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DESIGN OF FIBER PREFORMS FOR WORLD'S LARGEST FIBERGLASS COMPANY

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Introduction

How to design the most suitable fiber bundle direction angle and areal weight according to different application requirements has become a technical problem that the fiber fabric production enterprises have to face, and also an important weight to measure the core competitiveness of enterprises. China Jushi Co., Ltd has become the largest fiberglass manufacturer in the world, but they mainly rely on experience to determine the structural parameters of fiber fabric, which is not only time-consuming, but also difficult to achieve the optimal.

Bridging Model

The Bridging matrix $[A_{ij}]$ describe the relation between homogenized stress of the composite material, the matrix and the fiber.

$$d\sigma_i = \frac{1}{V'}\int_{V'} d\tilde{\sigma}_i dV = V_f d\sigma_i^f + V_m d\sigma_i^m \quad \{d\sigma_i^m\} = [A_{ij}]\{d\sigma_j^f\} \quad [A_{ij}] = \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ 0 & a_{22} & a_{23} \\ 0 & 0 & a_{33} \end{bmatrix}$$

SCFs of matrix

In order to analyze the failure and strength behavior of a composite based on properties of component materials, the homogenized stresses in the matrix must be converted into true values in terms of the stress concentration factors (SCFs) of the matrix.

$$d\overline{\sigma}^m = \{K_{11}d\sigma_{11}^m, K_{22}d\sigma_{22}^m, K_{12}d\sigma_{12}^m\}^T$$

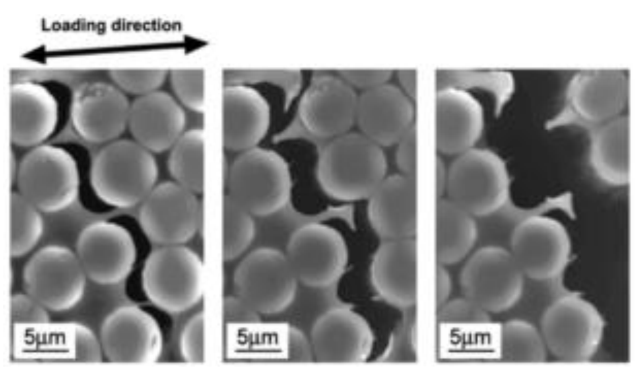

Fig 1. Interface cracks under transverse tension

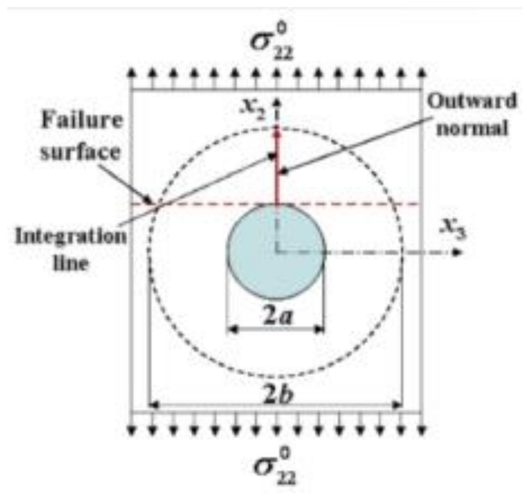

Fig 2. Sketch for calculating SCF before interface debonding

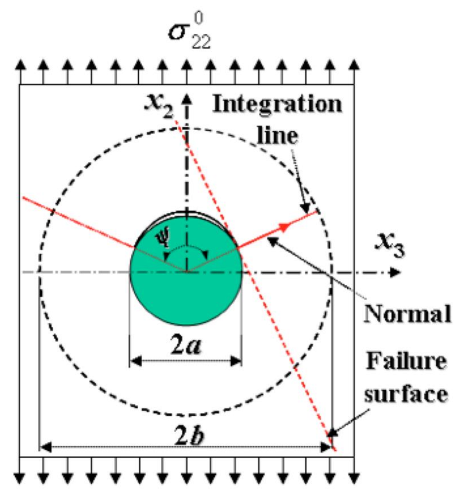

Fig 3. Sketch for calculating SCF after interface debonding

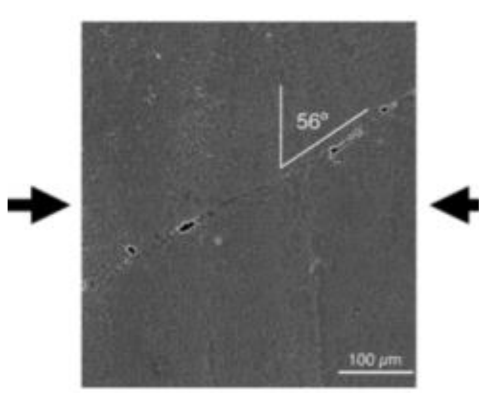

Fig 4. Fracture surface Under transverse compression

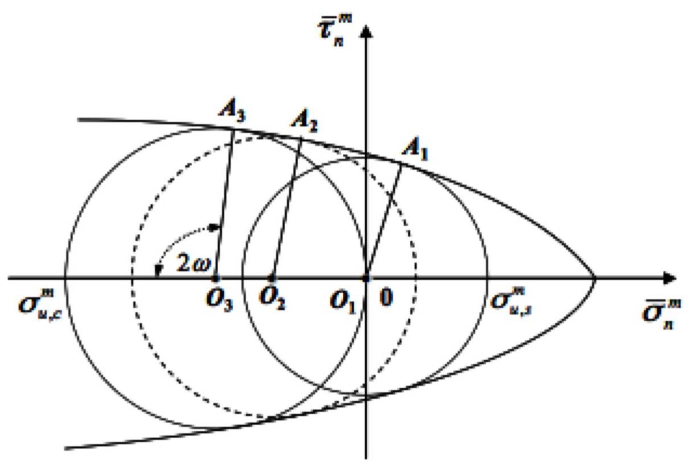

Fig 5. Fracture surface angle can be obtained based on Mohr's theory

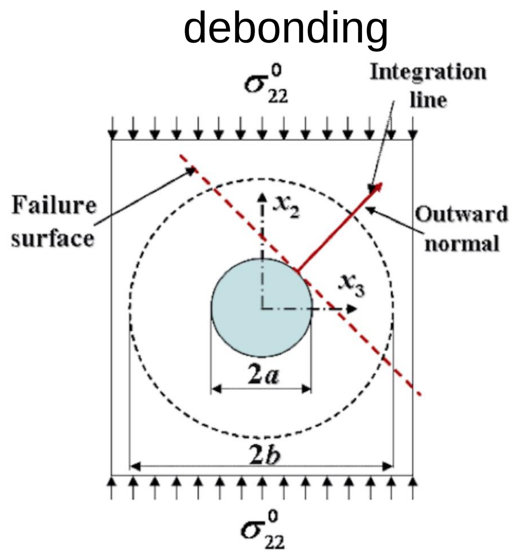

Fig 6. Sketch for calculating SCF Under transverse compression

Failure criterion

- Interface crack criterion

$$\overline{\sigma}_e^m \geq \hat{\sigma}^m \text{ and } \overline{\sigma}_1^m > 0$$

- Matrix failure criterion

$$F_1[(\overline{\sigma}_{11}^m)(\overline{\sigma}_{11}^m) + (\overline{\sigma}_{22}^m)(\overline{\sigma}_{22}^m) - (\overline{\sigma}_{11}^m)(\overline{\sigma}_{22}^m)] + F_2(\overline{\sigma}_{12}^m)(\overline{\sigma}_{12}^m) + F_3[(\overline{\sigma}_{11}^m) + (\overline{\sigma}_{22}^m)] \geq 1$$

$$F_1 = 1/(\sigma_{u,t}^m \sigma_{u,c}^m), F_2 = 1/(\sigma_{u,s}^m)^2, F_3 = 1/\sigma_{u,t}^m - 1/\sigma_{u,c}^m$$

- Fiber failure criterion

$$\sigma_1^f \geq \sigma_{u,t}^f, \sigma_3^f \leq -\sigma_{u,c}^f$$

- Matrix Degradation

$$E^m = 0.01E_0^m$$

- Ultimate Failure

  if either of the three conditions is fulfilled:

  (a) There is a fiber fail

  (b) There is a matrix failure and a laminate strain in absolute value greater than the critical value

  (c) The matrix in all of the layer fail and stress of one layer fulfills normal Tsai-Wu criterion.

Results

	X(MPa)	X'(MPa)	Y(MPa)	Y'(MPa)
Experiment	1370	914	46.4	169
Prediction(True Stress)	1287.8	1018	49.2	181.4
Error	-6%	11.40%	6%	7.30%
Prediction(Homogenized stress)	1287.8	1018	155.4	426.5*
Error	-6%	11.40%	234.90%	152.30%

Table 1. Uniaxial strengths of E-7 UD1560 laminate

	0° Tension		0° Compression		90° Tension		90° Compression		In-plane Shear	
	Modulus	Strength	Modulus	Strength	Modulus	Strength	Modulus	Strength	Modulus	Strength
	(GPa)	(MPa)	(GPa)	(MPa)	(GPa)	(MPa)	(GPa)	(MPa)	(GPa)	(MPa)
Experiment	33.6	800	35.5	660	14.3	126	14.7	207	7.94	216
Prediction (True Stress)	34.3	712.7	34.2	574.2	16.4	114.8	16.4	225.5	8.45	194.8
Error	1.80%	-11.40%	-3.70%	-13.20%	14%	-8.90%	10.90%	8.90%	6%	-9.80%
Prediction(Homogenized Stress)		783.7		682		184.6		432.8		304.1
		-2%		3.30%		46.50%		109%		40.70%

Table 2. Modulus and strengths of E-7 TLX1215 $[0^o/\pm45^o]_s$ laminate