Experimental study of the performance of low-bake structural adhesives exposed to moisture and surface contamination

JFM Lopes | VCMB Rodrigues | EAS Marques (INEGI, Portugal) | RJC Carbas | LFM da Silva

1. Introduction

Body in white (BIW) manufacturing increasingly uses one component (1k) structural epoxy adhesives which are typically cured during the E-coat baking stage (Figure 1) [1]. As OEMs push toward lower the baking temperatures of around 180°C to reduce energy consumption, adhesives must still achieve adequate cure and joint strength within a reduced thermal window [2]. In addition, BIW bonding is often performed on sheet metals that retain stamping oils, making oil tolerance critical. This on-going work aims to present preliminary discussion regarding the use of a low-bake 1K epoxy adhesive cured at two temperatures, standard bake and low bake.

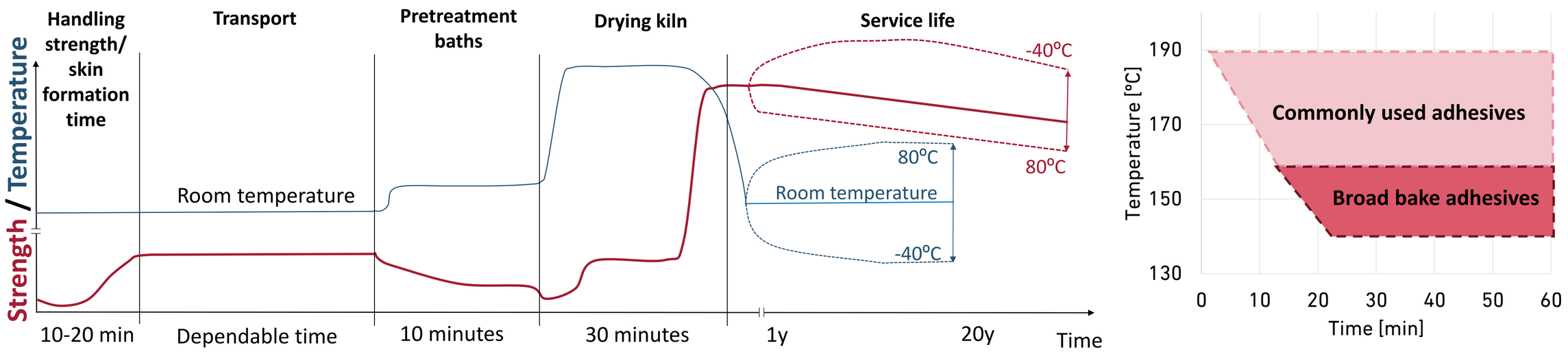

Figure 1. a) strength evolution of 1k epoxy adhesives in the BIW along the production line and life span of the body frame; b) Baking window trend of low curing 1k epoxy systems

2. Baking conditions

One component epoxy system with the two baking conditions represented in figure 2: standard baking (SB) and low baking (LB).

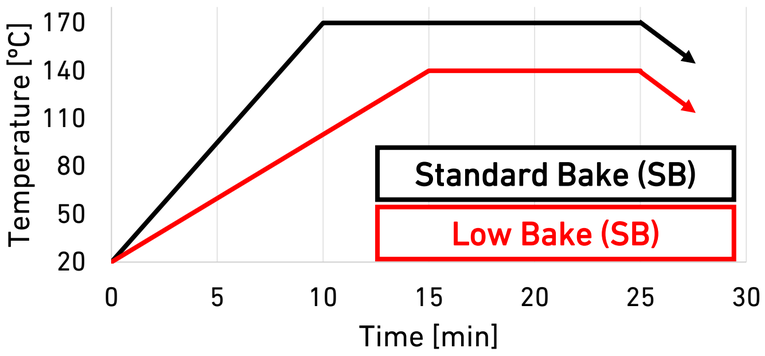

Figure 2. Baking curves for the Sb and LB conditions

3. Testing methods

Single lap joints (SLJs) were tested for both Baking conditions with high strength steel (HSS) and a mild steel, used in the BIW. In addition, both curing conditions were also studied in mild steel for degreased samples and samples submerged in a BIW residual oil (for 5 seconds with a dwell time of 12 hours prior to bonding) to benchmark the adhesive oil absorption capacity.

Testing conditions		
Test	Rate (mm/min)	Specifications
SLJ	1	HSS and mild steel substrates, 12.5mm of overlap length (ASTM D1002)

4. Results

Figure 3 shows the load-displacement curve for the HSS SLJs. Notably, the low baking condition denotes a 30% lower lap shear strength (LSS) and a small reduction in stiffness. Figure 4 illustrates the results of the mild steel adherends with and without oil on the surface. In general, oil does not alter the failure mechanism of the joint and even enhances the adhesive ductility. All substrates showed plastic deformation hence further tests with HSS are required to better access this phenomenon.

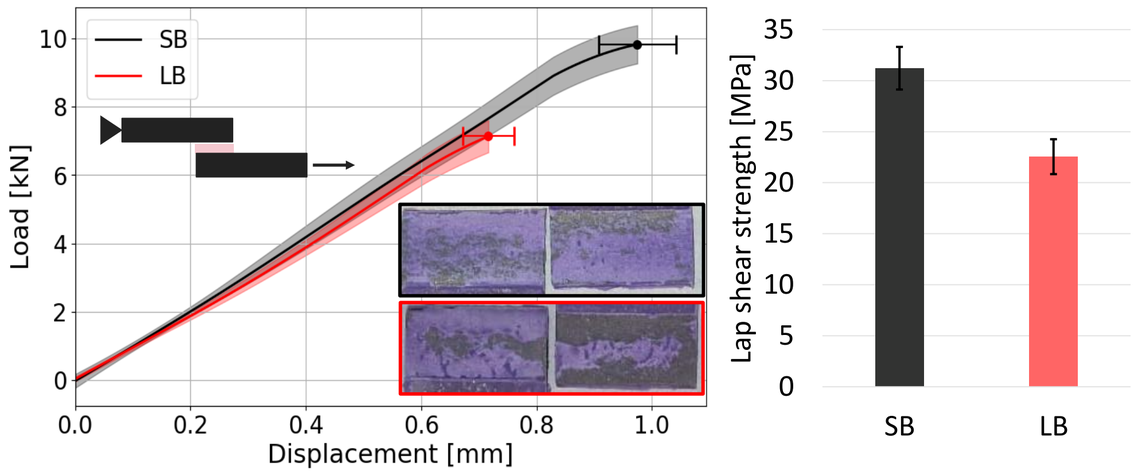

Figure 3. HSS SLJ load-displacement curves and LSS comparison

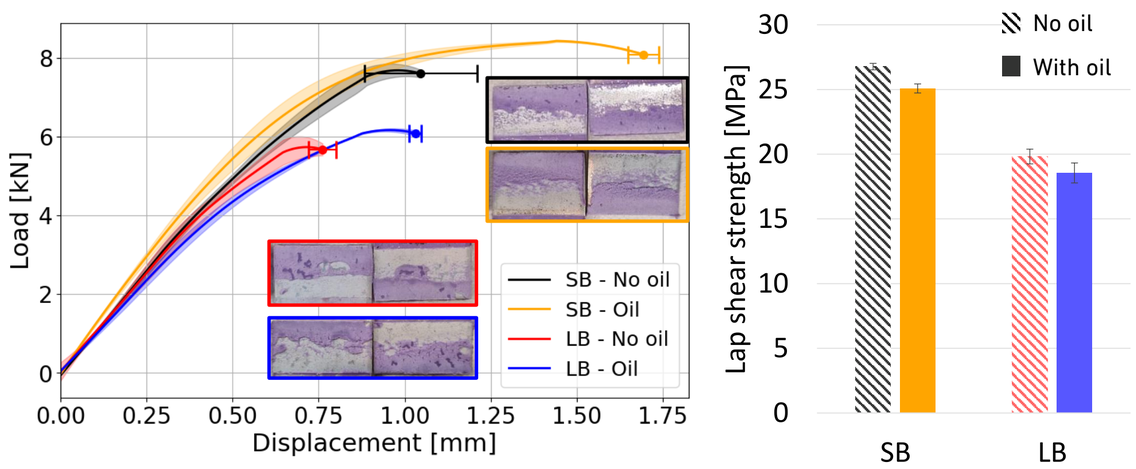

Figure 4. Mild steel SLJ load-displacement curves and LSS with and without oil

5. Conclusions

Overall, the low-bake 1K epoxy system shows promising in-joint performance on both clean and oily substrates, but a complete assessment requires bulk tensile testing and quantifying moisture by measuring water uptake and fitting it with Fick's diffusion law to therefore use those parameters to evaluate water uptake effects in the SLJs.

References

[1] Andreas Lutz, Alexander Droste, and Christof Br¨andli. Structural Bonding in Lightweight Vehicle Construction: Characteristics of Modern Structural Adhesives, Simulation and Application in Bodyshell Work and During Assembly. Verlag Moderne Industrie, 2013.
[2] Tyler Auvil, Gary L. Jialanella, Felix Koch, and Eric E. Cole. Epoxy adhesive having improved low-temperature impact resistance, May 05 2018. WO 2018/081032 A1.

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