UV-Cured Pressure Sensitive Adhesives – Lower Total Cost Of Ownership And Environmental Superiority

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Introduction

An eco-efficiency study was conducted to compare the environmental impacts and total costs of UV-cured pressure sensitive adhesives (PSAs) versus thermally-cured solventborne and waterborne PSAs. PSAs are designed to bond without the use of heat or moisture. They have a wide variety of consumer and commercial applications (e.g. masking tape, electrical tape, labels) and are rapidly gaining market share from wet glue tapes and labels. PSAs also have specialized industrial applications such as clear protective barriers on appliances and automobile components, reflective material on signs, and bonding a variety of surfaces, either permanently or temporarily. Formulations are normally composed of bonding solids (e.g., an elastomer or polymer and tackifying resin), additives, carriers, and oils. The general categories of elastomers and polymers used in PSAs include rubbers, acrylics, and silicones. In some cases, more than one resin is used to provide additional properties not available with single resin formulations. Other additives or fillers may be used to improve performance characteristics such as viscosity or specific gravity, lower cost, or adhesive color.

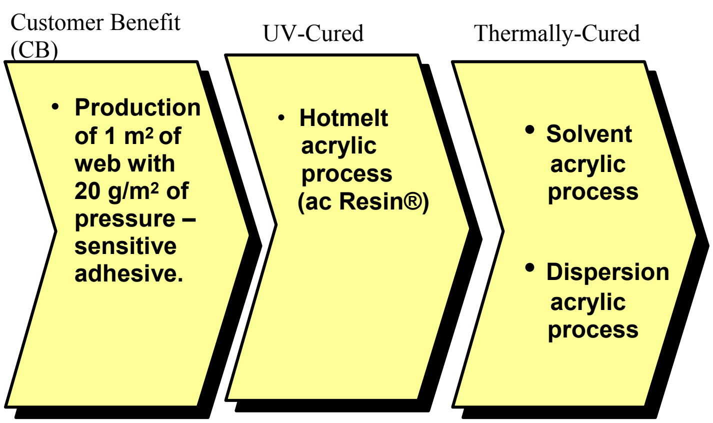
UV-cured PSAs promise an enhanced performance, higher productivity and an improved environmental footprint versus traditional solvent- and waterborne adhesives. Eco-efficiency is one tool that can be used to strategically develop and pursue the best products. The traditional formulation of PSA is either solvent- or water-based. Solvents are used as carriers, allowing the formation of a liquid that is easily transported and applied to the substrate material (the web). The solvents are removed through evaporation and the rubbers, resins and other coating solids remain on the web when the coating is dry. The pressure sensitive tapes and labels sector uses significant quantities of solvents such as toluene, heptane, MEK, xylene and mineral spirits, which are flammable liquids that quickly evaporate in air. In addition to the fire and explosion hazards, the U.S. EPA considers them volatile organic compounds (VOCs) that can contribute to ambient air quality problems and are, therefore, regulated under the Clean Air Act. Toluene, MEK and xylene are classified as hazardous air pollutants (HAPS) that can cause adverse health effects. The use of solventborne adhesives can generate significant VOC and HAP emissions. VOCs and HAPS are emitted when solventborne coatings are stirred, when they are applied to the web, and when they dry. Therefore, the pressure sensitive tapes and labels sector is currently regulated by the states and the U.S. EPA. However, the U.S. EPA is developing additional regulations under the Clean Air Act Amendments that will significantly affect the use of HAPS and VOCs by the pressure sensitive tapes and labels sector.

Eco-efficiency Methodology and Base Case

Eco-efficiency is a methodology that assesses the environmental and economic impacts of products and processes over their life-cycle.[1]. The methodology was created in partnership with an external consultant, has been further developed by BASF, and is based upon the ISO14040 standards for life-cycle analysis with some additional enhancements that allow for expedient review and decision-making at all business levels. Since its inception in 1996, more than 260 analyses have been completed on products ranging from vitamins to building materials and industrial chemicals. Energy, emissions, toxicity, health effect potential, resource consumption and land use are assessed to gauge the environmental impacts, and for economic impacts, the total cost of using the three adhesive technologies were assessed for materials, manufacturing, wastes, energy and EHS programs.

The first step is to define the customer benefit (CB), so that the application and use for all of the alternatives considered can be compared. Here, application and curing of adhesive on one square meter of web surface area is considered. The three acrylic adhesive technologies compared are shown in Figure 1 and the study encompasses the production, transportation, coating, drying and finishing.

Fig. 1 Eco-efficiency of Pressure Sensitive Adhesives



Coating application and curing parameters are based upon manufacturers' recommendations, and other base case assumptions for product use and disposal are shown in Table 1. For the base case the environmental impacts and costs are analyzed for the production of 1 m^2 of web with a dry coat weight of 20 g/m^2 and coating width of 0.8 m, normalized to a total annual production of 76.8×10^6 m^2 with a 5% material loss multiplier. No capital investments were included since this study compares costs of using the adhesives and not startup costs, and supply chain costs were assumed to be captured in the purchase price of the adhesives.

Table 1 Summary of assumptions for base case			
Input data (per 1m^2 web)	**Acrylic Adhesive Technology**		
Adhesive	Hotmelt	Solvent	Dispersion
Input Adhesive	21 g	21 g	21 g
Input Solvent	-	23.7g	-
Total	21 g	44.7 g	38 g
Solids	100%	47%	55%
Adhesive layer on coated tape	20 g	20 g	20 g
OPP	25 g	25 g	25 g
Silicone	1.1 g	1.1 g	1.1 g
Drums	2.2 g metal	11.5 g metal	1.8 g plastic
Transport distance – adhesive	7200 km	1000 km	1000 km
Transport distance – OPP	200 km	200 km	200 km
Line Speed	200	167	100
Coating (Web) Width	0.8	0.8	0.8
Production Rate	9,600	8,016	4,800
Yearly Production Operation	8,000	8,000	8,000
Annual Production	76,800,000	64,128,000	38,400,000
Normalized Production Time	104	125	208
Production Normalization Factor	1.00	1.2	2.0

Material prices for the three technologies are based on drum amounts in truck-load quantities, and price represents adhesives with similar performance, i.e. high end specialty and low-end commodity prices were omitted. Abatement of VOC vapors was handled via a thermal oxidizer (TO) was based on a recuperative system with a 35% heat recovery with the following operational parameters: process air flow 30,000 SCFM, process temperature of 200 ^{0}F, VOC loading of 60 lbs/hr, heat of combustion of VOCs at 15,000 BTU/lb, a thermal efficiency of 95% and VOC destruction efficiency of 98%. Maintenance and operational costs for the TO were calculated to the specific production parameters of this analysis and were developed using several peer-reviewed publications, including ones from the U.S. EPA[2,3,4]

Eco-efficiency of Pressure Sensitive Adhesives

Total Cost of Ownership

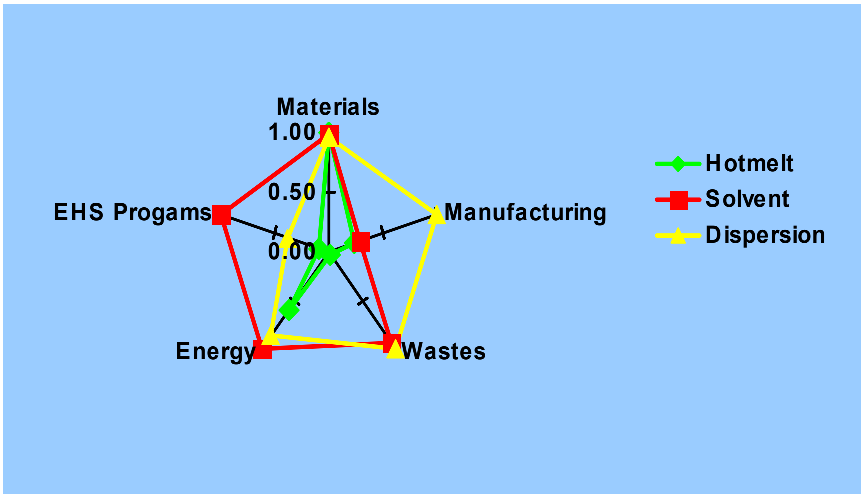
The benefits of the UV-cured Hotmelt were demonstrated in reduced energy costs and higher line speeds, which resulted in lower manufacturing costs. The total cost of using the three adhesive technologies were assessed for producing 100 m^2 of coated web under the conditions of the base case, and included costs for materials, manufacturing, wastes, energy and EHS programs. The results, as shown in Table 2 and Fig. 2, demonstrate that the Hotmelt adhesive has the lowest total cost of ownership, with a 50% cost savings as compared to the Solvent adhesive and a 40% savings compared to the Dispersion process. Energy was a significant differentiator in the cost model. The results found that the Hotmelt process uses more electricity than the other two processes during adhesive preparation, coating, curing and finishing; however, natural gas consumption for the Solvent and Dispersion during curing and solvent incineration results in a higher overall costs for those two technologies. The benefit of the UV-cured Hotmelt is elimination of natural gas consumption for VOC vapor abatement via a thermal oxidizer, which reduces energy consumption by 30% as compared to the Solvent-based adhesive.

Table 2: Total cost of ownership for production of 100 m^2 of coated web.

Cost Item	Units	Technology		
		Hotmelt	Solvent	Dispersion
Materials	$/100m^2$	$ 128.17	$ 127.28	$ 124.00
Manufacturing	$/100m^2$	$ 9.02	$ 10.81	$ 38.00
Wastes	$/100m^2$	$ 0.005	$ 0.19	$ 0.20
Energy	$/100m^2$	$ 397.88	$ 666.42	$ 575.60
EHS Progams	$/100m^2$	$ 0.003	$ 0.028	$ 0.010
Total Cost	**$/100m^2$**	**$ 535.08**	**$ 804.73**	**$ 737.81**
Normalized		**1.0**	**1.5**	**1.4**

Even though the price per kg as supplied (wet) for the Hotmelt adhesive was higher than the Solvent or Dispersion technologies ($5.90, $2.59 and $2.13 respectively) the total material cost per 100 m^2 of coated web is about equal due to higher solids content. The total material cost was $128, $127 and $124 dollars per 100 m^2 for the Hotmelt, Solvent and Dispersion technologies, respectively. The cost for silconized paper and OPP film were the same for all three adhesives. Analysis of manufacturing costs and waste costs showed that the Hotmelt adhesive had lower ownership costs. Labor and operation and maintenance costs were lower due to the high line speed that results in a higher annual production (m^2/yr) and a subsequent lower cost per (100 m^2). The Hotmelt process has a line speed of 200 m/min, which produces 20% more coated web annually compared to the Solvent process and 100% more than the Dispersion process. The waste costs for the Solvent and Dispersion adhesives were higher, as compared to the Hotmelt, due to disposal of solvents and waste water treatment for the dispersion adhesive.

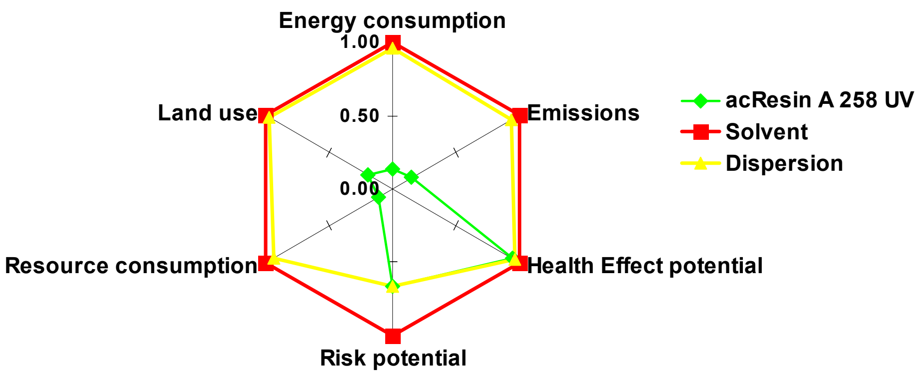
Fig. 2. Results by cost item for use of adhesives.



Environmental Impacts

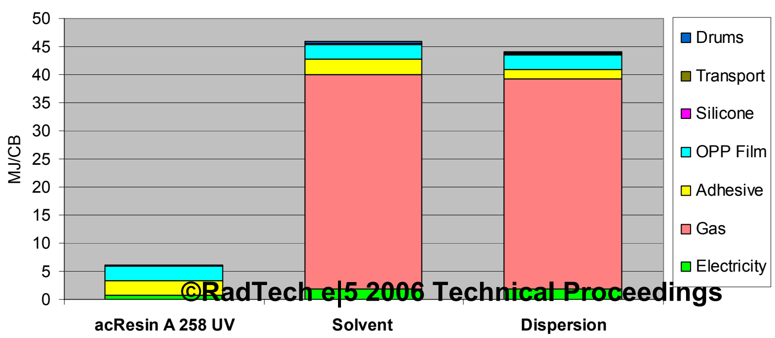
Figure 3 shows the relative environmental impact of the PSA in six environmental categories. The most significant differences occur in emissions, energy and resource consumption, land use and risk potential. The overall health effect potential for the PSA is similar.

Fig. 3. Ecological fingerprint for PSA.



The greatest environmental benefit of UV-cured adhesives is the outstanding efficiency of the curing process. Figure 4 shows the individual energy consumption data (MJ/CB), which are summarized on the ecological fingerprint.

Fig. 4. Energy consumption



The thermally cured Solvent and Dispersion adhesives have longer, more energy-intensive curing processes, which consume large quantities of natural gas and result in correspondingly higher environmental impact and utility cost. This characteristic is also the reason for the high resource consumption of the thermally cured adhesives. The overall emissions results are primarily impacted by the air emissions. Figure 5a and 5b show the global warming (GWP) and photochemical oxidant (i.e. smog) creation potentials (POCP) for the alternatives, respectively. The thermally cured adhesives have the highest GWP due to the natural gas produced and used for curing.

Fig 5a. Global warming potential.

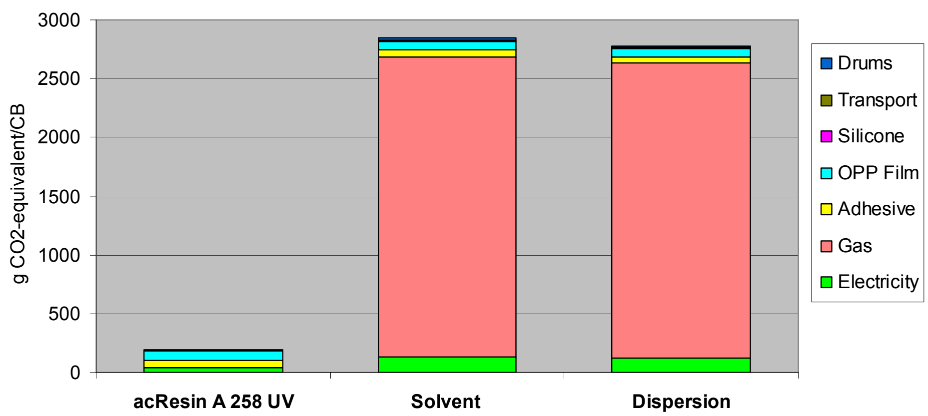
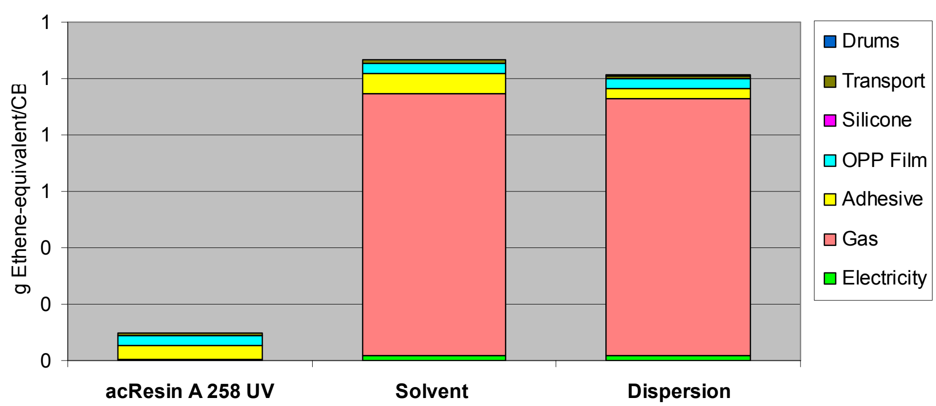


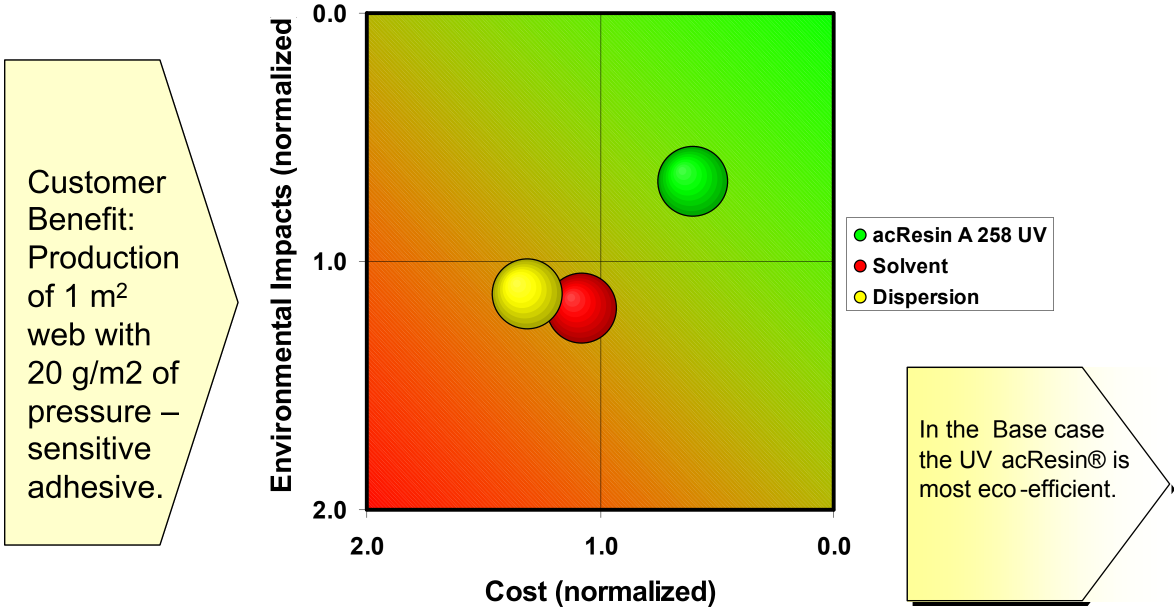
Fig 5b. Smog creation potential.



Conclusions

The eco-efficiency portfolio consolidates all of the individual environmental and economic results into one representation, allowing for an overall picture of which products are best. The most eco-efficient products lie in the upper right-hand quadrant, which corresponds to the lowest environmental and cost impacts. Figure 6 shows the portfolio for pressure sensitive adhesives when the total cost of using the products is considered. The UV-cured Hotmelt adhesive is the most eco-efficient—due to the more efficient curing processes they have less overall environmental impact and lower costs than the thermally cured Solvent and Dispersion adhesives.

Fig. 6: Eco-efficiency portfolio for PSA.



The results of the eco-efficiency study demonstrate the advantages of UV-cured Hotmelt adhesives as compared to both Solvent and Dispersion adhesives in both a reduced environmental footprint and lower total cost of ownership. UV-cured Hotmelt adhesives are successful products that support industry sustainability initiatives.

References

[1] Saling, P.; Kicherer, A.; Dittrich-Kraemer, B.; Wittlinger, R.; Zombik, W.; Schmidt, I.; Schrott, W.; Schmidt, S. Int. J. Life Cycle Assess. 2002, 7 (4), 203.

[2] USEPA (2002a). EPA Air Pollution Control Cost Manual, 6th ed. January 2002. United States Environmetal Protection Agency. Office of Air Quality Planning and Standards. Research Triangle Park, North Carolina 27711. EPA/452/B-02-001.

[3] ICAC (2002). ICAC Guidance Method for Estimation of Gas Consumption in a Regenerative Thermal Oxidizer. Institute of Clean Air Companies. July 2002.

[4] NWMOA (1999). The Northeast Waste Management Officials' Association and The Northeast States for Coordinated Air Use Management. Pressure Sensitivie Tapes and Labels: The Clean Air Act Ammendments of 1990 and Pollution Prevention Opportunities, March 1999