Boost the vibration damping properties of your LASD coatings with the Interactive Avanse™ technology

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Introduction

Coatings have been widely used for decorative and protection purposes against fire, moisture, corrosion…another functionality of interest being the control of sound propagation.

There exist different ways of managing sound propagation mainly based on barrier and dissipative treatments such as sound absorption by polyurethane foams and sound vibration damping by asphaltic membranes or viscoelastic materials.

The acrylic polymer technology has shown to be an efficient chemistry for dampening sounds originating from vibrating metallic substrates when properly formulated into protective coatings combining decorative, and protective functionalities.

The sound dampening performance of such coatings is usually controlled by the amount of the polymeric phase used in the formulations, some key formulating knowledge and the thickness applied.

This paper will show how the acrylic Interactive chemistry through its capability of interacting with other inorganic components of the formulations offers the possibility to significantly boost the sound dampening performance of such coatings by energizing the inorganic phase and turning it into a real contributor to the overall sound dampening efficiency of the formulated coating.

Sound dampening with viscoelastic materials

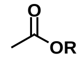
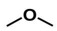
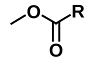
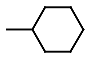
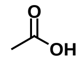
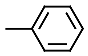
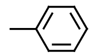
Viscoelastic materials offer the possibility to dampen sound vibration through heat dissipation when operated in the vicinity of their glass transition temperature (Tg)
The viscoelastic properties of a polymeric material are often expressed by its Tan δ defined as the ratio of the viscous also called loss modulus (E”) to elastic modulus (E’) as follows:

$$\text{Tan}\ \delta = E'' / E' \qquad (1)$$

The sound damping efficiency of a polymeric material can be expressed by its loss area (LA) and defined as the area under the loss modulus / temperature curve in the vicinity of the Tg of the polymer.
It could be demonstrated that the loss area (LA) is a function of the structure of the mer unit of the polymer following a group contribution approach of each functionality contained in the mer as shown below:

$$LA = \Sigma(LAi)\ Mi / M = \Sigma\ Gi / M \text{ where } Gi = (LAi)\ Mi \qquad (2)$$

Based on this group contribution approach method it could be highlighted that the acrylic polymer chemistry is particularly well suited to sound dampening as showing some of the highest LA values offered by mer structures as shown in Table 1 below :

Group	Location	$(La)_i$ (Gpa K)	G_i (Gpa K) (g/mol)	Group	Location	$(La)_i$ (Gpa K)	G_i (Gpa K) (g/mol)
$-CH_2-CH-$	Backbone	3.4	91.8		Directly attached	20.8	936
	"	19.1	305.8		"	20.1	905
	In side chain	3.5	287		"	20.8	936
	"	2.2	166		"	11.9	916
$-CH_2-CH(CH_3)-CH_3$	"	-1.7	-98	$-CH_3$	"	11.0	165
$-CH_2-$	"	0.5	7	—OMe	"	21.7	674
$-CH-$	"	-3.0	-42	—OH	"	4.7	80
—CN	"	14.5	377	—CN	"	23.2	603
—Cl	"	15.7	556	—Cl	"	9.2	327

Chang, M. C. O.; Thomas, D. A.; Sperling, L. H. *J. Polym. Sci., Part B: Polym. Phys.* **1988**, *26*, 1627-1640.

Table 1: Loss Area Group Contribution Theory

The sound damping efficiency is practically determined by the measurement of the Loss Factor (ɳ) (3) at a given temperature and obtained by the Half Power method as follows that characterizes the ability of the sound damping material to dampen the vibration of an excited metallic bar as described in Figure 1 and 2 below :

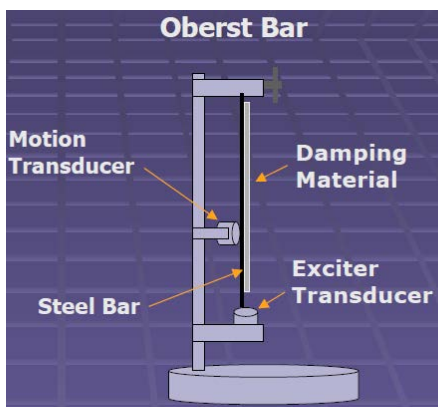


Figure 1: CLF measuring device

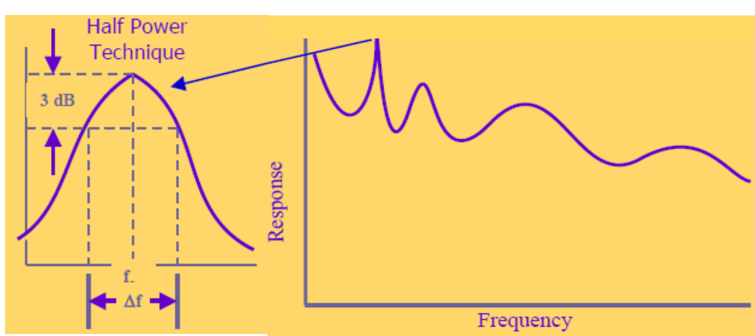


Figure 2: Half Power technique to determine the Composite Loss Factor

$$\eta = \Delta f / f \quad (3)$$

The integration of the loss factor over a broad range of temperatures gives the Composite Loss factor (CLF) that characterizes the performance of the sound damping material over its range of operating temperatures (Figure 3). The higher the CLF the better the sound damping performance.

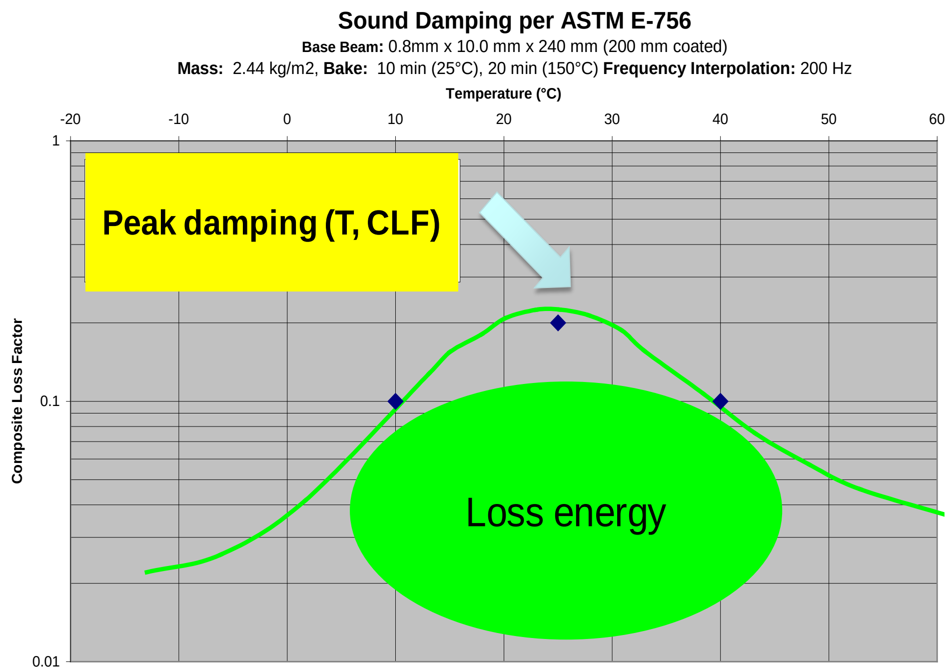


Figure 3: Composite Loss factor curve

Sound dampening with the acrylic chemistry

The peak CLF temperature can be shifted to the lower end or higher end of the temperature range by adjusting the Tg of the polymer as shown in Figure 4 making the acrylic chemistry the technology of choice for this kind of application:

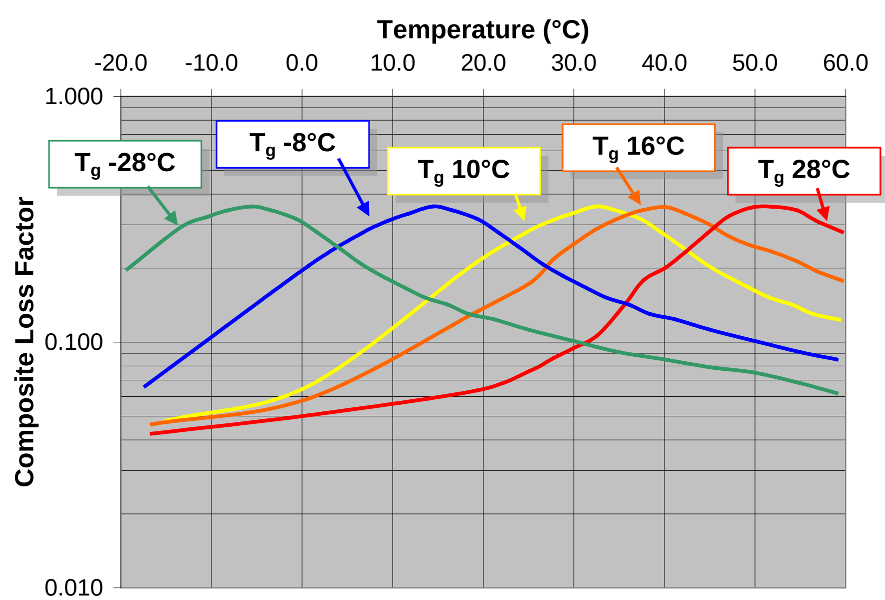
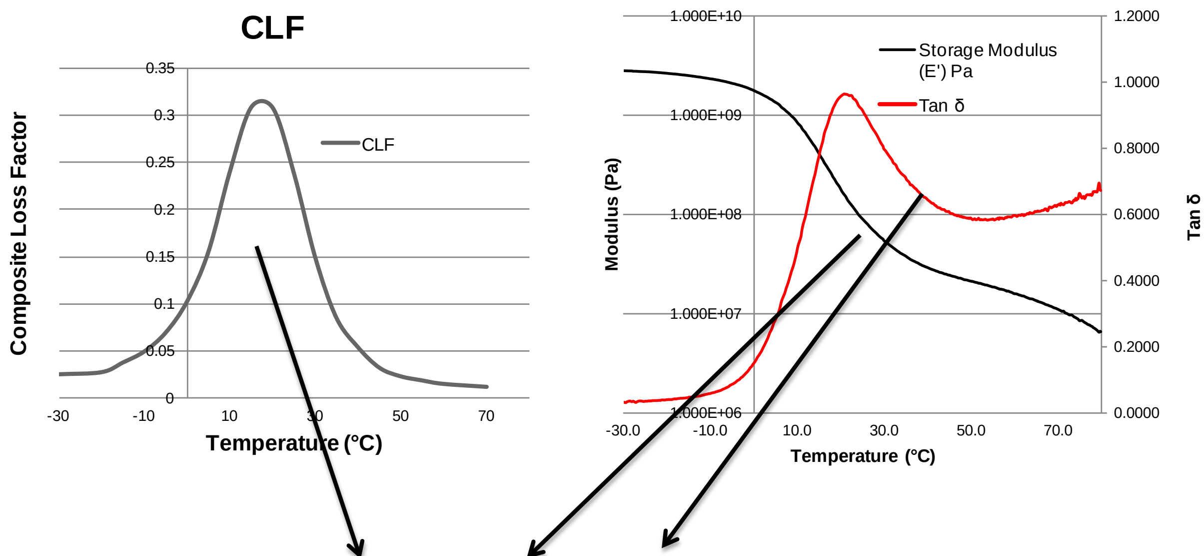


Figure 4: Impact of polymer Tg on Composite Loss Factor curve

In the same way moving from a purely thermoplastic acrylic polymer to a cross-linkable composition will also shift the Composite Loss factor curve to the upper temperature range.
As can be expected an opposite effect can be obtained through the use of external plasticizer.
As expected there exists a strong correlation between the CLF peak temperature / intensity and the Tan δ of the material measured by Dynamic Mechanical Thermal Analysis. The last parameter playing a major role in the overall performance of the coating is the thickness applied as shown below:



CLF ~ k.Elastic modulus .Tan δ.Thickness^2

Figure 5: Correspondence between Composite Loss factor and Dynamic Mechanical Thermal Analysis

The sound damping material comprises the waterborne binder, an extender package and appropriate formulating aids as shown in the following typical formulation:

Type :	MATERIALS :	% A.I.	Density	Parts by weight :	Volume	PVC (%)	% Dispersant / Pigment
	A) GRIND						
Extender	Mica 325	100,0%	2,85	129,60	45,47	12,1%	
Extender	Durcal 40	100,0%	2,75	386,60	140,38	37,3%	
Extender	Carbon Black	100,0%	2,60	6,00	2,31	0,6%	
	GRIND TOTAL			522,20	188,16		
	B) LETDOWN						
Binder	Acousticryl AV-2240	46,0%	1,04	446,00	428,85		
Additives	Acrysol ASE 60	30,0%	1,06	10,10	9,50		
Additives	Tego Evonik 2315XP	100,0%	0,91	2,00	2,20		
Dispersant	Orotan N4045	45,0%	1,32	5,50	4,17		0,5%
Additives	Tergitol 15 S 40	100,0%	1,06	3,50	3,30		
Water	Water	100,0%	1,00	10,10	10,10		
Additives	Ammonia (28%)	100,0%	1,00	0,60	0,60		
	TOTAL			1000,00	646,88	50,0%	0,5%

Weight solids % :	72,7%	
Vol solids % :	58,2%	
PVC % :	50,0%	
Pigment / Binder (W/W ratio) :	71,8%	28,2%
% Coalescent / Dry Polymer :		
% Dispersant / Pigment :	0,5%	
Grind weight solids % :	100,0%	
Grind density :	2,78	
Density :	1,55	

Table 2: Typical vibration sound damping formulation

This high solids material can be applied by air less at a 1 to 3 mm thickness hence its name: LASD (Liquid Applied Sound Damping) and shows the following appearance :

Figure 6: Acrylic polymer based vibration sound damping material

Such a material already out performs conventional sound damping materials such as bitumen pads as shown in Figure 7 by the Composite Loss factor measurements conducted at a 200 Hz frequency:

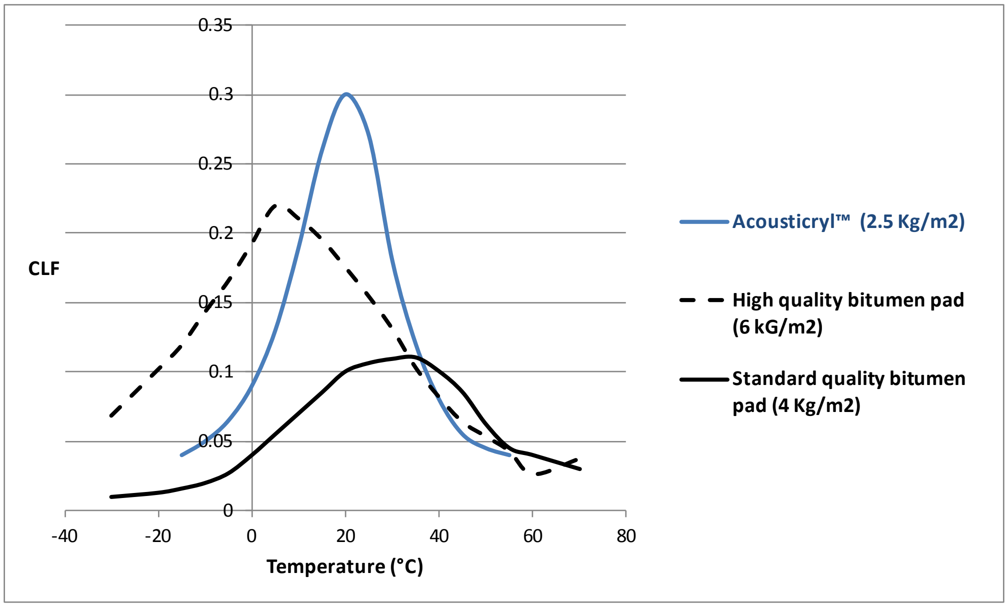


Figure 7: Comparative Composite Loss factor curves of asphalt membranes and acrylic LASD

As explained before the performance of the coating is influenced by the intrinsic polymer properties, the polymer level (Pigment Volume Concentration) and the thickness applied.
As a general rule the lower the PVC the higher the performance of the formulation.

However lowering the PVC has got an immediate adverse effect on formulation cost and increasing the thickness a similar adverse effect on application cost.

The introduction of the interactive Avanse™ technology has allowed a significant boost in performance at lower formulation (higher PVC) and application cost (lower thicknesses) as demonstrated below.

Sound dampening with the interactive Avanse™ acrylic chemistry

The interactive Avanse™ acrylic chemistry has been developed to energize the usually inactive extender fraction of the formulation by closely adsorbing onto inorganic particles such as calcium carbonate, clays ,…this way turning the extender fraction into an active component of the formulation now contributing to the sound damping properties of the material as shown in Figure 8 :

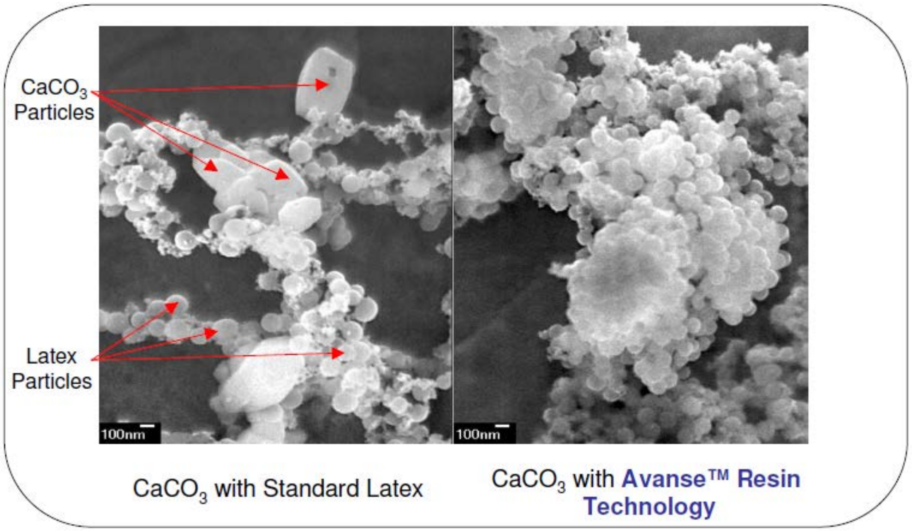


Figure 8. Interactive Avanse™ acrylic LASD chemistry adsorbing onto inorganic particles

The Avanse™ interactive acrylic chemistry will preferentially adsorb onto positively charged inorganic surfaces as follows:

Inorganic material	Calcium carbonate	Calcium carbonate	Talc	China Clay	Mica	Graphite	Wollastonite
Particle size D50 (µ)	30	4	1,7	2,2	5	3,4	12
Adsorption level (%)	15	37	31	99	87	20	77

Table 3: Adsorption of Interactive Avanse™ acrylic LASD chemistry onto inorganic particles

This strong interaction between the organic and inorganic matrices allows the formation of a composite material with reinforced mechanical properties translating into a enhanced sound damping performance as shown in Figure 9:

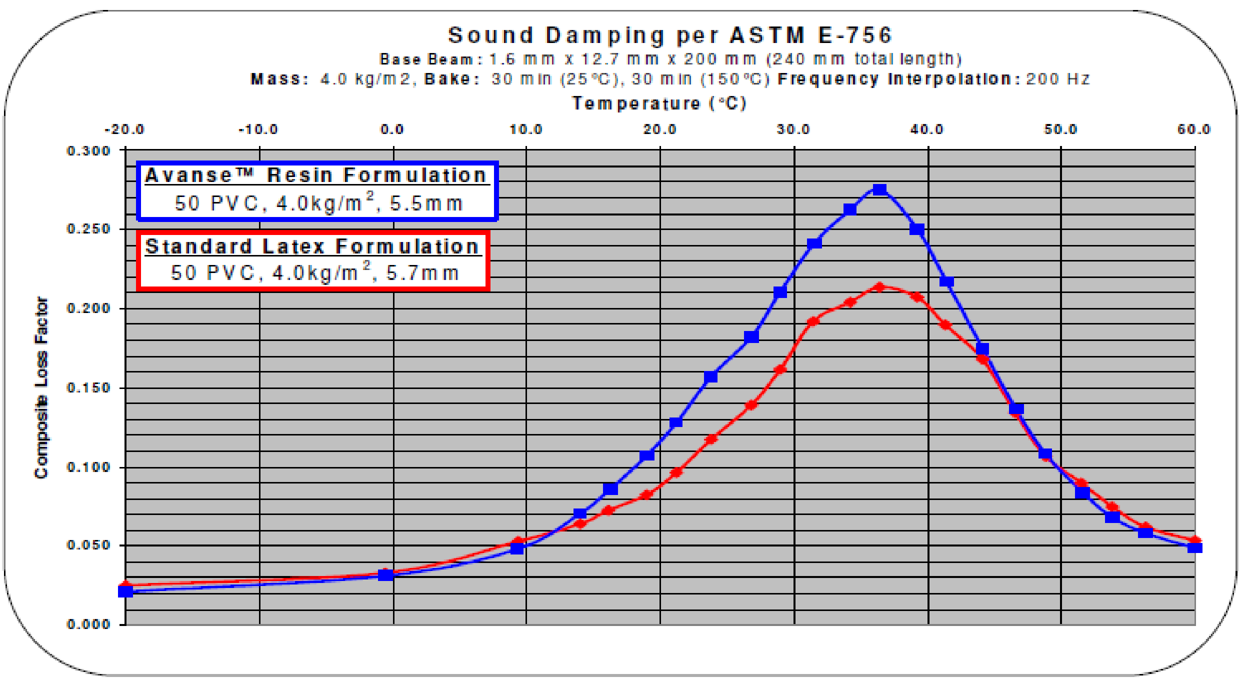


Figure 9: Increase in vibration sound damping performance with the Avanse™ acrylic chemistry

This increase in performance can in turn be declined into lower cost formulations (increased PVC) or/and lower application cost (lower thicknesses) as demonstrated in Figures 10 and 11.

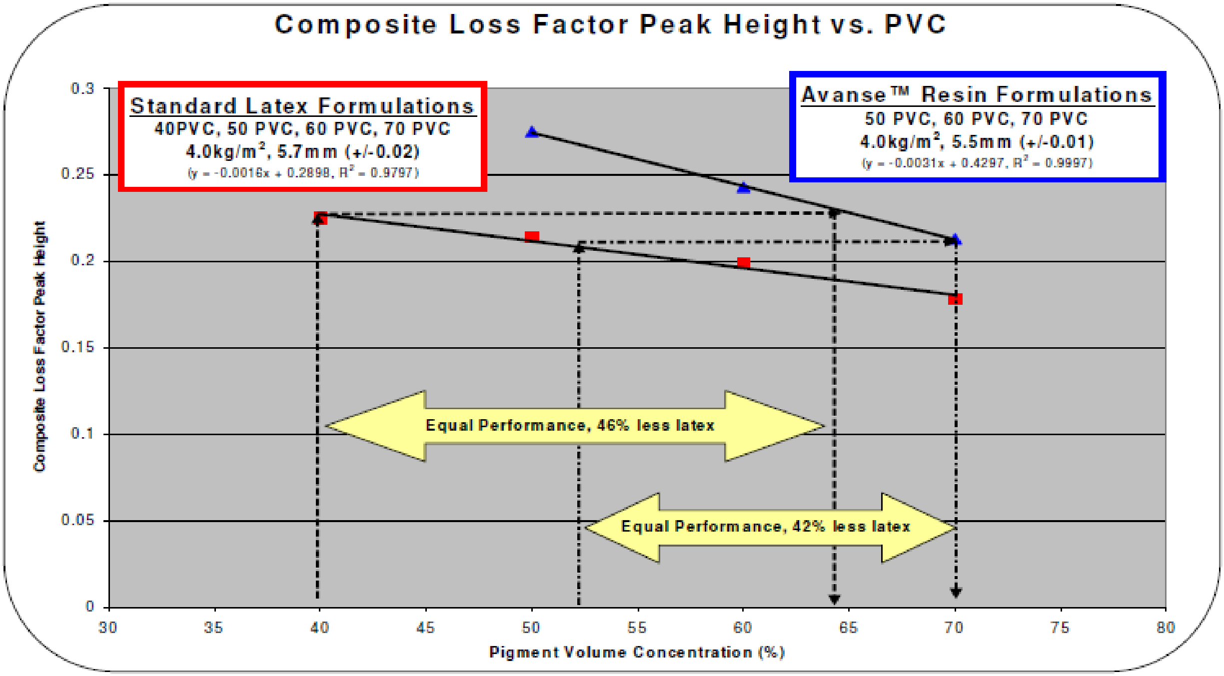


Figure 10: Composite Loss factor versus formulation PVC

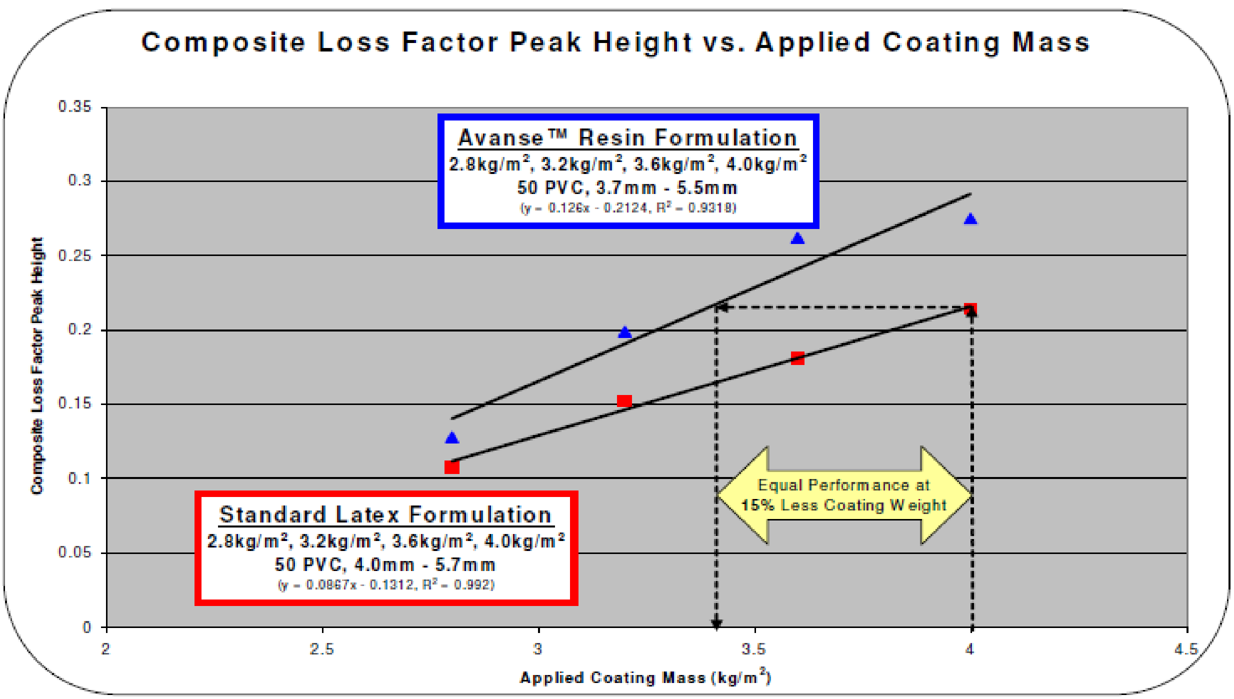


Figure 11: Composite Loss Factor versus application thickness

Applications involving the Interactive Avanse™ Liquid Applied Sound Dampening technology

As it could be demonstrated the Interactive Avanse™ acrylic technology can be formulated into high performance / low formulation cost sound dampening formulations that can applied at lower application thicknesses and cost for a range of industrial applications (Figure 12)
This allows formulators to develop multifunctional formulations combining sound dampening and fire resistance or anti-condensation properties as in following examples of formulations for use in machinery

rooms or in building applications when applied on roofing metallic panels and sheet metal constructions for example, white goods being another potential area of application for this technology:

Figure 12: Application areas for the LASD acrylic Avanse™ vibration sound damping technology

Such formulations will be better applied by airless in 1 to 2 mm thicknesses.and show excellent adhesion properties on a variety of metallic substrates.
Drying properties will be a function of the thickness applied and the temperature and humidity conditions and will range from 2 to 4 hours for the TD (Touch Dry) to 5 to 10 hours for the DT (Dry Through) times.

Example of formulation (Table 3) combining acoustic and condensation resistance properties for use as internal coating on building roofing panels:

Material Name	Type	Kg	Liters	Level	
Acousticryl	Binder	237,04	227,92		
Tego Foamex 1488	Defoamer	4,81	4,81		
Tergitol 15-S-40	Surfactant	2,41	2,24		
Orotan 850	Dispersant	16,16	13,47	1,00%	% Disp
Tioxide TR92	TitaniumDioxide	109,40	27,35	10,00%	PVC
Barytes	Extender	60,17	13,68	5,00%	PVC
Perlite	Light weight filler	142,22	54,70	20,00%	PVC
Alfrimal 446	ATH	99,28	41,03	15,00%	PVC
Durcal 40	CaCO3	73,85	27,35	10,00%	PVC
Texanol	Coalescent	8,30	8,73	7,00%	% Coal
Acrysol ASE-60	Thickener	9,62	9,08		
Water	Water	236,73	236,73		
Totals		1000,00	667,09		

Property	Value (without additives)	
Total PVC	60,00	%
Volume Solids	41,00	%
Weight Solids	60,35	%
Density	1,4990	kg/l
Dry Density	2,1884	kg/l
Total Dispersant	1,00	%
Total Coalescent	7,00	%
VOC Generic Water Excl.	29	g/l

Table 3: Example of multifunctional (sound vibration damping + condensation resistance) formulation

Conclusion

The Interactive Avanse™ acrylic chemistry is particularly well suited to vibration sound damping applications.
Thanks to its unique ability to make composites with inorganic components it allows the formulator to develop high performance / low formulation cost compositions that can be targeted to a variety of industrial applications across the Marine, Building and White Goods segments.

References

1. David I.G. Jones, Handbook of viscoelastic vibration damping, 2001
2. L.H. Sperling, Sound and vibration damping with polymers, 1990
3. Jennifer Renninger, Understanding damping technologies for noise and vibration control, 2000.
4. Tom Irvine, Damping properties of materials, 2004.
5. M. C. 0. Chang, D. A. Thomas, and L. H. Sperling, Group Contribution Analysis of the Damping Behavior of homopolymers, statistical copolymers and interpenetrating polymer networks based on acrylic vinyl and styrenic mers, 1987
6. ISO-6721. Determination of mechanical properties of plastics..Flexural vibration. Resonance curve method, 1996
7. Stanley Cook, SAE Conference: Water based sprayable damping coatings property improvements with the creation of composite latex-pigment particles in the coating through latex adsorption techniques, 2010

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