USE OF LATENT CROSSLINKING FOR MODIFICATION OF ADHESIVE REMOVABILITY AND REPOSITIONABILITY IN PRESSURE-SENSITIVE GRAPHICS APPLICATIONS

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Abstract:

A significant portion of the pressure-sensitive graphics applications in the US is aimed at indoor-outdoor advertising and automotive industries. These applications require superior removability and repositionability of the adhesive from its end-use substrates. This study outlines a novel approach to modify removability and repositionability of water-based acrylic adhesives using latent crosslinking technologies. Use of such approach has been explored by our team in multiple different adhesives to understand its impact on overall performance in graphics applications. The various systems have been evaluated using 3 types of facestocks - monomeric vinyl, polymeric vinyl, and polypropylene. The study shows that use of this technology allows tailored modification to the removability and repositionability of the water-based adhesives, opening up diverse options in graphics applications.

Introduction:

The global graphic design market is substantial. As of 2023, it was valued at approximately $57.5 billion and is projected to reach around $78.25 billion by 2030, growing at a compound annual growth rate (CAGR) of 4.5%.[1] This industry encompasses a wide range of applications, including branding, advertising, signage, vehicle wraps, and window films. Despite the increasing interest in and shift to digital advertising and branding, the traditional graphics industry remains strong, especially in North America.[2] Growth in the traditional graphics sector is being fueled by vehicle graphics and outdoor advertising and branding. The traditional graphics industry uses printed media with pressure-sensitive adhesives for easy peel-and-stick application.

Figure 1. Examples of graphics applications for indoor-outdoor advertising and automotive.

Various types of pressure-sensitive adhesives, predominantly acrylic adhesives, are used in this industry. Water-based and specialty solvent-based acrylic adhesives are most common for short-term and long-term applications due to their widespread availability and cost-effectiveness. In certain specialty applications, UV acrylic adhesives are also used, and their market presence is growing due to increased line speed and operational savings for high-performance applications.

Adhesives used for graphics need to deliver a wide array of performance properties, including durability, weatherability, UV resistance, optical clarity, non-yellowing, and either permanence or quick removability, depending on their end applications. For example, vehicle wraps and advertising applications require adhesives to be durable, weatherable, and UV-resistant. Retail advertising graphics, on the other hand, require adhesives to be optically clear and removable on demand. Graphics adhesives, therefore, vary from permanent to semi-permanent to removable to ultra-removable, based on their ease of removal after use. Solvent-based adhesives offer some advantages with achieving various degree of ease of removal with one base polymer. Some solvent-based adhesive properties can be adjusted from permanent to ultra-removable simply by varying the loading of crosslinking agents. These adhesives offer optimal shelf life regardless of the crosslinking agent loading. Water-based adhesives, on the other hand, typically require different formulations for permanent versus removable or ultra-removable applications. While external crosslinking agents can be added to water-based systems, most such systems results in a short shelf life (less than 48 hours) for the adhesive, which limits the operational flexibility needed during the coating and converting processes.

This work outlines a novel approach that allows for the crosslinking of the adhesive without sacrificing shelf life. Such crosslinking has been shown to shift the adhesive properties from permanent to removable performance. While the crosslinking agent used in this study is not new to the market, a unique adhesive was developed and used for this study.

Method

Adhesion and loop tack testing was conducted using PSTC 101 and PSTC 16 methods respectively. 2 mil PET films were used as facestock for standard adhesive testing, unless otherwise indicated. Testing was conducted using 25 g/m² coating thickness (dry) for the adhesives in all cases. For vinyl shrinkage testing on monomeric vinyl facestock, the FINAT 14 test method was used.

Results and Discussions

A unique water-based acrylic adhesive, Adhesive A, was developed for this study. This adhesive was analyzed for its physical properties, and the results are tabulated below. Adhesive A was crosslinked with ‘Crosslinker X’ to tailor its adhesion properties from permanent (typically 180° peel on stainless steel > 2 pounds per linear inch) to removable (typically 180° peel on stainless steel < 1 pound per linear inch) properties.

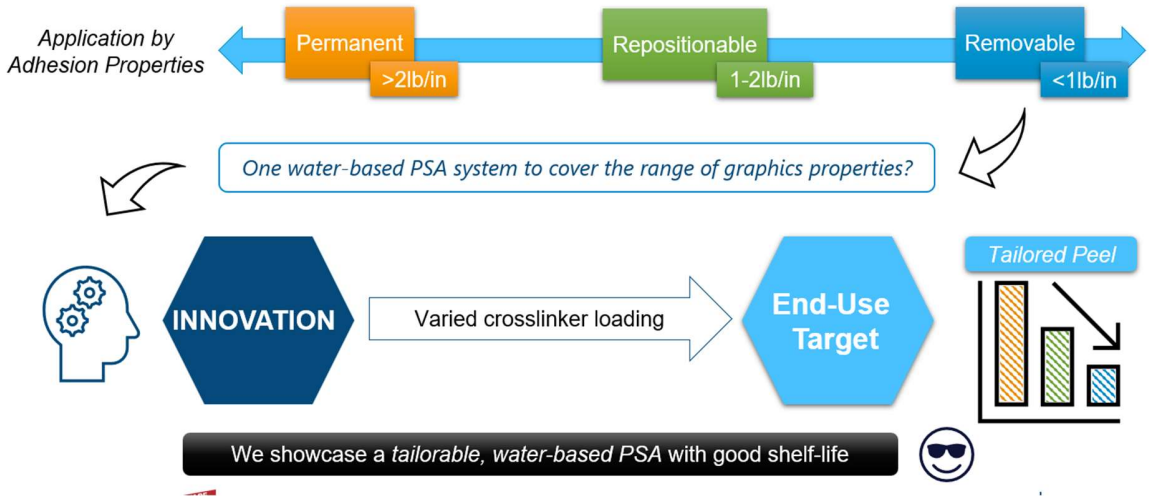

Figure 2. Schematic overview highlighting the key focus of this study.

Crosslinker loading in Adhesive A was varied from 0 % to 2.5% (by weight, wet on wet). Immediate peel adhesion (according to PSTC 101, 2 mil PET facestock, 30 min dwell, 25 g/m² dry coat weight), loop tack (according to PSTC 16, 2 mil PET facestock, 25 g/m² dry coat weight), and static shear (PSTC 107, 2 mil PET facestock, stainless steel substrate, 0.5" X 0.5" X 500 gm, 25 g/m² dry coat weight) properties were evaluated for Adhesive A as its modfied versions with various loadings of crosslinking agents.

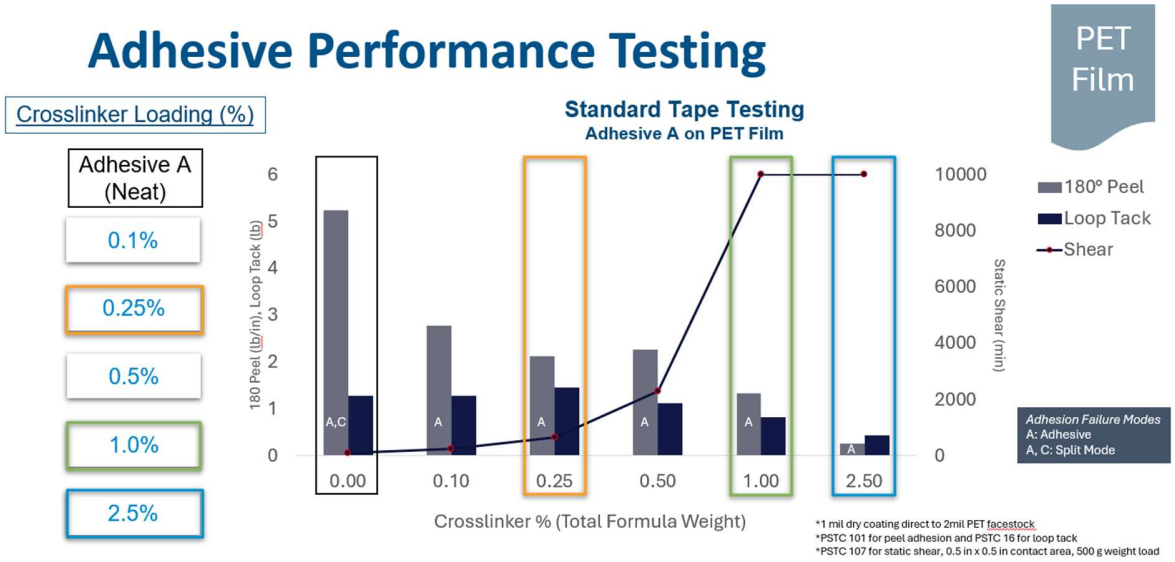

Figure 3. Peel adhesion, loop tack, and static shear for Adhesive A at different crosslinker loading.

The results show that Crosslinker X is capable of tailoring the properties of Adhesive A from permanent to removable families. Adhesive A and its derivatives with various loadings of Crosslinker

X were tested for shelf life. All formulations, including the version with highest crosslinker loading, showed more than 6 months of shelf life.

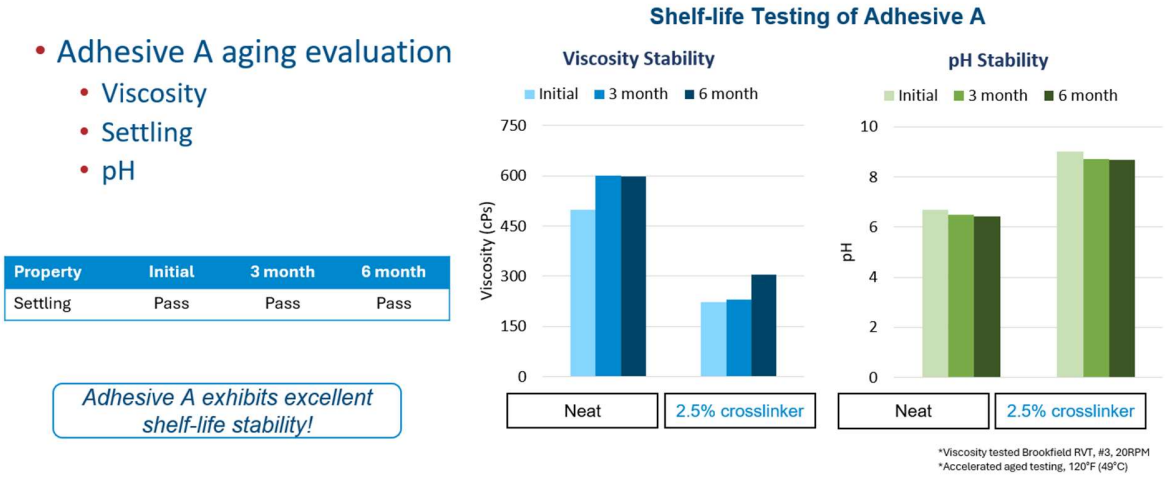

Figure 4. Summary of shelf life (liquid aging) for Adhesive A and Adhesive A + 2.5% Crosslinker X.

These results confirm that, together with Crosslinker X, Adhesive A offers tailorable pressure-sensitive properties while maintaining adequate shelf life. This is unique for water-based adhesives and enables a user to use a single adhesive base polymer for a wide range of applications.

To explore the feasibility of this technology in graphics applications, adhesion properties were evaluated using vinyl and polypropylene facestocks. Monomeric vinyl facestock was chosen for this study as the worst case scenario as this tends to pose more challenges in applications due to the nature of plasticizer present in it. Additionally, Adhesive A performance was evaluated - with and without crosslinking agent - on BOPP (biaxially oriented polypropylene) facestock as it is finding increased use in the graphics industry due to its sustainability benefits. Unlike vinyl facestocks, BOPP does not contain plasticizers and adhesives tend to perform on these facestocks differently than on vinyl.

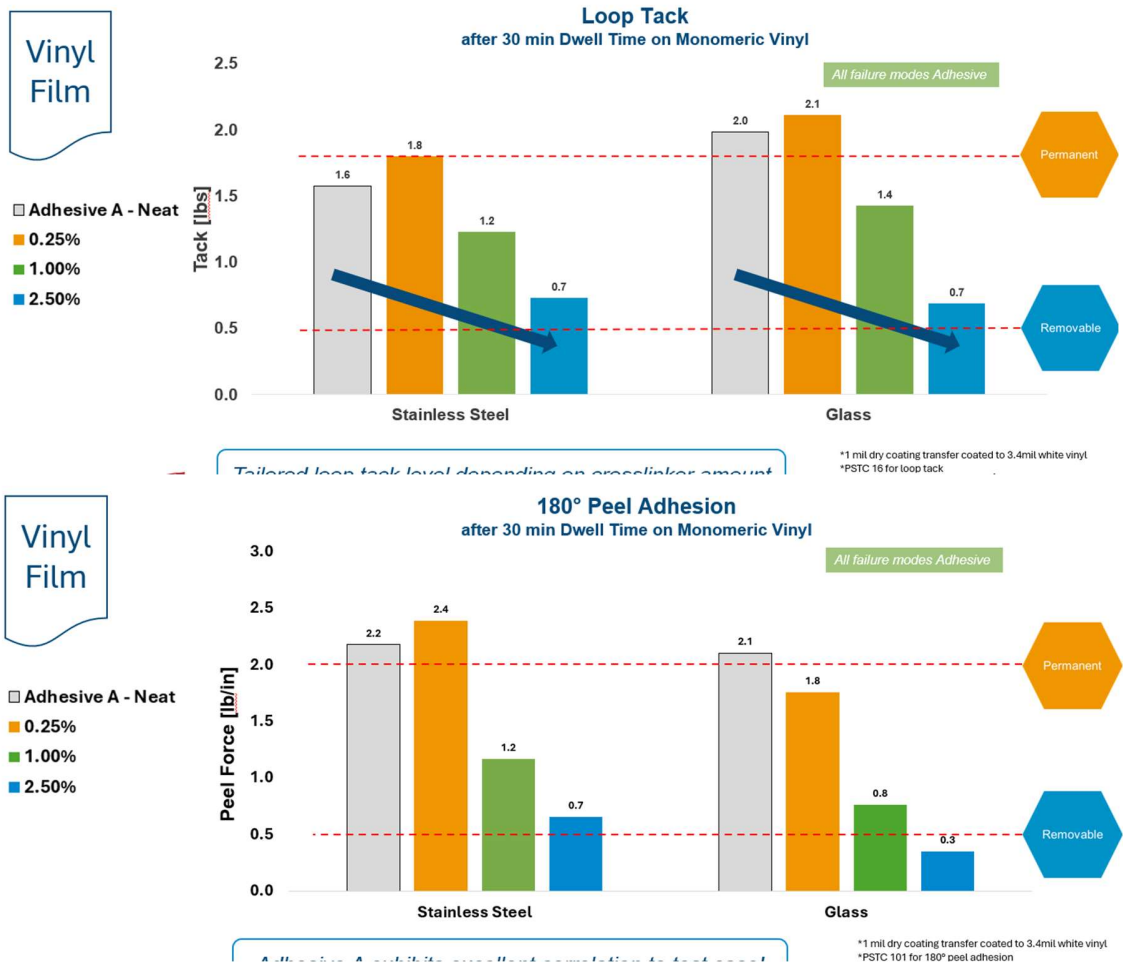

Figure 5. Summary of 180° peel adhesion (top) and loop tack (bottom) results for Adhesive A with various Crosslinker X loading using monomeric vinyl facestock.

Testing on monomeric vinyl facestock showed promising results, with Adhesive A exhibiting a shift in adhesion properties from permanent to removable realm with changes in crosslinking agent loading. This trend was observed on both stainless steel and glass substrates, which are commonly used substrates for such applications. Loop tack testing also showed a similar trend — loop tack

decreases with increasing Crosslinker X loading in Adhesive A. Notably, even with the highest loading of Crosslinker X, Adhesive A shows approx. 0.7 lbs/in loop tack, which is comparable to benchmark removable adhesives.

Shrinkage of the facestock from vinyl facestocks is usually a major concern with adhesive selection as the later might have significant effect on the resistance to shrinkage from the plasticizer migration. Shrinkage for Adhesive A as well as Adhesive A + 2.5% Crosslinker X was evaluated with monomeric vinyl facestock. Results show that Adhesive A — without and with 2.5% Crosslinker X — meets application requirements for shrinkage- typically <1% shrinkage is desired.

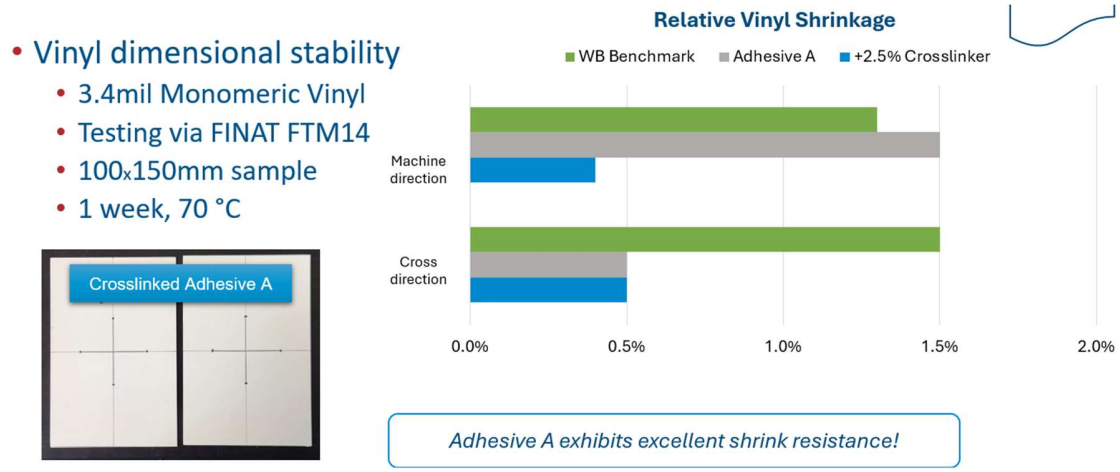

Figure 6. Summary of shrinkage data for Adhesive A and Adhesive A with 2.5% crosslinker.

180° peel adhesion and loop tack testing were conducted using clear BOPP facestock. The results are summarized below.

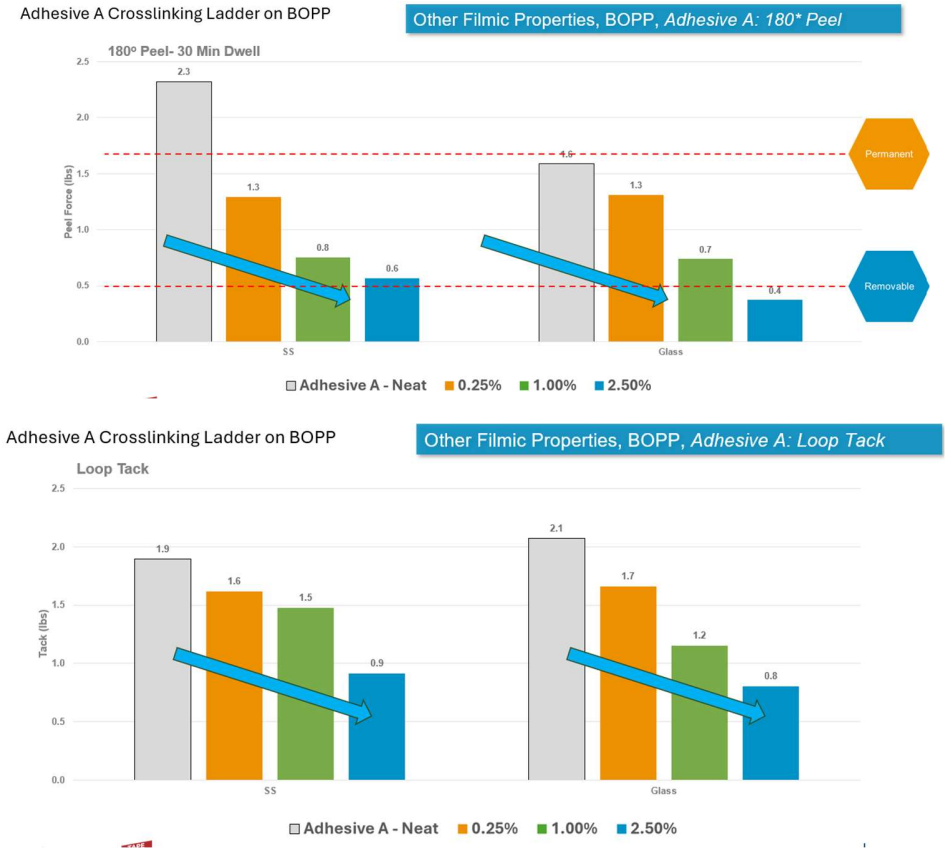

Figure 7. Summary of 180° peel adhesion (top) and loop tack (bottom) results for Adhesive A with various Crosslinker X loading using clear BOPP facestock.

Consistent with testing using 2-mil PET and monomeric vinyl facestocks, Adhesive A showed a shift in adhesion properties from permanent to removable performance on clear BOPP as well. Adhesion to both stainless steel and glass exhibited a similar trend. Loop tack testing showed that Adhesive A with the highest loading of Crosslinker X maintains between 0.7 - 0.8 pli of loop tack on stainless steel and glass respectively — consistent with benchmark removable adhesives.

Conclusions

Overall, the study demonstrates that Adhesive A performs effectively as a permanent adhesive. Due to its unique composition and design, Adhesive A can be successfully crosslinked with various loadings of Crosslinker X without sacrificing shelf life. All crosslinked systems exhibited a shelf life of over 6 months.

As anticipated, higher crosslinking density in Adhesive A gradually shifts the adhesion properties from permanent to removable. Comparisons with water-based acrylic benchmark permanent and removable adhesives confirm that Adhesive A, with appropriate crosslinking loading, can be used in a wide array of graphics applications, ranging from permanent to removable adhesives.

The tunable adhesion properties combined with a stable shelf life make Adhesive A quite versatile for various graphics applications.

References:

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2. Graphic Design Market Size, Share, Growth, and Industry Analysis, By Type, By Application, and Regional Insights and Forecast 2032. Business Research Insights, 2024. Report ID BRI117837.