule Of Mixtures

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1 Aim

The objective of this experiment is:

1. Validate the **Rule of Mixtures** for a composite laminate in **Longitudinal Direction** (E_1).

2 Apparatus

- Compression Moulding Machine to cure the laminate.
- Composite stacking station to make the laminate.
- UTM Machine for Sample Testing.
- Cutter: To cut out testing samples from laminate.

Figure 1: Compression Moulding Machine

Figure 2: Cutter Used to Cut Samples

3 Procedure

- Prepare the **matrix** by mixing **epoxy** with a hardener (reaction catalyst).
- Stack the fiber laminates, ensuring thorough impregnation with the matrix.
- Place the laminate in a compression moulding machine and cure for 24 hours.
- After curing, mark dimensions and cut samples using the cutter for burnout and UTM tests.
- Prepare 2–3 samples per v_f value to ensure experimental accuracy.
- Test samples on the UTM to obtain maximum stress and calculate **stiffness modulus** (E_x) from the slope of the stress-strain curve.

- Average the modulus values for each v_f.
- Plot E vs v_f, which should ideally be a linear relationship.

Figure 3: Prepared Samples

Figure 4: Cut Samples for Testing

4 Results

4.1 From burnout test

From using two specimens(50 mm X 50 mm X 1.7mm) for finding out volume fraction .

S.No	Weight(g) (before test)	Weight(g) (after test)	Volume fraction
1	7.735	4.448	0.575
2	7.044	4.284	0.608

Table 1: Burnout Test Results

Average Volume fraction comes out to be **0.592**

4.2 Pure matrix Modulus

Table 2: Specimen-1 Pure Matrix Dogbone specimen

S.No	**Tensile Stress at Max Load**	**Young's Modulus (MPa)**	**Length(mm)**	**T**	**W**
1	50.62	1553.09	40	3.7	5.08
2	42.75	1615.95	40	3.65	5.12

Gauge length was 40 mm for dogbone, T-Thickness, W-Width
Average Young's modulus of Pure matrix specimen Is **1584.52 MPa**

4.3 Modulus for Laminate

On testing in UTM , we get the following results for the laminate prepared by of Volume fraction 0.592. Gauge length in UTM was 100 mm, with width of 25 mm

S.no	Breaking Stress(MPa)	Young's Modulus(MPa)	Width(mm)	Thickness(mm)
1	585.14	7880.71	25	1.75
2	516.11	7207.16	25	1.68

Table 3: Experimental Results

Average Young's modulus comes out to be **7543.93 Mpa**

4.4 Pure fiber

The young's modulus of Pure glass fiber comes out to be **63423 MPa** from Group F data.

4.5 Comparison of Theoretical and Experimental Modulus Using Rule of Mixtures

The Rule of Mixtures (ROM) provides an estimate for the longitudinal modulus E_1 of a unidirectional composite as:

$$E_1 = V_f E_f + (1 - V_f) E_m \tag{1}$$

where:

- E_1: Longitudinal modulus of the composite
- V_f: Volume fraction of the fiber
- E_f: Modulus of the fiber
- E_m: Modulus of the matrix

Given:

- Average $V_f = 0.592$
- $E_m = 1584.52$ MPa (Average from pure matrix samples)
- $E_f = 63423$ MPa (Taken from another group's data)

Theoretical Modulus:

$$E_1 = (0.592)(63423) + (1 - 0.592)(1584.52) == \textbf{38192 MPa}$$

Experimental Modulus:
From UTM testing on composite laminate samples, the average modulus was found to be:

$$\mathbf{E}_{\text{exp}} = 7543.93 \text{ MPa}$$

Comparison:

Modulus Type	Value (MPa)
Theoretical (ROM)	38192 MPa
Experimental (UTM)	7543.93 Mpa

Table 4: Comparison of Theoretical and Experimental Moduli

The deviation between theoretical and experimental values may arise due to factors such as imperfect bonding, voids, misalignment of fibers, or inaccuracies in volume fraction measurement.

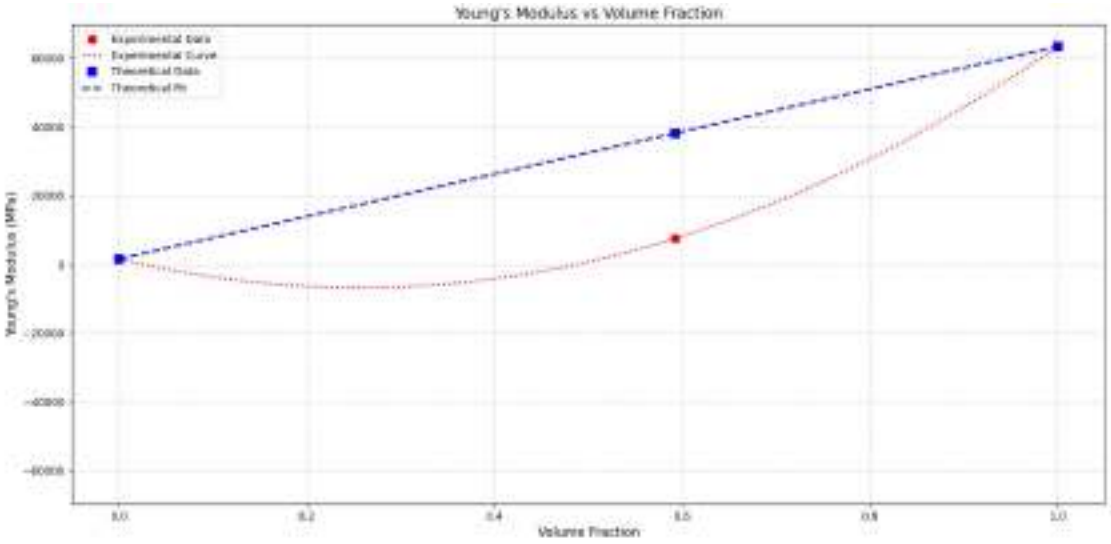

Figure 5: Young's modulus vs Volume fraction

4.6 Conclusion

- Rule of Mixtures was verified experimentally.
- A high amount of error is observed with possible reasons being:
  - Man Made Fabrication
  - Improper Alignment of Fibers in longitudinal direction.