Effects of surface treatment on the curing quality of adhesively bonded metal and polymer joints

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1. Introduction

The mechanical performance of adhesive joints depends on the degree of cure and the surface treatment of the substrates. This study explores how anodizing, laser texturing, and plasma treatment influence the curing kinetics and strength of epoxy adhesive joints on aluminum and polypropylene. Results show that surface modifications affect not only adhesion but also the thermal behavior and curing degree of the adhesive, ultimately impacting joint performance.

2. Methodology

Adhesive system used in this study was a two-component epoxy formulation with a 2:1 mixing ratio. The Kamal model [1] was used to predict the degree of cure based on the adhesive temperature.

Figure 1. Surface treatment approaches

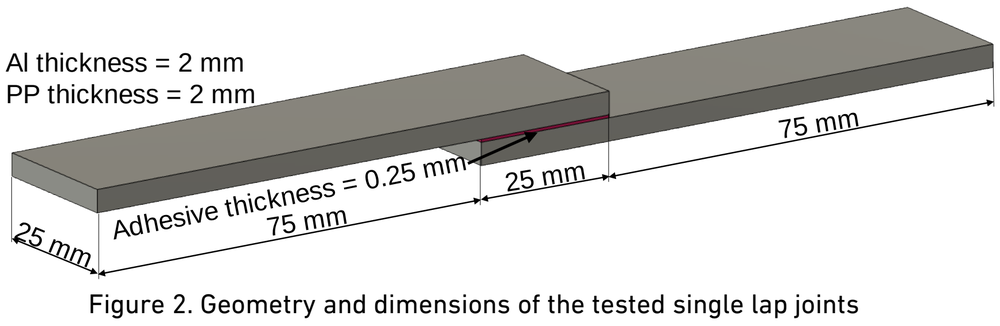


Figure 2. Geometry and dimensions of the tested single lap joints

Curing Condition	Time at RT [min]	Time at 90°C [min]
Curing Condition A	240	40
Curing Condition B	240	70
Full Curing	240	100 + slow cooling

3. Results

The table summarizes the curing degree and maximum temperature achieved for each surface treatment and curing condition.

Curing degree and maximum temperature reached for each surface treatment and curing condition, as predicted by the Kamal model based on adhesive temperature.

Condition	Curing Degree [%]	Max Temperature [°C]
Anodized Al (A)	59.6	72.1
Anodized Al (B)	89.8	88.7
Laser Al (A)	75.5	80.3
Laser Al (B)	94.3	89.1
PP (A)	81.2	83.5
PP (B)	95.8	90.2

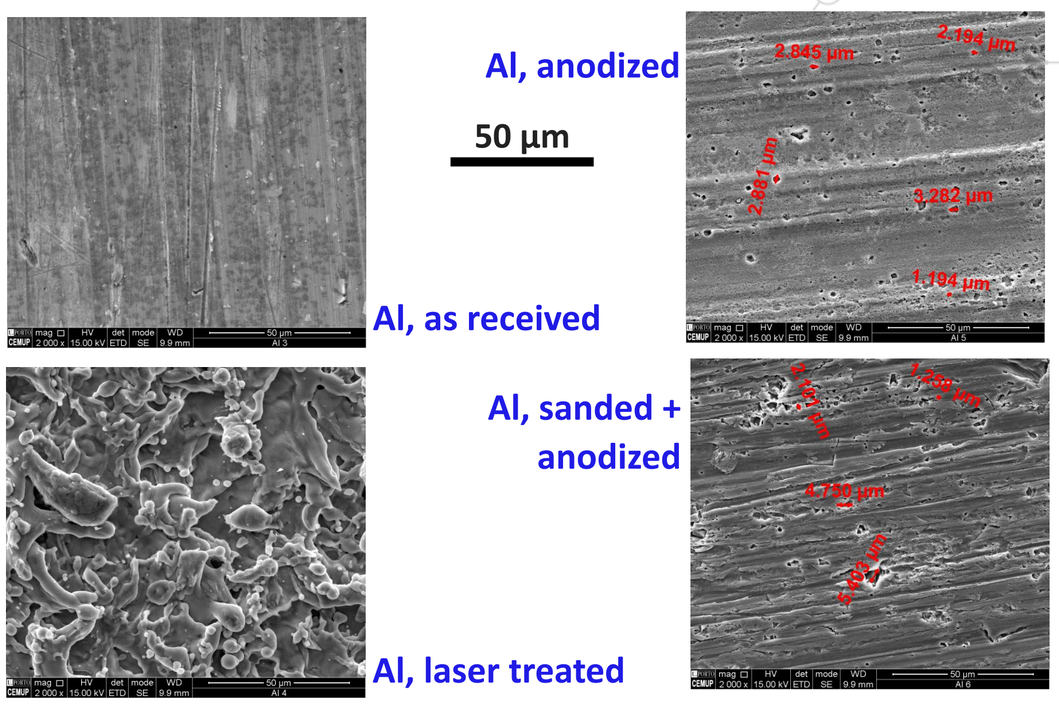
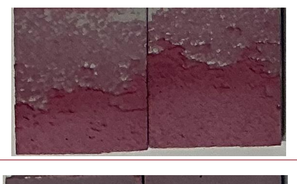
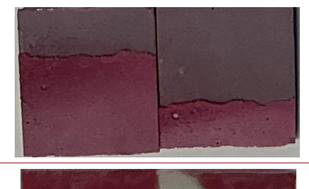
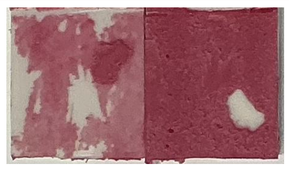


Figure 3. SEM images of Al surfaces under different treatment conditions

SLJ failure modes depend on curing degree and surface treatment. At low curing, adhesive or mixed failures occur; at high curing, cohesive failure dominates, especially for aluminum. For plasma-treated polypropylene, adhesive failure prevails regardless of curing.

Fracture surface images for different substrates, surface treatments, and curing conditions.

	Condition A	Condition B	Fully cured
Anodized Al			
Laser treated Al			
Plasma treated PP			

4. Conclusion

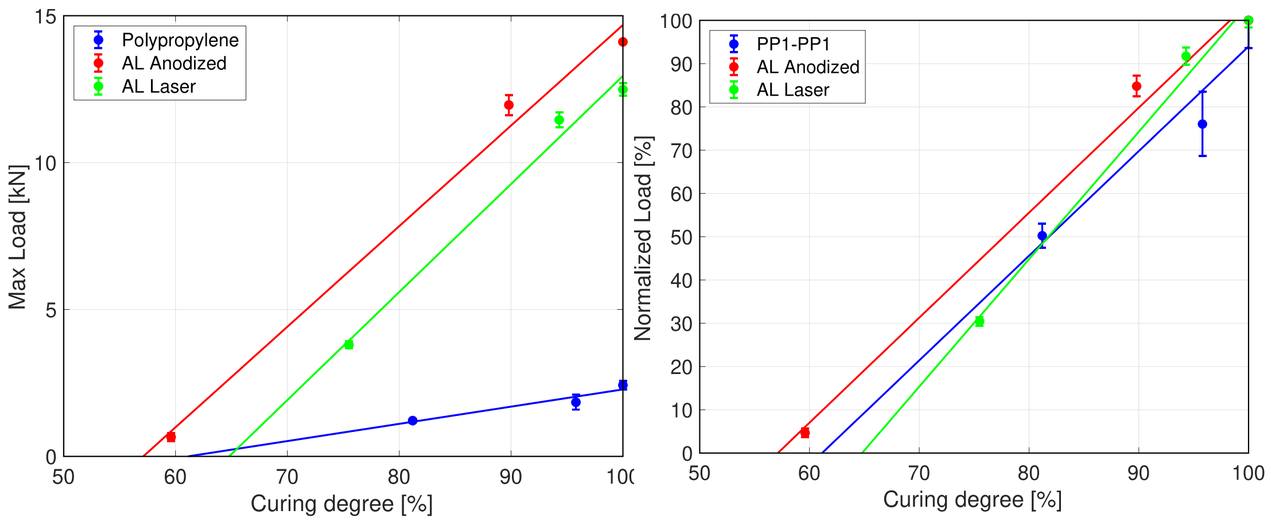


Figure 4. Relationship between curing degree and maximum load for different substrates and surface treatments.

Reference

[1]Kamal, M.R.: Thermoset characterization for moldability analysis. Polymer Engineering & Science 14(3), 231–239 (1974) https://doi.org/10.1002/pen.760140312

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