INTRODUCTION OF DEBONDING CAPABILITY IN METHACRYLATE ADHESIVE FOR METAL-COMPOSITE JOINTS USED IN AUTOMOTIVE APPLICATIONS

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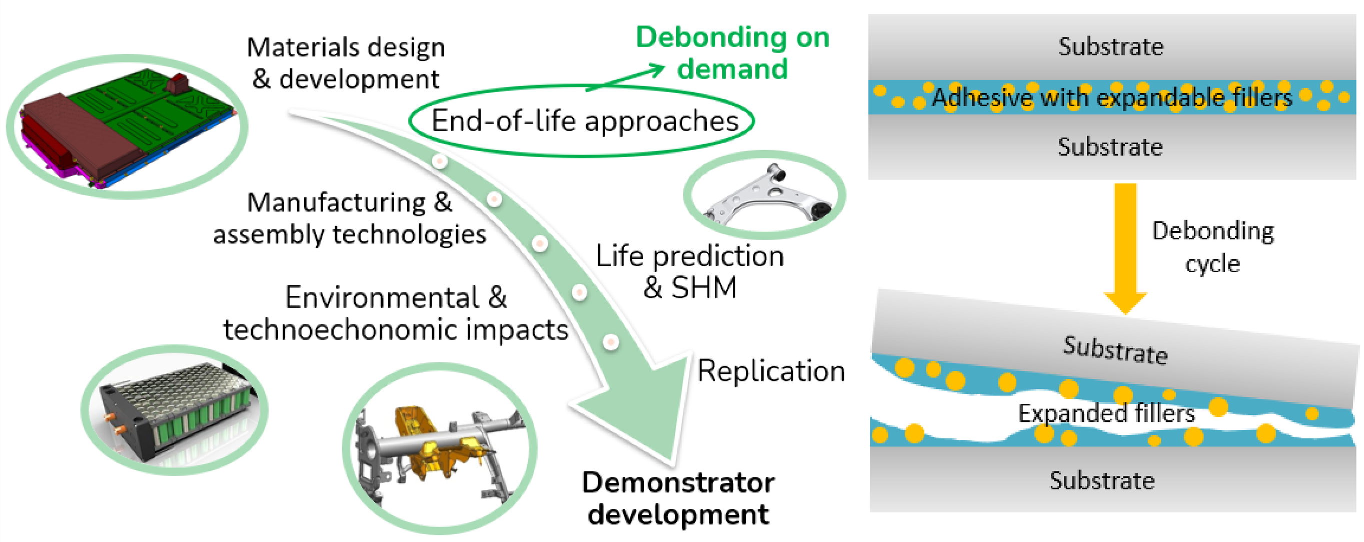
LEVIS LIGHT MATERIALS FOR ELECTRIC VEHICLES

1. INTRODUCTION

The End-of-Life (EoL) is a key aspect for the introduction of hybrid metal-composite solutions in the automotive sector. While the combination of different materials can offer optimal solutions for a component in terms of its functionality, their separation at EoL is sometimes a great challenge. In this sense, one of the technologies being developed in the LEVIS project is related to the improvement of recyclability and re-use of multi-material products through the incorporation of debonding on demand capacity in structural adhesive joints. Specifically, the concept is to introduce a damage mechanism in the adhesives that can be activated on demand without affecting significantly the joints performance in service.



This work presents part of the investigation done about the introduction of TEPs/TEMs in a methacrylate adhesive (BOSTIK® SAF 30/45), a commercial system selected to solve some specific hybrid metal-composite joints proposed in the project, to introduce the debonding on demand capability. Overall, high debonding effectiveness (%DE) was reached when a proper debonding cycle and concentration of particles are used.

2. METHODOLOGY

1. Determination of the debonding window

DSC / TGA characterization for debonding window adjustment
Conditions: 10ºC/min under N_2 atmosphere

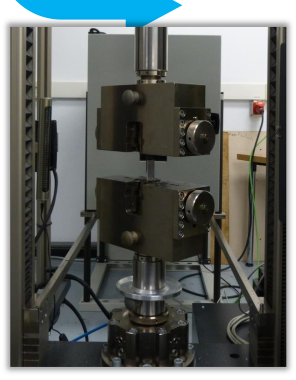
2. TEPs/TEMs selection

First filtering. Heating cycles with various adhesives/particles mixtures. Visual inspection of damage versus temperature. Mixing procedure.

4. TEPs/TEMs expansion under different debonding cycles

Optical microscopy, SEM, thickness and density before and after different debonding cycles and TEPs/TEMs concentrations for the adhesive/particles selected.

5. Debonding effectiveness – joints testing



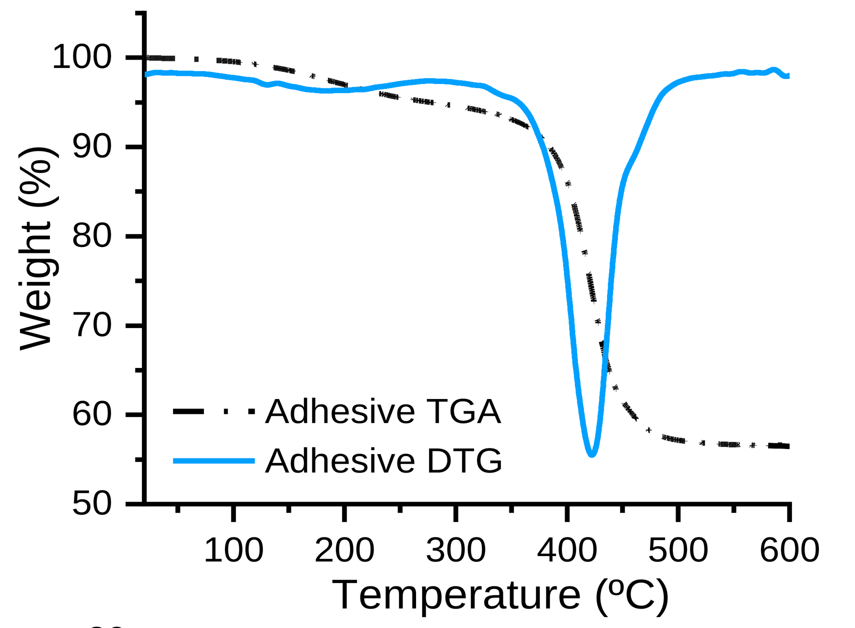
Single Lap Shear according to ASTM-5868 using aluminium substrates. Reduction of joints strength after the debonding cycle. Properties variation due to he incorporation of TEPs/TEMs before and after heating. Campaign covering different particles concentrations.

4. REFERENCES

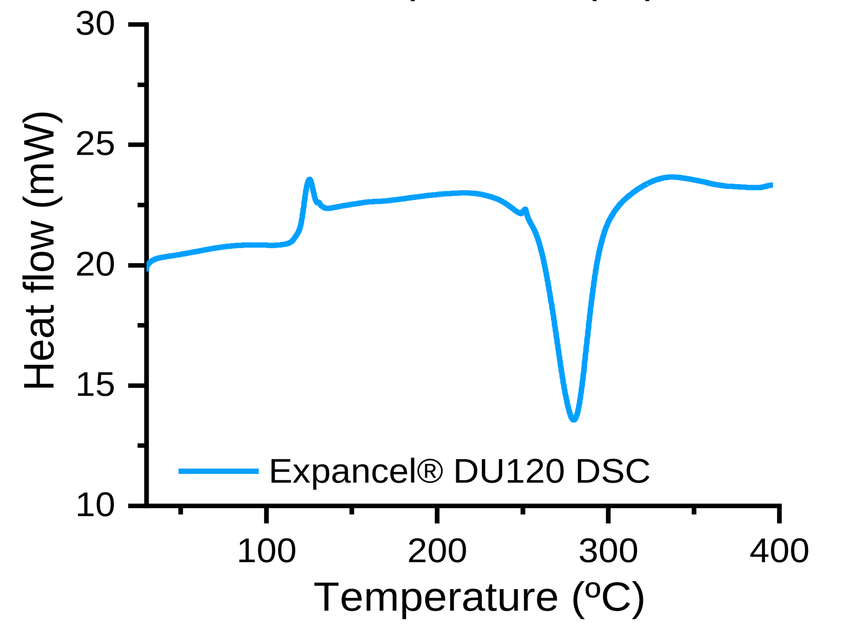
(1) R.Ciardiello, G.Belingardi, B.Martorana, V.Brunella, Physical and mechanical properties of a reversible adhesive for automotive applications, International Journal of Adhesion and Adhesives 89 (2019) 117–128.
(2) ASTM D5868-01(2014), Standard Test Method for Lap Shear Adhesion for Fiber Reinforced Plastic (FRP) Bonding.
(3) Yuchen Lu, An Evaluation and Development of Bonding Technologies for Rapid Disassembly of Automotive Vehicles, Doctoral thesis, 2015.

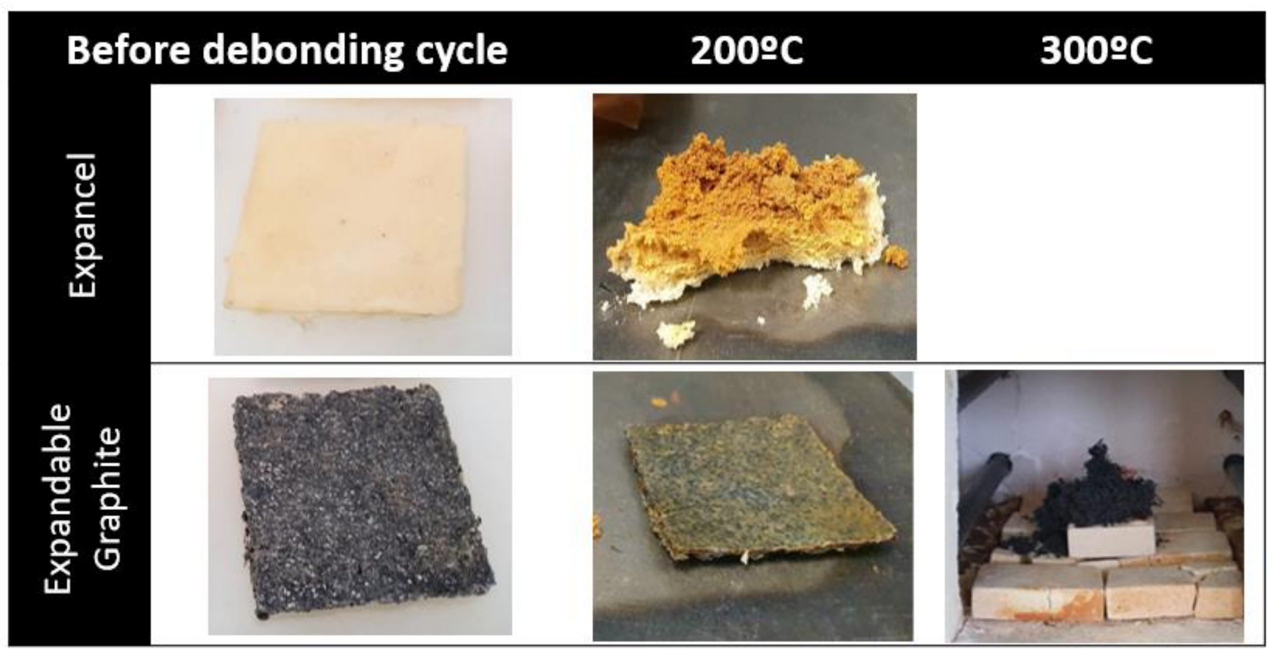
3. RESULTS

Based on adhesive and composite TGA measurements, it was concluded that the maximum temperature in the debonding cycle **must be below 200 ºC.** Under this condition the adhesive degradation will be driven by the TEPs/TEMs expansion.

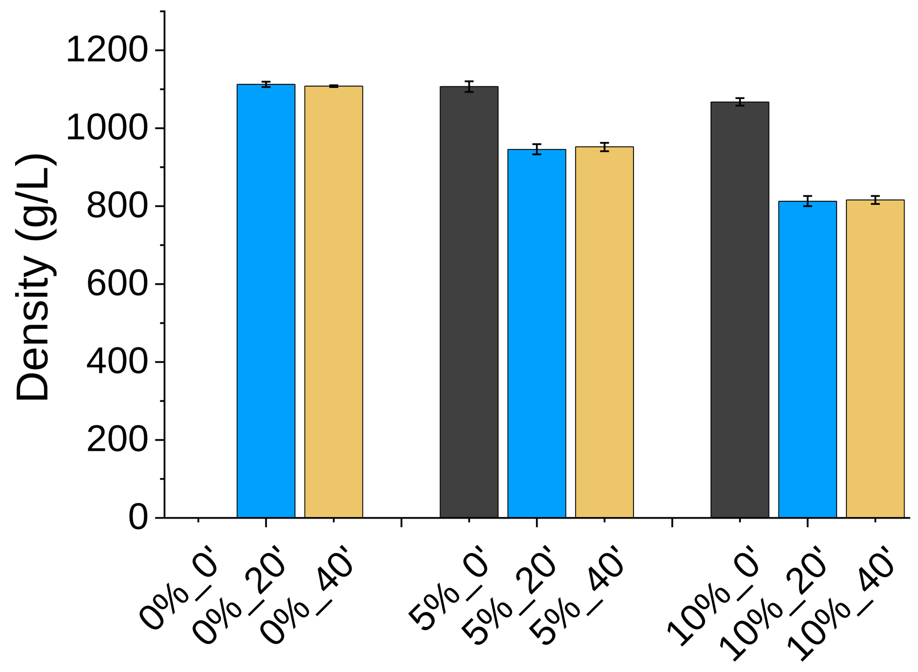


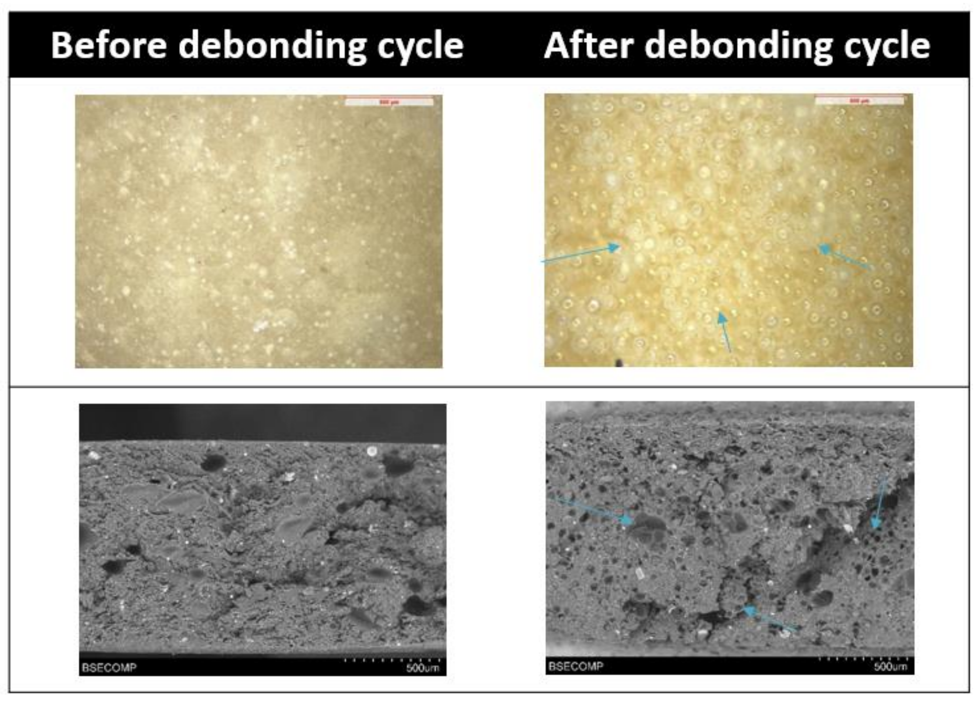
Different grades of thermo-expandable microcapsules and expandable graphite were initially evaluated. In this case, only Expancel® microcapsules have evidenced that can be activated at a temperature below that previously identified as maximum (DSC graph). The system finally selected for the methacrylate adhesive modification was Expancel ® DU 120. Then, different particles/adhesive ratios were studied.



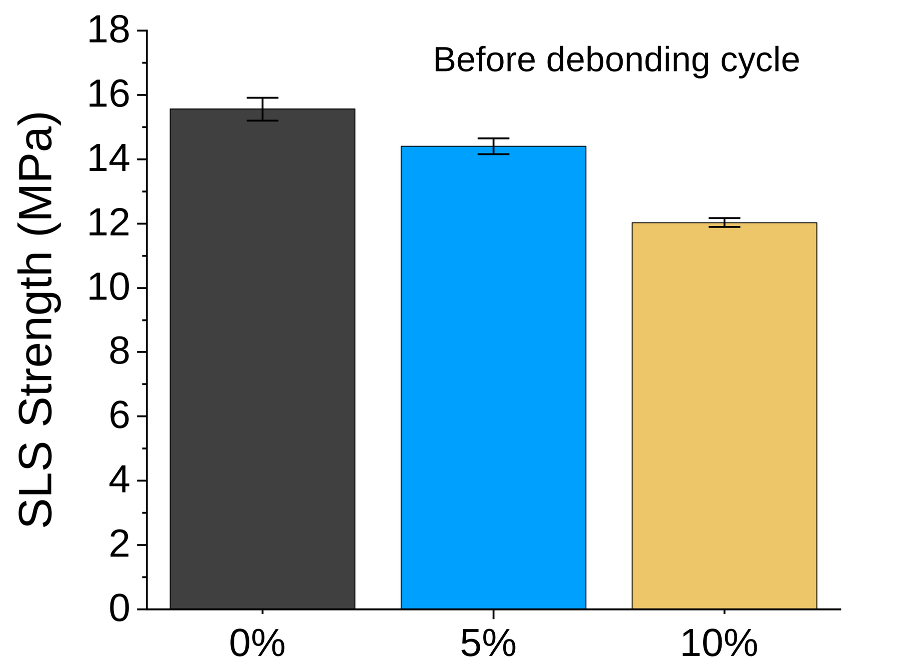


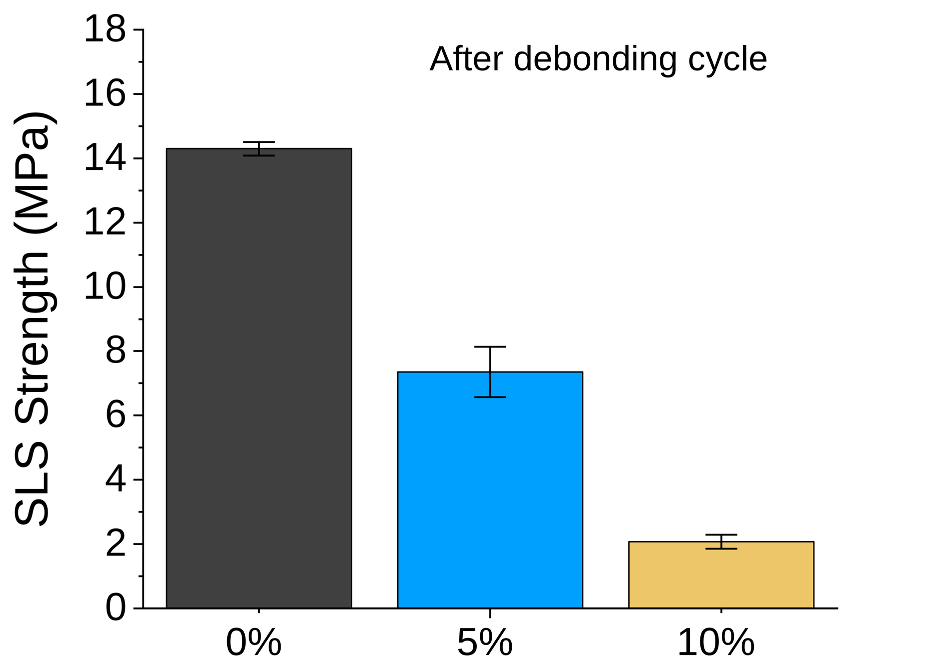
The concentrations tested were **0%, 5% and 10 % w.t.** The debonding cycles initially considered were 20 and 40 minutes at 140 ºC. It has been observed that the density is reduced proportionally to the microcapsules concentration. Their expansion at 140ºC also decreases notably the mixture density, without significant differences between 20 min and 40 min. From these analyses, it was concluded that the microcapsules can expand inside the adhesive and **produce certain damage** for the temperature and times tested.





However, 40 minutes at 140ºC was no not able to reduce significantly the joint strength in SLS test. Instead of 140ºC a higher temperature was tested. The new debonding cycle was **40 minutes at 180ºC.** The comparison of the joints' strengths for the different microcapsule concentrations:





Before the debonding cycle: mechanical reduction proportional to the % w.t. However, with a 10% w.t., the strength is still in a proper range for a structural adhesive for the LEVIS applications.

After the debonding cycle: strengths are significantly reduced. The effect is more pronounced for the higher TEPs concentration.

Debonding effectiveness: % of strength reduction compared to references without activation

0 % microcaps - 8,1% | **5 % microcaps - 48,9 %** | **10 % microcaps - 82,7 %**

5. CONCLUSIONS

The results show an **effective debonding capability** for the SAF® 30/45 methacrylate adhesive modified with 10 % w.t. of the Expancel® DU120.
In addition, the **adhesive maintains proper mechanical and adhesion properties** for its operation in service.
A **debonding effectiveness of 82,7%** was observed for the cycle and formulation proposed.

ACKNOWLEDGMENT

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