

Hot and Heavy EVs, a Deep Dive into Adhesion Promoters for Sealer and Underbody Selection

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Introduction

Electric Vehicles (EV) fundamentally differ from traditional automobiles in two ways:

1. Weight and thickness of the frame/chassis of an EV are often greater than a traditional car to support the heavier frame/chassis housing the EV battery
2. Increased frame/chassis thickness effects the thermodynamics during baking; the frame remains 10-20 °C below oven temperature leading to underbake of sealers and underbody coatings (UBC)

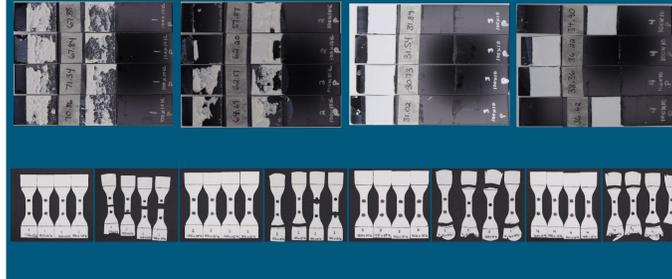
These differences have led to reevaluation of current sealer and underbody technologies to provide the same or improved functionality. The desire to lightweight these more supportive frames/chassis has led to manufacturers seeking new ways to bond similar and dissimilar materials such as coated metal to aluminum. Our lab at Sunstar conducted a survey of some common and new adhesion promoters in the automobile industry with a focus on the chemistries.



Toyota Tacoma EV (Expected: 2026) Honda 0 Saloon (Expected: Late 2026) Subaru Trailseeker (Expected: Early 2026) Source: <https://www.caranddriver.com/news/g29994375/future-electric-cars-trucks/>

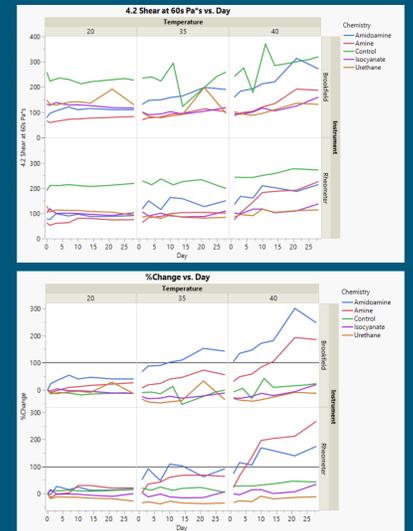
Testing Methods

Lapshears were pulled using a 10 kN Instron (5966) to determine strength and failure mode, cohesive, adhesive, or mixed. Lapshears testing was conducted on 8 substrates: 1 coated Al (P), 1 uncoated Al alloy (Al), and 6 coated steel alloys (S1-S6). Lapshears testing was also conducted on dissimilar metals of coated-Al with all other substrates. Tensile tests were pulled using a 500 N Instron (5944) at 50 mm/min to determine tensile strength and elongation. Viscosity testing was performed with a TA HR20 to determine rheological differences between chemistries and changes over time.



Rheology

Viscosity measurements monitoring the effect of thermal aging were taken at intervals over 28 days on a TA HR20 rheometer at 4.2 s⁻¹ shear for 60 s at 20°C and with a Brookfield Ametek HB-07 spindle set to 20 RPM after 60 s.



Importance of Adhesion Promoters for EVs

- Growing importance and share of the automotive industry
- Market is expanding
- Adhesion promoters are necessary to bond to new coating materials and to bond dissimilar materials
- Numerous adhesion promoter chemistries are being explored

Adhesion Promoter Definition

"An adhesion promoter is used as an additive or as a primer to promote the adhesion of coatings, inks, or adhesives to the substrate of interest. An adhesion promoter usually has an affinity for the substrate and the applied coating, ink, or adhesive. Without the adhesion promoter, the properties of the applied coating may not be sufficient to meet the performance requirements needed for the end product... [Eastman Chemical]"

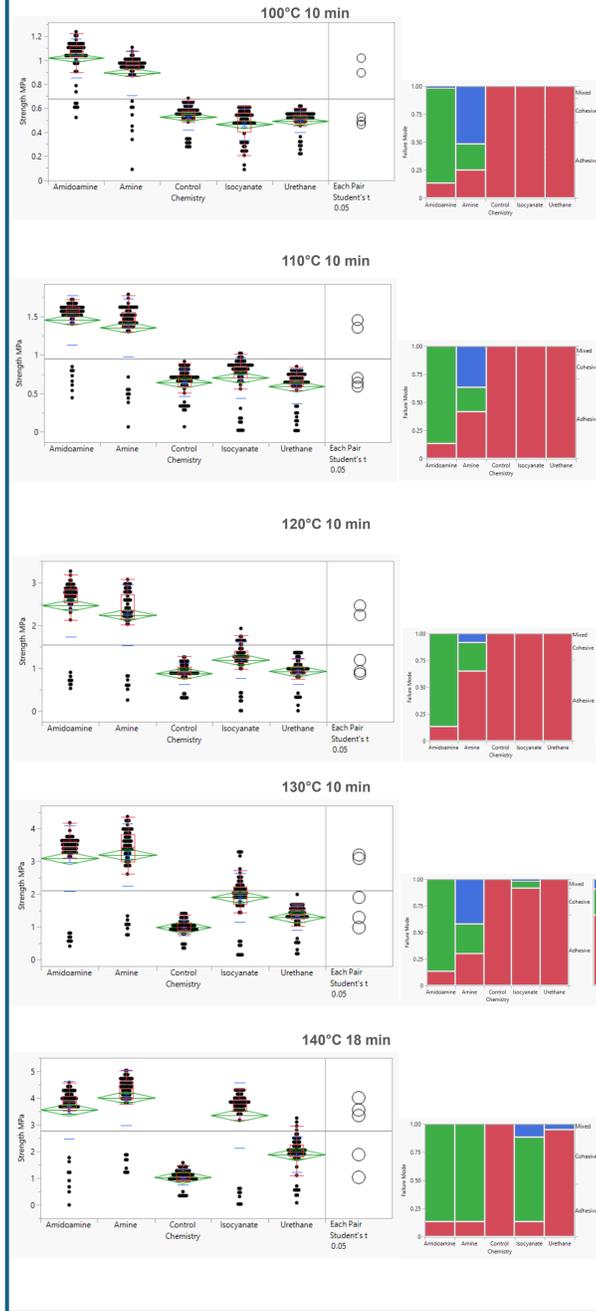
"The objective of adhesion promoters and coupling agents is to create as many stable additional bonds on these phases. [BYK]"

"Adhesion promoters are difunctional or multifunctional monomers or oligomers where one or more reactive groups chemically bond to the substrate and the other reactive groups form bonds with the adhesive, thus creating a molecular bridge. [ScienceDirect Topics]"

"...an adhesion promoter as a single primary compound that is able to interact (either based on chemical or physical principles) with two layers of materials for which adhesion needs to be improved."¹

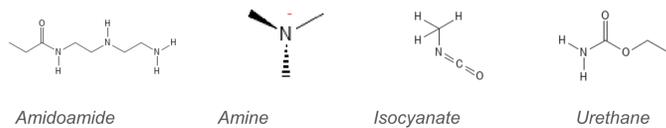
Results

Lapshear strength and failure modes across all ecoats and uncoated Al control



Test Methodology

4 Chemistries of Adhesion Promoter were tested, amidoamine (#1), amine (#2), blocked isocyanate (#3), and urethane (#4)

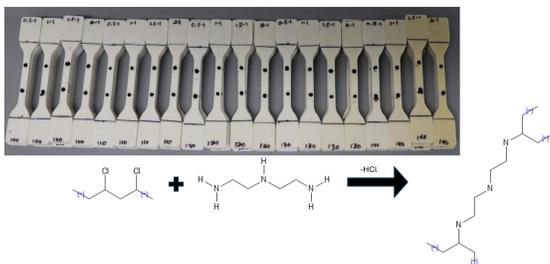


Base formula

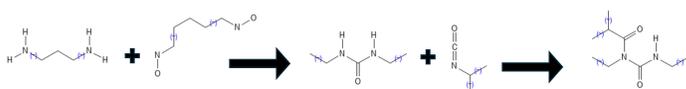
Formulations were made with 25% plasticizer, 25% PVC dispersion grade resin, 2% odorless solvent, 0-5% adhesion promoter (chemistry dependent), remaining % of formulation was filler. Formulations were kept simple and consistent to be informative and comparative. Adhesion promoter loading was determined by values in good testing ranges from modelled results of four-point loading screening tests on this formulation. Amidoamine = 1.3% Amine = 1.6% Isocyanate = 4.2% Urethane = 3.9%

Probable reaction mechanisms

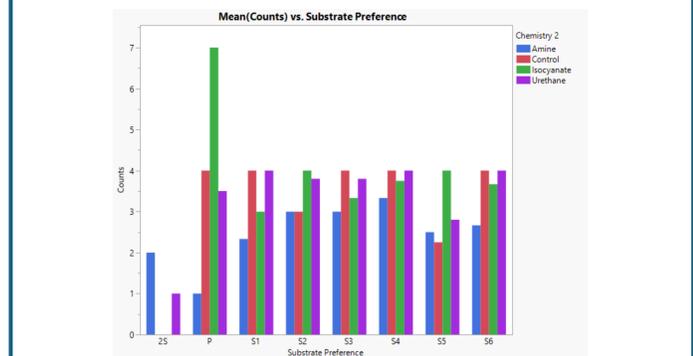
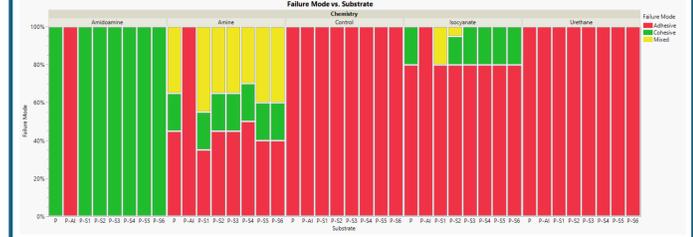
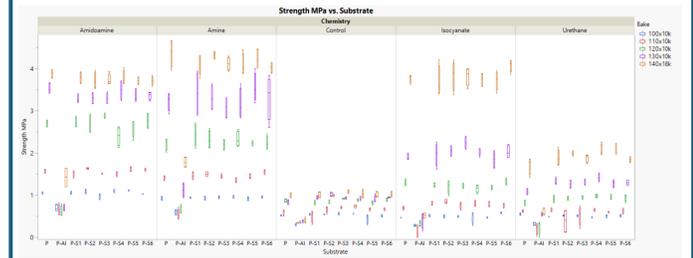
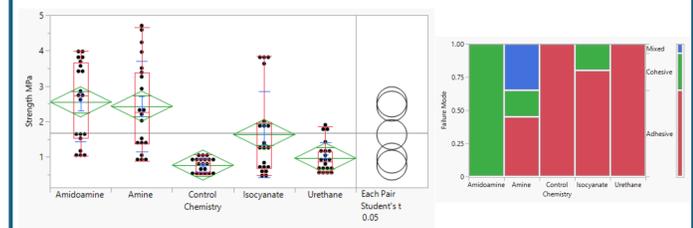
Amines with PVC, the PVC undergoes a substitution reaction where N is the added group and Cl- is the leaving group. Other amines on the chain react in the same manner with other sections of PVC leading to crosslinking through amine bridges². The thermal stability is affected by the amine chain length. We saw support for this from yellowing of amine adhesion promoter samples at high temperatures. Amidoamines are similar to amines with an O that might help stabilize loose Cl ions during the formation of the N-bridge.



Isocyanates are often blocked to prevent unwanted reactions prior to a desired temperature. Blocked isocyanates are often accompanied by an amine or epoxy to facilitate bonding at lower temperatures. Isocyanates and amine groups can react with each other to form urea bridges³. Crosslinking also occurs between epoxy and isocyanate compounds⁴. Crosslinking is often facilitated by maleic anhydride and/or styrene. Urethanes can be synthesized through diol + diisocyanate reactions. The resulting urethanes often contain isocyanate groups⁵.



Aluminum ecoat (P)



Discussion

At lower temperatures amidoamines showed better strength and cohesive failure modes across all substrates tested except for the control substrate Al. All samples experienced adhesive failure on Al. Strength and failure mode of the blocked isocyanate improved at higher temperatures to be comparable with amidoamine. Amines also saw increased lapshear strength and more cohesive failure modes at higher temperatures.

Amines and amidoamines had the highest tensile strength. There were no trends evident in the elongation, different chemistries performed better at some temperatures than others.

Amidoamines and amines saw significant increases in viscosity when subjected to high temperatures, perhaps indicative of increasing the chemical crosslinking between the adhesion promoter and the PVC resin.

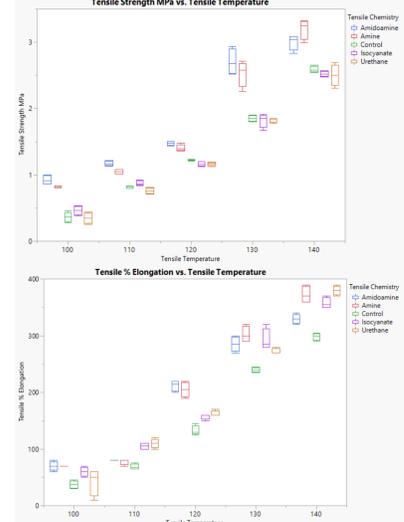
Samples with bonding to dissimilar substrates all had one substrate as ecoated Al, P. Amidoamines gave the best consistent failure modes and strengths. Isocyanates did show some preference for ecoated Al, P, during adhesive failures compared to other substrates.

Research into the reactions with the substrate and interface formation are ongoing.

Summary

The performance of the amidoamine adhesion promoter gave the best failure modes (cohesive) and highest strength over the full temperature range and across substrates including P without the yellowing seen in the amine adhesion promoter. The amidoamine and the amine had significantly worse aging at high temperatures.

Tensile Testing



References:

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