Mechanical Response of Dissimilar Composite-to-Steel Adhesive Joints for Automotive Floor Structures under Multi-Rate Loading Conditions

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INTRODUCTION

The integration of dissimilar materials in automotive floor structures is a key enabler for lightweight vehicle design while ensuring sufficient crashworthiness. Adhesive bonding provides an effective solution for joining metal and composite substrates [1]; however, the rate-dependent mechanical behavior of such joints under severe service and crash-related loading conditions remains insufficiently characterized. This study investigates the mechanical response of single lap joints consisting of high-strength steel, composite materials, and their hybrid configurations bonded with a structural epoxy adhesive.

METHODS

Single-lap joint (SLJ) specimens were fabricated using glass fiber-reinforced thermoplastics (GFRTP, Asahi Kasei, Japan) and high-strength steel in both similar (GFRTP-GFRTP) and dissimilar (GFRTP-steel) configurations, bonded with an epoxy-based thermoplastic film adhesive. Mechanical tests were conducted at −30 °C and 23 °C, and lap shear loading was applied at rates of 1 and 180 000 mm/min using an Instron universal testing machine and an in-house impact testing system. The combined effects of substrate pairing, strain rate, and temperature on lap shear strength (LSS) and failure behavior were evaluated.

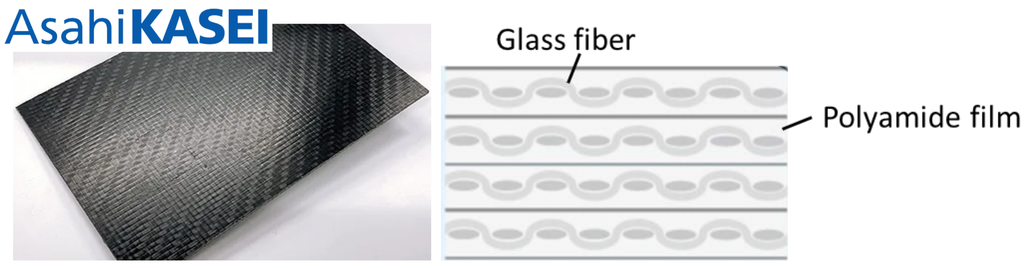

Figure 1 – Appearance and lamination of GFRTP (Asahi Kasei, Japan).

	GFRTP	Steel
Density [g/cm3]	**1.9**	7.8
Tensile strength [MPa]	**530**	490
Flexural modulus [GPa]	27	200
Energy absorption [kJ/kg]	**41.2**	9.1

Table 1 – Comparison of properties between GFRTP and steel.

RESULTS

- Dissimilar joints behave better under quasi-static at −30 °C
- Composite similar joints behave better under impact at 23 °C
- Predominantly interfacial mixed failure mode was consistently observed under all conditions, hence joint strength was stable over a wide temperature range
- Due to less stiffness of composite, similar composite joints experienced higher peel stress (72% of its original thickness) at the adhesive edges

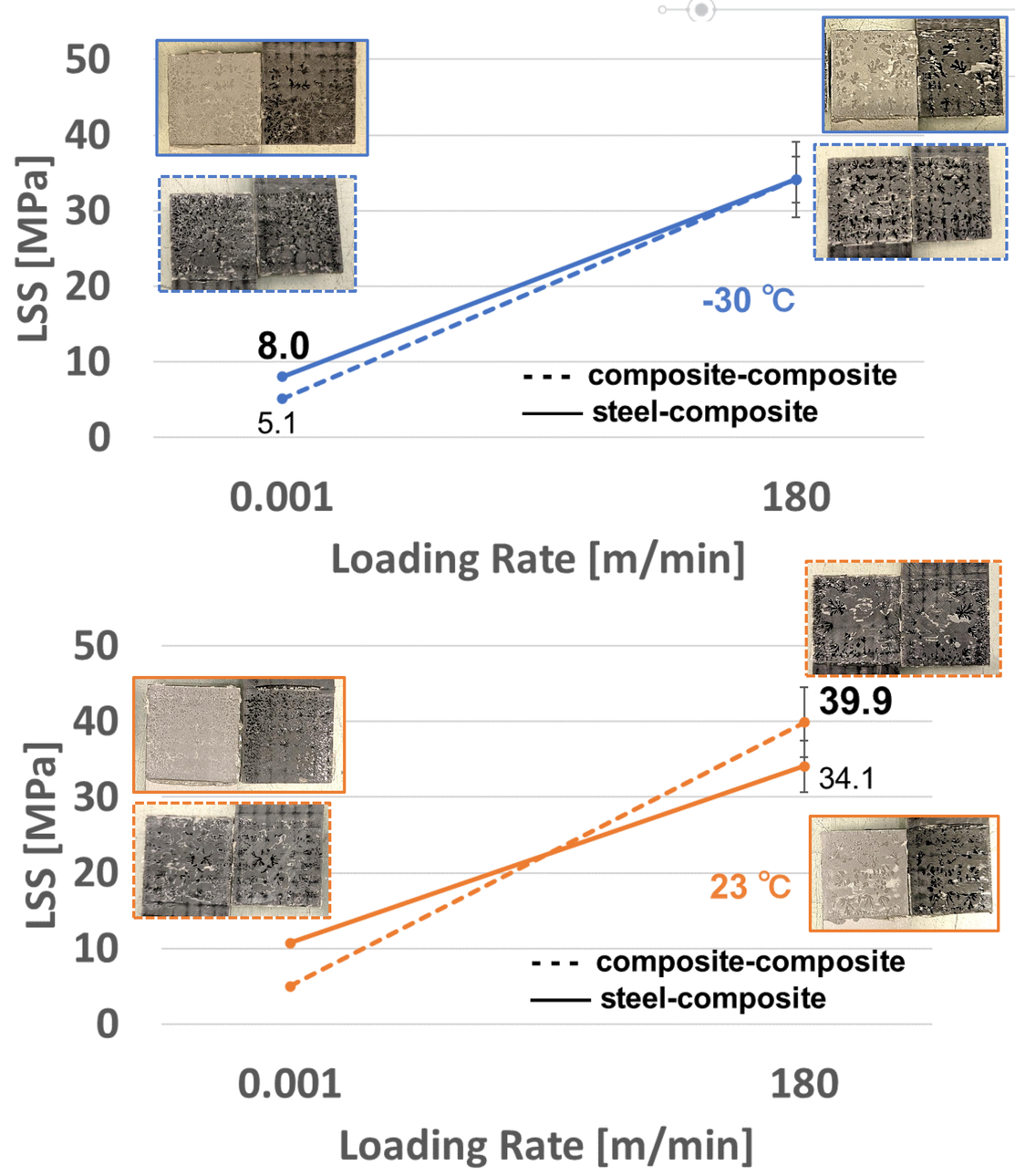

Figure 2 – Summary of lap shear strength and fracture surface at each temperature.

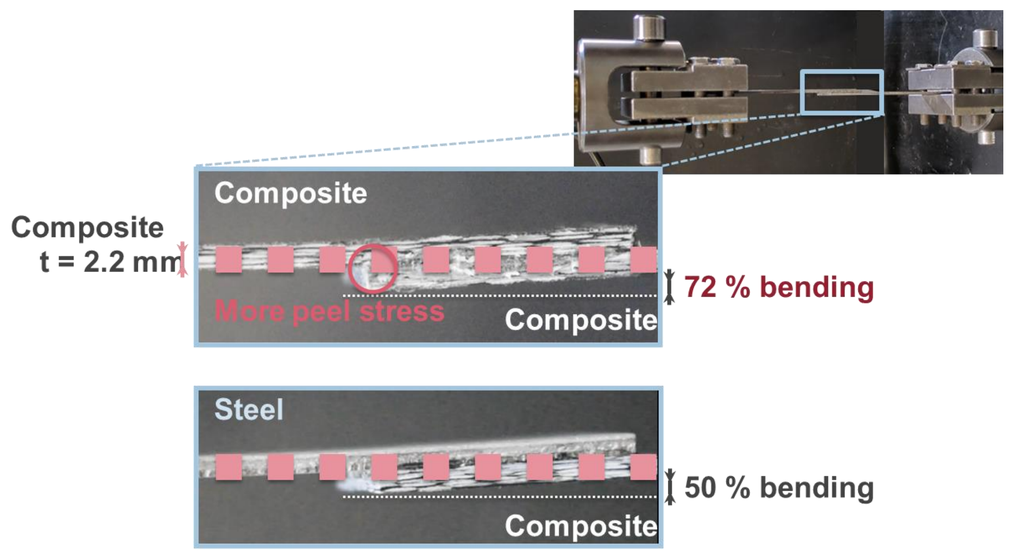

Figure 3 – Substrate bending observation under static conditions.

CONCLUSIONS

- Dissimilar joints had about twice higher load under quasi-static conditions than similar joints
- Composite similar joints had better performance under impact at room temperature

REFERENCES

[1] J. Bidadi, H.S. Googarchin, A. Akhavan-Safar, R.J.C. Carbas, L.F.M. da Silva, Applied Sciences, 13.23, 12879 (2023).