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NASA TECH BRIEF

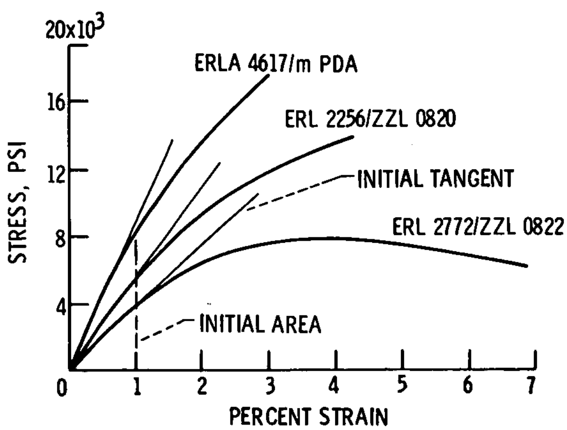
Lewis Research Center

Criteria for Selecting Resin Matrices for Improved Composite Strength

The Problem:

There are a large number of resins currently available for use as matrices in fiber reinforced plastic composites. These matrices have properties differing in modulus, toughness, elongation, strength, and strength retention at elevated temperatures. In addition, the mechanical properties of any one matrix can be substantially altered by suitable additives. The researcher and/or designer is confronted with the problem of selecting the best matrix from the large number of available matrices which will provide composites with improved mechanical properties for a specific application. The main difficulty in selecting a matrix resin is that matrix mechanical properties do not transfer to composite mechanical properties in a parallel correspondent manner.

In recent years, considerable effort has been directed toward correlating matrix properties with composite strength. These efforts have concentrated on correlating composite strength with matrix ultimate strength, ultimate elongation, fracture toughness and other final matrix properties. Taken individually or jointly, no criterion has emerged from the aforementioned efforts which can be used to assess the matrix contribution to composite strength.



The Solution:

Considering a typical stress-strain diagram for various matrix resins (see figure), the area under the matrix stress-strain diagram bounded by the one percent strain is a good index for a priority assessment of the matrix contribution to composite strength. The initial tangent modulus to the stress-strain curve (see figure) is a useful parameter in translating matrix properties to composite properties. In general, the greater the value of these parameters, the greater the matrix contribution to composite strength and composite mechanical properties.

How It's Done:

Micromechanics are used in conjunction with experimental data generated at the Lewis Center, and also taken from the literature, to identify those matrix properties which influence composite unidirectional strength. Unidirectional specimens were made from graphite fibers and low-modulus, intermediate-modulus, and high-modulus resins. These specimens were tested for strength in longitudinal flexure, transverse tension, and compression, and interlaminar shear. The corresponding literature composite strength data included longitudinal tension and compression, transverse tension, and interlaminar shear. Comparisons of composite strength data (see table) with the various matrix properties led to the identification of convenient and practical criteria which can be used to assess the matrix contribution to composite strength.

Notes:

1. The criterion should be useful to fiber/resin-matrix composite designers, fabricators and researchers for the aerospace, marine, automotive, building, appliances, and sporting goods industries.
2. The criteria can be used to guide polymer researchers to develop new resins.
3. Further information is available in the following report:

   NASA TM-X-68166 (N73-15597), Criteria for Selecting Resin Matrices for Improved Composite Strength

(continued overleaf)

Property	Units	Resin		
		ERLA 2772[a]	ERLA 2256[b]	ERLA 4617[c]
Matrix				
Initial modulus	10^6 psi	0.4	0.56	0.82
Proportional limit stress	10^3 psi	3.3	4.5	7.3
Proportional limit strain	percent	0.75	0.8	1.0
Ultimate strength	10^3 psi	7.8	14.0	17.6
Ultimate elongation	percent	6.9	4.3	3.0
Toughness = $\int_0^{\varepsilon_{ult}} \sigma \, d\varepsilon$	10^3 in.-lb/in.^{2}	0.417	0.368	0.310
Impact-strength	in.-lb	10.5	3.07	2.15
Proportional limit stress times proportional limit strain	in.-lb/in.^{3}	24.8	36.0	73.0
Initial modulus times impact strength	10^6 lb^2/in.	4.2	1.72	1.76
Composites (50 percent fiber volume)				
Composite longitudinal flexure strength ($S_{\ell 11F}$)	10^3 psi	122.[d]	150.[e]	205.[e]
Composite transverse tensile strength ($S_{\ell 22T}$)	10^3 psi	6.1	6.3	6.0
Composite transverse compressive strength ($S_{\ell 22C}$)	10^3 psi	---	25.6	25.8
Composite interlaminar shear strength ($S_{\ell 12S}$)	10^3 psi	7.8	11.5	15.0

a - Hardener ZZL 0822 (20.0 phr)
b - Hardener ZZL 0820 (27.0 phr)
c - Hardener MPDA/BF_3MEA (27.0/1.5 phr)
d - Compression failure
e - Tensile failure

Copies may be obtained at cost from:
Aerospace Research Applications Center
Indiana University
400 East Seventh Street
Bloomington, Indiana 47401
Telephone: 812-337-7833
Reference: B74-10005

4. Specific technical questions may be directed to:
Technology Utilization Officer
Lewis Research Center
21000 Brookpark Road
Cleveland, Ohio 44135
Reference: B74-10005

Patent Status:

NASA has decided not to apply for a patent.

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(LEW-12057)