STATIC AND FATIGUE PERFORMANCE OF WIND TURBINE BLADE EPOXY ADHESIVES

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ABSTRACT

In this research work, short-glass fiber modified and core-shell rubber particle modified epoxy adhesives used in the wind turbine rotor blade assembly are considered for developing four different hybrid adhesives. The adhesives are fabricated by two different methods, an automated machine mixing method (M1) at the facilities of Gurit (UK) Ltd and a manual mixing (M2) at CCLab/EPFL. The manufacturing and hybrid effects on the material properties were determined by dynamic mechanical analysis, quasi-static tensile, V-notch shear and single-edge-notch bending tests. The adhesive toughening due to hybridization increases the strain to failure and the tensile toughness, decreases the strength and modulus and has no significant effect on the glass transition temperature. Additionally, tensile-tensile fatigue experiments are conducted to investigate the influence of geometry (ASTM D638-22 Type I and Type II) and hybridization on the fatigue life. The S-N curve slope is similar for all the tested adhesives whereas Type I specimens show a steeper slope of 7.32% to 15.56% than Type II specimens.

The material composition of different adhesive materials manufactured by M1 and M2 methods are shown in Figure 1 and their material properties are summarized in Table 1. No significant effect of the manufacturing method on the adhesive strength and modulus is observed. The toughening strategies can be used to tailor the modulus, strength and plane strain fracture toughness values depending on the loading requirements.

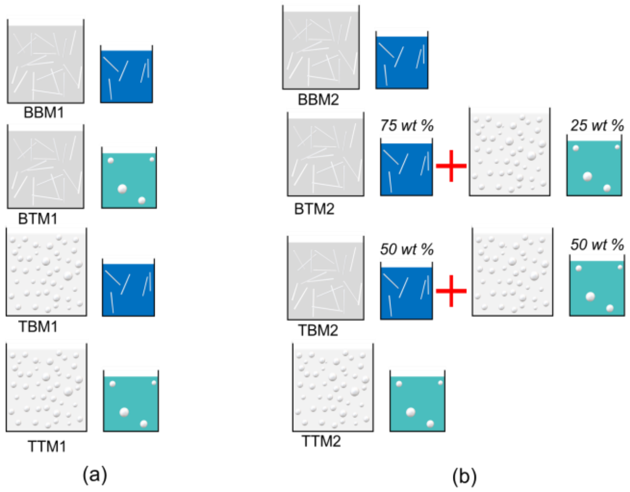

Figure 1: Composition of pristine and hybrid adhesive materials (a) machine mixing, M1 and (b) manual mixing, M2.

The S-N curves of the different adhesive systems are compared in Figure 2. The adhesive having higher quasi-static tensile strength exhibits better fatigue performance, confirming the strength-life equal rank assumption (SLERA). The slope of the S-N curves for the Type II specimens is constantly lower than that of the Type I specimens.

Table 1: Adhesive material properties [1, 2].

Specimen	Glass transition temperature T_g (℃)	Tensile modulus (E) GPa	Tensile strength (σ_u) MPa	Shear modulus (G) GPa	Shear strength (τ_u) MPa	Fracture toughness (K_{IC}) MPa√m
BBM1	73.4±0.5	5.1±0.08	60.16±2.65	2.12±0.19	51.02±1.79	1.84 ± 0.17
BTM1	75.4±1.8	4.57±0.22	61.17±2.18	1.13±0.03	51.50±1.14	2.12 ± 0.18
TBM1	74.5±1.6	3.43±0.07	52.56±0.64	0.80±0.04	41.19±0.20	2.17 ± 0.05
TTM1	71.4±0.7	2.98±0.14	45.36±0.15	0.73±0.06	36.91±1.11	1.63 ± 0.05
BBM2	72.6±0.8	5.59±0.39	69.01±0.51	1.90±0.50	51.65±1.70	2.64 ± 0.12
BTM2	76.9±0.4	4.95±0.32	65.01±2.23	1.63±0.06	46.54±0.34	2.39 ± 0.17
TBM2	76.1±2.9	4.02±0.06	55.98±0.87	1.57±0.05	43.03±0.29	2.43 ± 0.27
TTM2	72.8±1.7	2.81±0.16	44.47±1.26	0.91±0.09	38.10±1.31	2.01±0.04

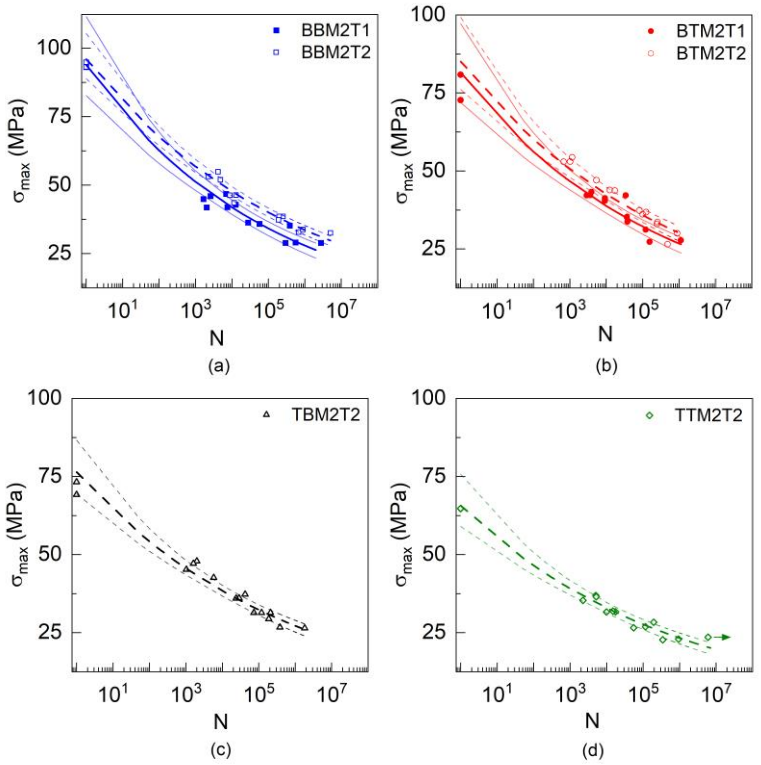

Figure 2: S-N curves of structural epoxy adhesives: (a) Type I- BBM2T1 & Type II- BBM2T2, (b) Type-I, BTM2T1 & Type II- BBM2T2, (c) Type II- TBM2T2 and (d) Type II- TTM2T2.

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