Thermoplastic adhesives in CFRP joints: An assessment of performance

RJC Carbas (INEGI, Portugal) | FCC Ribeiro | EAS Marques | LFM da Silva

INTRODUCTION

This study investigates the potential of film-based thermoplastic adhesives to significantly improve the performance of CFRP joints, offering an alternative to the thermoset adhesives. Specifically, this study focuses on understanding and highlighting the inherent advantages of thermoplastic film adhesives in avoiding delamination risks. Unlike thermoset adhesives, thermoplastics offer the potential for re-processing, which can lead to enhanced resistance to crack initiation and propagation – the primary drivers of delamination. This study aims to underscore the potential of thermoplastic film adhesives to provide superior damage tolerance in bonded CFRP structures compared to traditional thermoset systems. The insights gained from this research will pave the way for future studies exploring the application of these thermoplastic adhesives in more complex industrial joint designs.

EXPERIMENTAL DETAILS

Three different adhesives were compared. Table 1 shows the main characteristics and the Table 2 the mechanical properties of the adhesives used.

TABLE 1. Adhesives used in this analysis.

	Zeon LS-XU	AF 163-2k	Nagase Denatite XNR 6852 E3
Cure conditions	150ºC, 1 hour	150ºC, 1 hour	150ºC, 3 hour
Family	Hot-melt thermoplastic	Thermosetting modified epoxy	One-component epoxy
Form	Film	Film	Paste
T_g (ºC)	85	108	100

TABLE 2. Mechanical properties of adhesives.

	Zeon LS-XU	AF 163-2k	Nagase Denatite XNR 6852 E3
Young's modulus (MPa)	230.2	1520	1728
Shear modulus (MPa)	76.7	565	665
Tensile strength (MPa)	5.5	46.9	51.5
Shear strength (MPa)	5.1	46.8	44.9
Mode I fracture toughness (N/mm)	0.4	4.1	9.2
Mode II fracture toughness (N/mm)	--	9.7	51

The composite material used was a unidirectional prepreg CFRP (carbon-fiber reinforced plastic), specifically the Texipreg HS 160 T700, featuring a ply thickness of 0.15 mm.

The geometry of the single lap joint is illustrated in Figure 1.

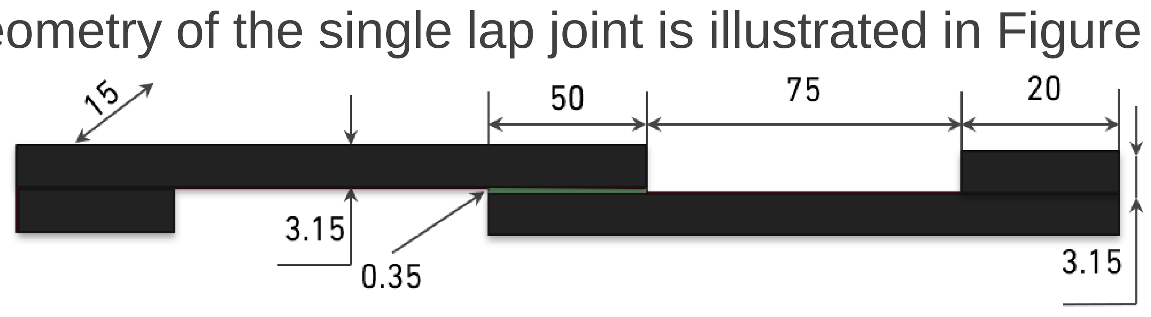

FIGURE 1. SLJ specimen geometry.

For the quasi-static tests, were evaluated using an Instron 3360 universal testing machine and conducted at a constant displacement rate of 1 mm/min.
Impact testing was performed on a custom-built drop-weight machine, a 10 kg mass was dropped at 3 m/s.

RESULTS

The joints were manufactured and subjected to quasi-static (1 mm/min) and impact (3 m/s) test conditions, as well as different test temperatures (-30, 23 and 80 °C). Figure 2 shows the typical load-displacement curves for the different conditions tested.

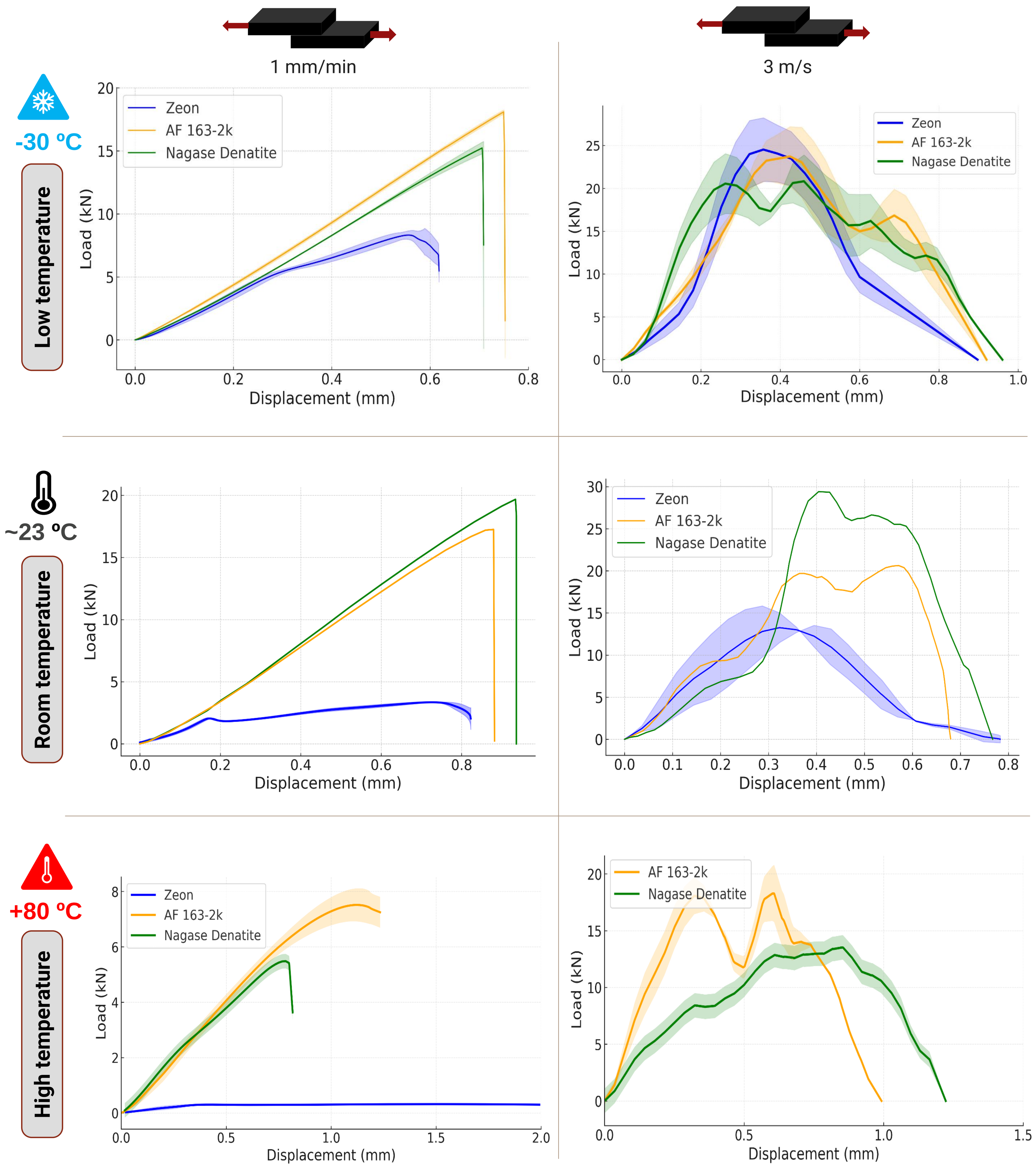

FIGURE 2. Load - displacement curves obtained experimentally and numerical for both configurations and adhesives.

CONCLUSION

- Performance of the LS-XU improved under impact, showing a very high strain-rate sensitivity;
- The LS-XU is excellent at low temperatures, acceptable at RT but totally unsuitable at 80 °C due to low T_g (85 °C);
- Energy absorption increased in both CFRP and wood joints, especially under dynamic loading;
- Overall, this adhesive is lightweight, recyclable and can be a viable repairable bonding strategy.

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