High Solids Acrylic Pressure Sensitive Adhesives

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Abstract

This paper presents a new technology platform designed to produce high solids content solvented PSA's without sacrificing coatability and performance. This approach utilizing unique polymer design and formulation enables one part products with coater ready viscosities at 15-20% higher solids content than traditional solvented products. Some of the potential benefits of this technology for the tape industry are improved line speeds leading to higher productivity, lower packaging and shipping costs, and better utilization of flammable storage space. In addition to providing potential productivity and sustainability advantages over conventional solvented products, the performance range of this platform can address critical performance needs through improved adhesion to low surface energy substrates while maintaining a robust balance of peel, tack and shear.

Background on High Solids Solvent Acrylics

Solvent acrylic pressure sensitive adhesives provide multiple performance benefits when compared to other adhesive categories, but with increasing pressures on improved environmental emissions from factories, alternative approaches to solvent based adhesives are desirable. Greater than 50% of a typical solvent acrylic PSA is organic solvent. Utilizing high solids adhesives means less solvent to remove and less to dispose of resulting in energy savings and lower overall VOC emissions. For tape producers, high solids solvent acrylic PSA's could also improve line speeds leading to higher productivity. Lower shipping and packaging costs, and better utilization of flammable storage space are some of the additional potential benefits when considering higher solids adhesives.

Pure acrylic PSA's are typically composed of 70-90% of soft monomers, 10-30% of hard monomers, 3-6% of functional monomers, and <1% of cross linker. The percent solids achieved using this traditional approach is typically between 35% and 45%. There are several existing approaches to increasing percent solids up to 55%-60% and beyond, but there are significant disadvantages. One approach is to blend tackifiers into high molecular weight polymers to optimize the performance – this approach provides the benefits of increased solids and generally increased peel and tack, but often sacrifices cohesion. A second approach is to use lower molecular weight adhesives and utilize a covalent crosslinker, such as an isocyanate. This approach can lead to higher solids, but often sacrifices tack, and suffers from shorter pot life resulting in the need for mixing immediately prior to coating.

New Approach for High Solids Solvent Acrylics

The new approach to produce higher solids solvent acrylics described here utilizes unique polymer design in combination with functionalized oligomers with MW <10,000. These oligomers have multiple cross linkable groups which react with specifically designed functionality in the acrylic system to effect crosslinking without sacrificing cohesion.

Some challenges in designing such an adhesive include careful selection of the appropriate monomers. The overall polymer composition and molecular weight distribution to achieve appropriate compatibility with the oligomers is very important using this new approach. The functionality, molecular weight and compatibility of the oligomers with the acrylic resins is equally important. The balance of these two components ultimately controls the final adhesive performance. Through careful polymer design and raw material selection, a broad range of adhesive performance requirements can be met to equal or even improve on existing acrylic capabilities, all while delivering significantly higher solids at coatable viscosities.

Traditional acrylic pressure sensitive adhesives adhere very well to relatively polar substrates such as steel, aluminum, tin, glass, and wood. Compared to conventional acrylic PSA's, this new approach can produce formulations with higher peel adhesion and aggressive tack with minimal impact to other properties. Improved adhesion to high surface energy substrates like metal, low surface energy substrates like HDPE, or even rough surfaces like foam are all possible in addition to achieving 10-15% higher solids and maintaining coatable viscosities to fit a range of different application and coating processes.

PSA Performance Comparison

While high solids is a clear benefit for sustainability and efficiency reasons, if the adhesive does not provide performance equivalence or benefits over conventional approaches, the technology does not have a fit in the tape market. While there is significant design space that could be considered, the performance of prototype samples in critical tape performance testing looks promising.

Figures 1A-D compare adhesive performance of a prototype high solids sample with acrylic adhesive grades that are typical of general purpose tape. The PSA performance of an example high solids formulation is in line with or exceeds the performance of some general purpose tape grade adhesives. Adhesion values are improved on stainless steel without sacrificing SAFT, and shear values within expectation for a general purpose adhesive. This performance is demonstrated while delivering solids of nearly 65% (an increase of 10-15% over the comparison grades) and a coatable viscosity of 6500cP.

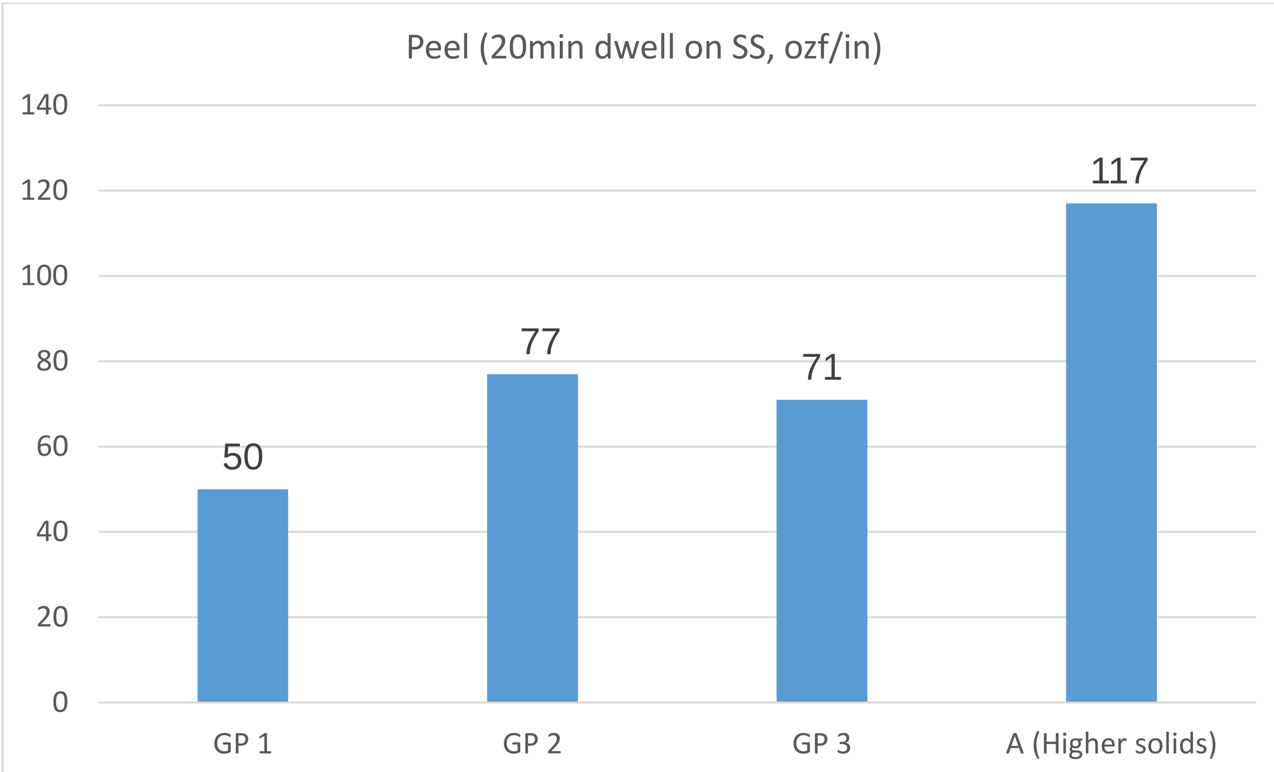

Figure: 1A: Peel adhesion is the force required to remove a pressure sensitive tape from a panel at a specified angle (180°) and speed. Peel samples are applied to a stainless steel panel with a 4.5 pound roller with 1 pass in each direction. Test is performed under constant temperature (72 ± 2˚F) and relative humidity (50 ±5%). All test results are performed in triplicate using a different panel for each replicate and 20 minute wet-out time.

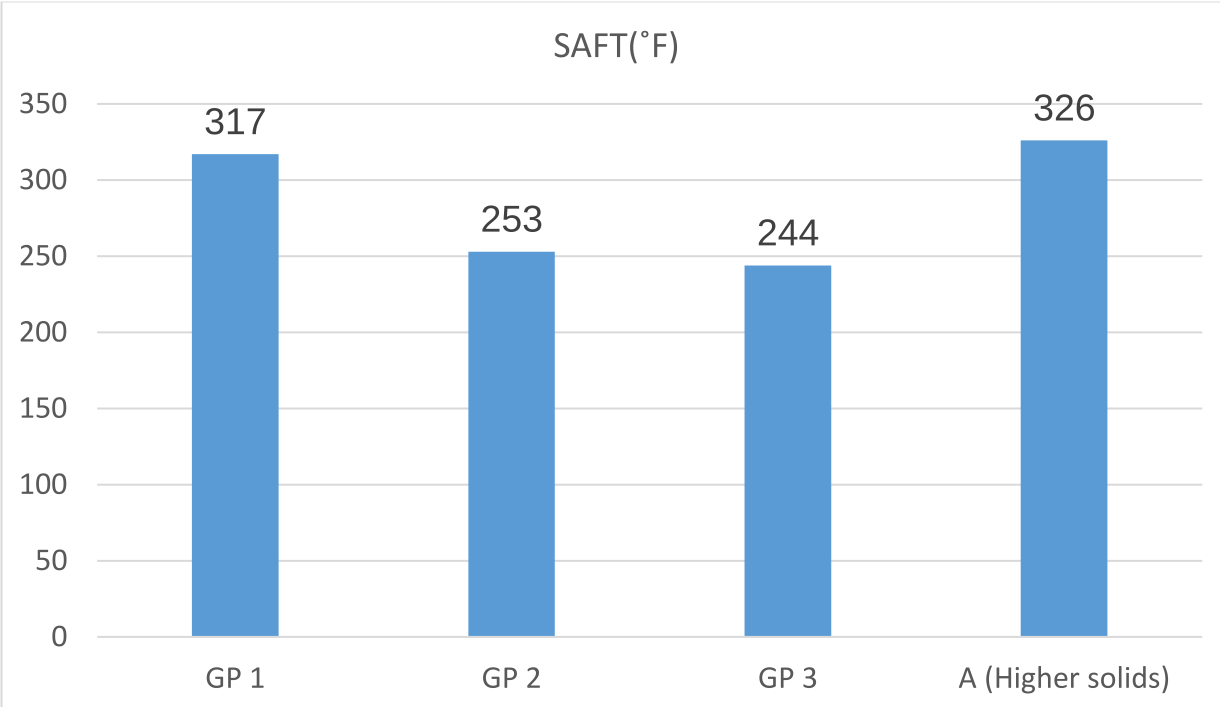

Figure 1B: Shear adhesion failure temperature (SAFT) is a method of determining the load-bearing capability of a pressure sensitive tape while elevating the temperature at a pre-determined rate. Test sample applied to a stainless steel panel with a 4.5 pound roller with 1 pass in each direction. All test results are performed in triplicate using a different panel for each replicate and 15 minute wet-out time before hanging weight.

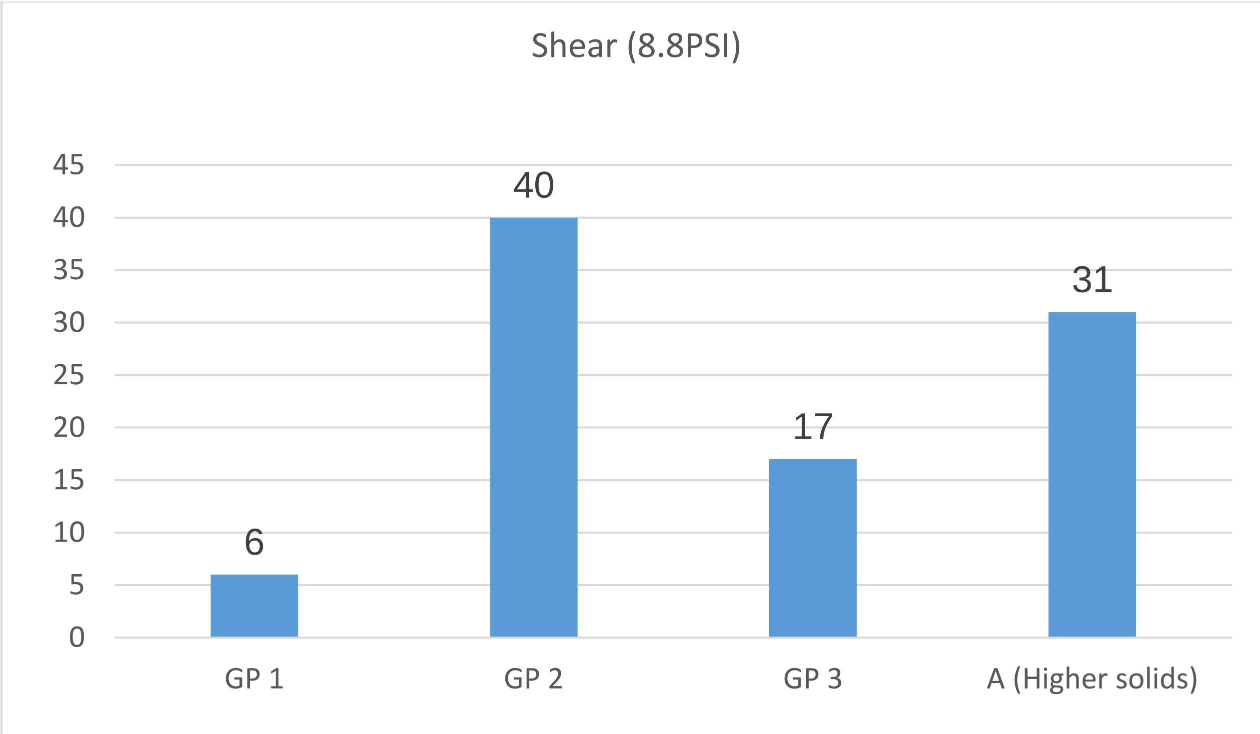

Figure 1C: Shear adhesion is a method of determining the load-bearing capability of a pressure sensitive tape. Shear sample applied to a stainless steel panel with a 4.5 pound roller with 1 pass in each direction. Test is performed under constant temperature (72 ± 2˚F) and relative humidity (50 ±5%). All test results are performed in triplicate using a different panel for each replicate and 15 minute wet-out time before hanging weight.

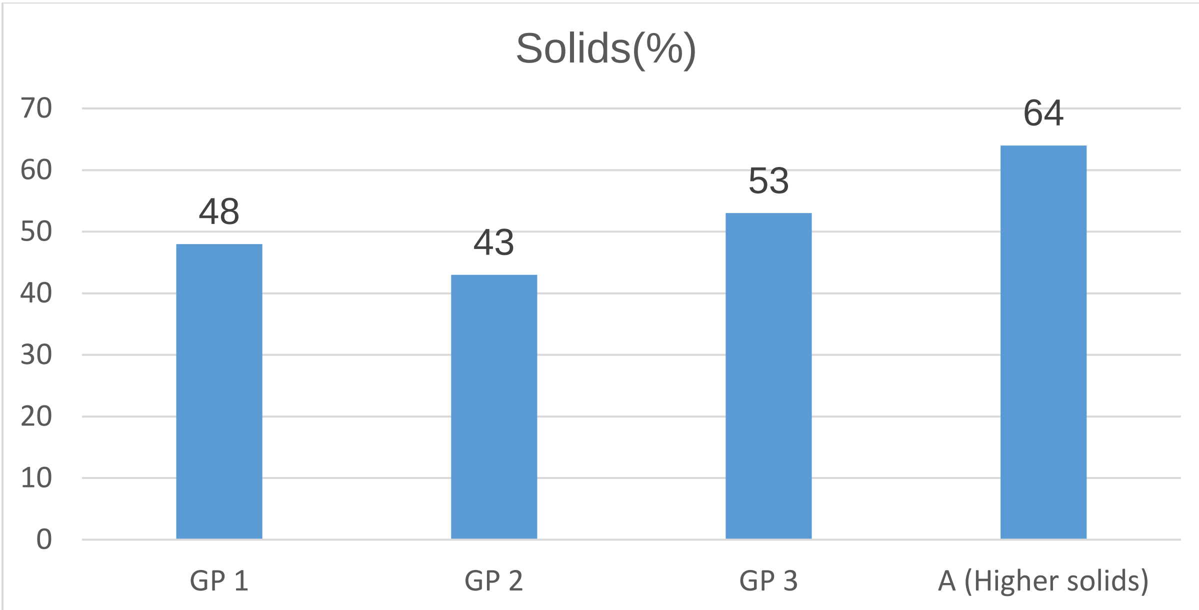

Figure 1D: Percent solids of conventional acrylic grades as compared to a prototype designed for similar general purpose market space.

Additional Formulations and Attributes

An important attribute for much of today's tape market is the adhesion to low surface energy substrates. This performance is achieved readily in acrylics through tackification, but often with a significant sacrifice in cohesive strength. Table 1 compares the performance of an additional higher solids formulation with an example tackified acrylic adhesive. The prototype formulation exhibits significantly higher shear adhesion and nearly double the peel adhesion to HDPE while maintaining tack and peel on a polar substrate such as a stainless steel plate. In addition to the improved performance, formulation B is more than15% higher in solids as compared to this example tackified acrylic with a liquid viscosity of only 4900cP.

Formulation	**Shear (72 °F) 4 PSI**	**180 Peel (ozf\in) 20 min SS**	**180 Peel (ozf\in) 20 min HDPE**	**Tack (oz)**
Tackified PSA (52% solids)	**5**	80	**45**	90
Formulation B (69% solids)	**36**	103	**93**	87

Table 1: PSA performance comparison of a prototype and a traditional tackified acrylic

Given the viscoelastic nature of pressure sensitive materials, the rheological profile of a PSA can provide insight into performance. Loss modulus (G") can be linked to a measurement of adhesion while storage (or elastic) modulus (G') can be linked to a measurement of cohesion. The temperature sweep below explains the performance profile seen in Table 1. The elastic modulus of the high solids formula is much higher at elevated temperatures meaning it has higher cohesion and better high temperature resistance compared to a tackified acrylic commercial adhesive. This is indicative of the more efficient crosslinking achieved in the high solids approach without the dilutive effect observed in a typical tackified formula. Additionally, the higher tan delta peak observed is indicative of the higher adhesion values seen for the high percent solids formula.

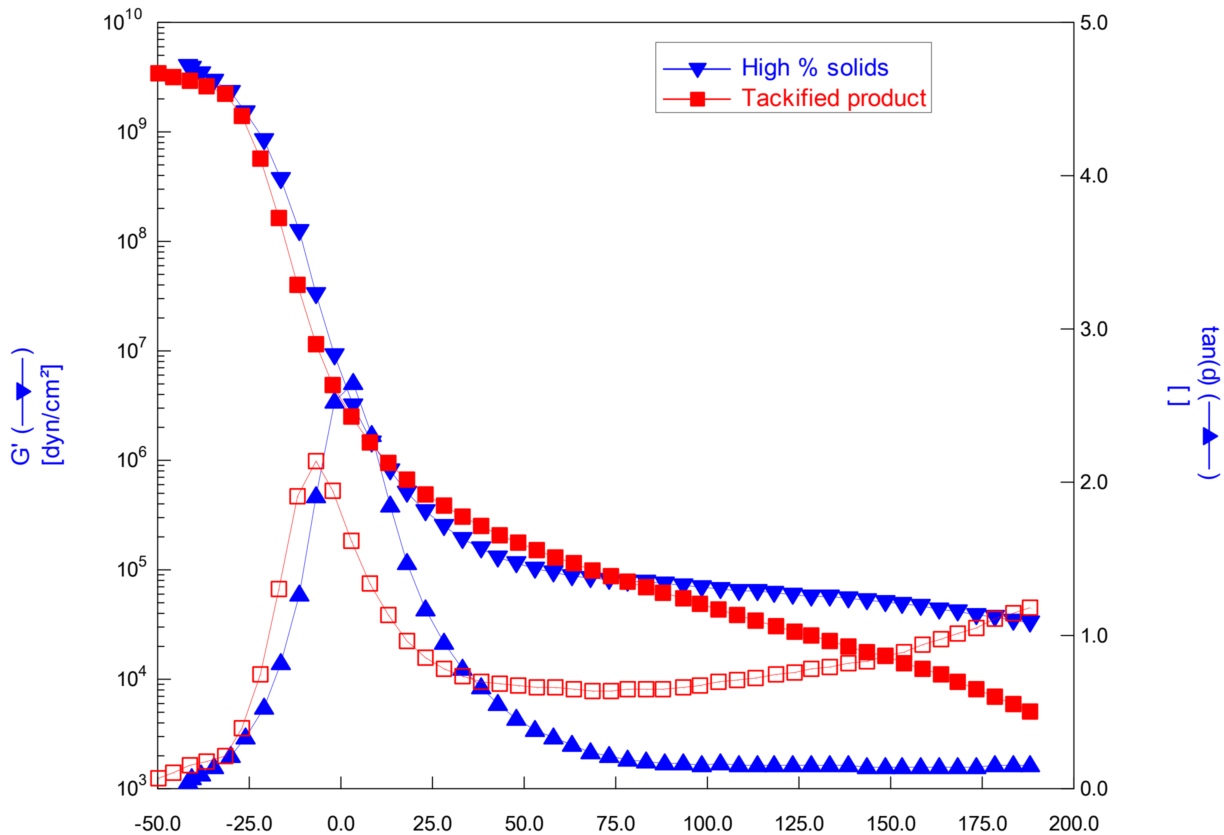

Figure 2: Rheological temperature sweep of high solids prototype compared to a tackified acrylic adhesive.

Table 2 highlights the breadth of performance achievable via this approach with two additional embodiments (formulations C and D) as compared to a commercial acrylic adhesive designed for high tack and peel. In this design space, almost 30% higher loop tack is achieved as compared to conventional approaches while other PSA performance attributes such as shear and stainless steel peel are maintained. Again both formulations have >15 % higher solids compared to conventional approaches while maintaining solution viscosities of 4800cP-7500cP.

Test	Acrylic PSA	Formulation C	Formulation D
Loop Tack (oz)	70	102	101
Shear 4PSI (hrs.)	3	20	31
Peel SS, 20 min (ozf/in)	98	102	104
Solids (%)	49	69	67

Table 2: Performance compare to Acrylic PSA

Solids and Viscosity

Figure 3 compares percent solids and viscosities of conventional acrylic adhesives with the new high solids approach. Using conventional approaches, the percent solids ranges from 45 to 55 with viscosities from approximately 2000 to 8,000 centipoise.

New high solids formulations can meet or exceed adhesive performance needs (as shown in earlier figures) while delivering significantly higher solids. This novel approach can achieve percent solids increases of 10-15% (or higher) with viscosity ranges suitable for the majority of coating methods used in the industry today. As with conventional acrylics, the viscosity can be tailored based on further solvent dilution (Figure 4) to enable this technology to benefit even coating techniques that require low viscosity.

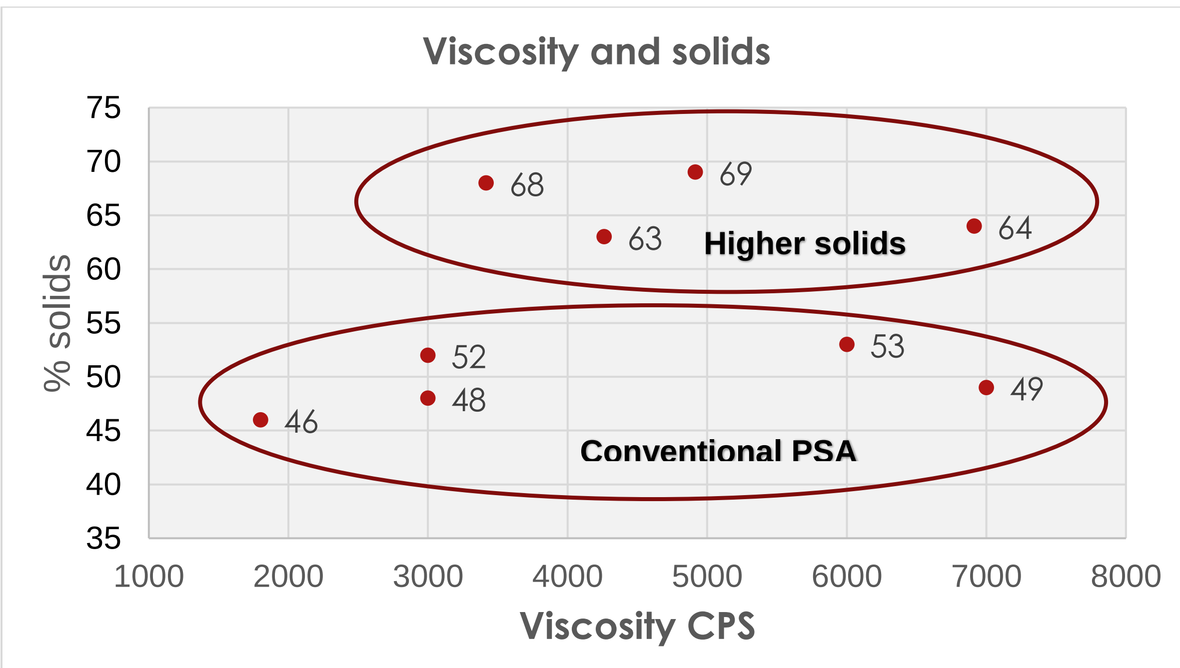

Figure 3: Viscosity comparison of higher solids vs. conventional PSA

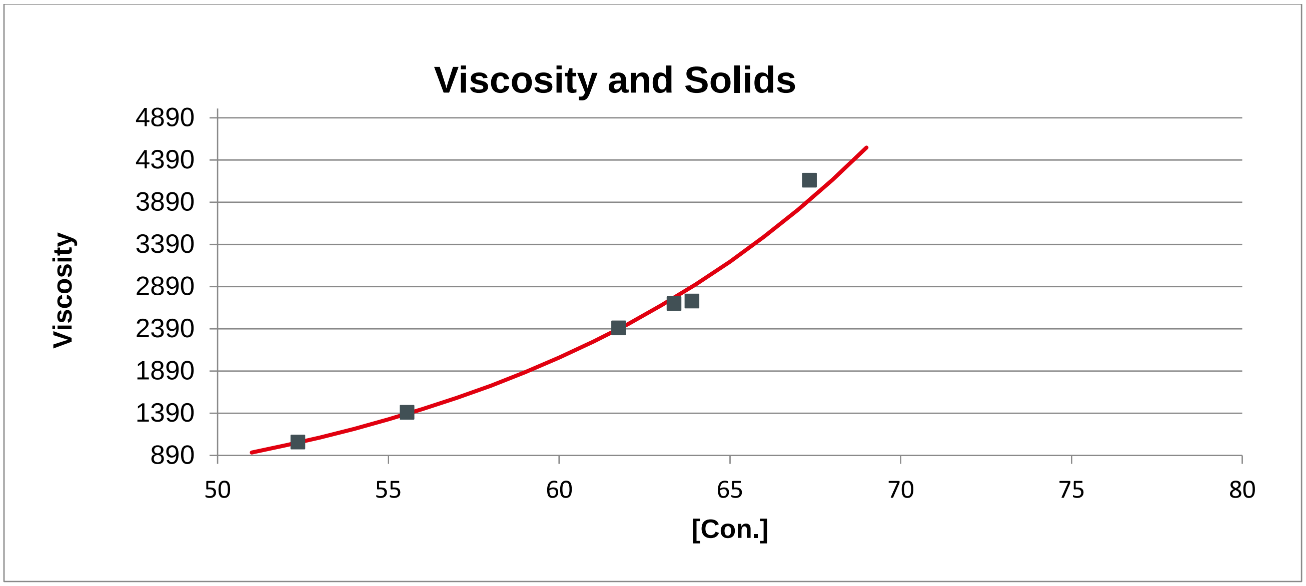

Fig 4: Dilution curve for high solids prototype formulation

Summary

This new approach to delivering high solids solvent acrylics can be used to produce 10% – 15% or higher solids than conventional solvent PSA. All the benefits of high solids can be achieved while maintaining coatable viscosities and the potential to additionally deliver improved adhesive performance. Attributes such as low surface energy adhesion, shear, and tack, can all be improved to meet or exceed traditional all acrylic or tackified acrylic systems. Further, the flexibility exists in this approach to tailor the performance and viscosity as per specific market or coater need. Improved line speed, lower costs in shipping and packaging, less storage space, less solvent to remove during coating, and less solvent to dispose of are some of the potential benefits of this approach.

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