Utilization of Polyurethane-Acrylic Blends to Achieve Optimum Performance in a 1K Water-Based Wood Floor Coating

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With the advent of an environmentally conscious consumer and increased regulatory pressure, the coatings formulator is faced with developing products within the constraints of lower volatile organic compounds (VOC) while still achieving specific performance targets. Although new resins are being developed which will meet or exceed the expectations of the formulator, a blend approach using already familiar resins is still a viable option given known performance attributes of each. This article discusses the utilization of various water-based polyurethane-acrylic blends in developing a one-component (1K) wood floor coating which achieves a VOC target of 275 g/L, a balance of hardness development with very good abrasion resistance, and excellent chemical resistance in comparison with commercially formulated water- and oil-based products in the consumer- and contractor-applied markets.

POLYURETHANE COMPARISON

The major resin of most water-based wood flooring formulations is the polyurethane dispersion (PUD). PUDs are manufactured by reacting isocyanate with various polyols through a step growth reaction process. Typical polyols used to create wood flooring products include polyesters (PES), which bring exceptional chemical resistance; polycarbonates (PC), which bring a balance of hardness and flexibility; and castor-based (C) products, which are noted for improved black heel mark resistance and amber appearance.

Five water-based polyurethanes were evaluated in combination with a medium-hard (MFFT 40C) self-crosslinking acrylic (AC-1) at a 55:45 ratio of PUD to acrylic based on solids so as to attain 275 g/L VOC target. A starting point formulation was used in which the wetting, defoamer, and coalescent packages were all kept constant. *Table* 1 describes each PUD.

Hardness Development

Each coating was applied to a glass plate with a 6 mil drawdown bar, and allowed to dry at ambient temperature and humidity for seven days. After

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Figure 1—Hardness development of the PUDs with AC-1.

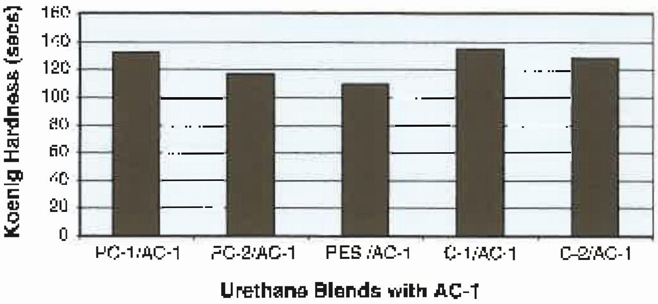
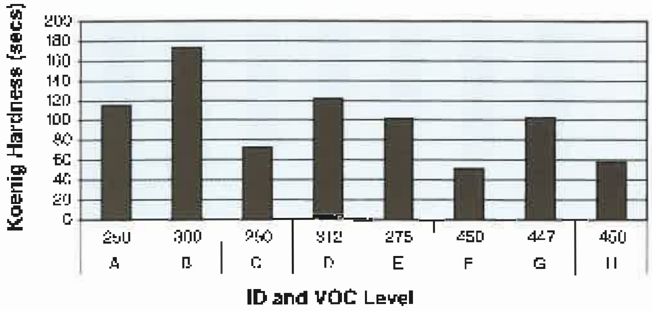


Figure 2—Hardness development of commercial wood coating products.



this drying period the hardness was measured via Koenig pendulum hardness instrument. *Figure* 1 illustrates the hardness development of the PUDs with AC-1.

The acrylic's (AC-1) hardness was measured to be 104 seconds via Koenig method. It is apparent that the nearly 1:1 blend affected each PUD in separate ways. For example, the PES/AC-1 is one of the softest due to a large impact of the AC-1 versus the harder PES component. This could be due to slight incompatibility or formulation ingredients interaction such as solvent evaporation. In the two other cases, PC-1 and C-1 blends, we see the impact of further crosslinking with increased hardness development versus the two individual components.

Commercially available one-component (1K) wood coatings tend to exhibit hardness in the range of 45 to 170 seconds measured via Koenig tester. *Figure* 2 illustrates the hardness development of each product, A to H, with its respective listed VOC maximums in grams/liter.

Abrasion Resistance ASTM D 4060

Abrasion resistance seeks to determine service life of the coating in a testing environment. Using a standard Taber abrader set up of 1000 g applied to CS-17 wheels, the coatings were subjected to 1000 cycles of wear. The average weight loss of triplicates was measured with an analytical balance. The results are reported in *Figure* 3.

As expected, the polycarbonate-based PUDs performed very well. One of the castor-based products had some decrease in resistance, but not so substantial as to discount it entirely as a floor product. To put these numbers in perspective, commercial products range in Taber resistance from 20 to 50 mg loss.

A significant finding is the balance of hardness and Taber abrasion of PC-1/AC-1 and C-1/AC-1. Each of these exhibits the highest hardness values of 132 and 135 seconds respectively, yet also the best abrasion resistance properties with 22 and 36 mg loss respectively.

For the commercial products, the Taber abrasion results varied from a low of 20 mg loss to 53 mg loss as shown in *Figure* 4.

Chemical Resistance

Floor coatings that are hard and wear resistant also need to be resistant to the common household chemicals that potentially could be present. Water, common water-based products, alcohols, and oils are used to evaluate resistance. Two coats are applied to oak flooring at 6 mil wet film thickness using a square bar to simulate final coating thickness of 4–6 mils dry, which mimics a three- to four-coat standard application. Sanding between coats allows for full coverage of any raised grain that may affect the rating of the chemical resistance of the film. Films are allowed to dry for seven days before spot testing with each chemical under watch glass covers is completed for the time indicated. After wiping of films and approximately 15-

Table 1—PUD Properties

PUD ID	% VOC	Elongation %	Koenig Hardness
PC-1	9.5	200	115
PC-2	9.0	160	130
PES	13.3	230	145
C-1	6.6	175	95
C-2	6.8	60	115

Figure 3—Abrasion resistance of PUDs with AC-1.

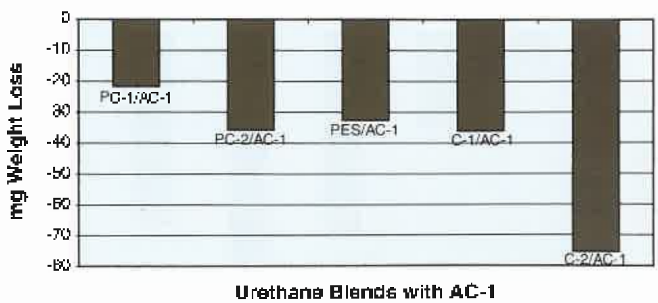


Figure 4 - Abrasion resistance of commercial wood coatings products.

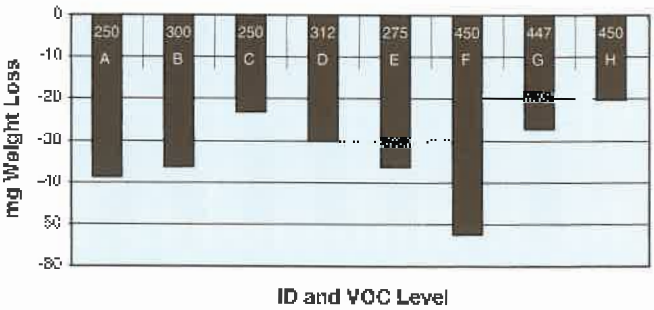


Figure 5—Gloss development of acrylics with PC-1.

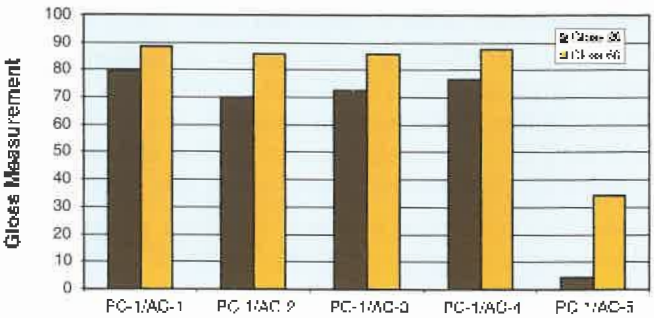


Figure 6- Hardness development of acrylics with PC-1.

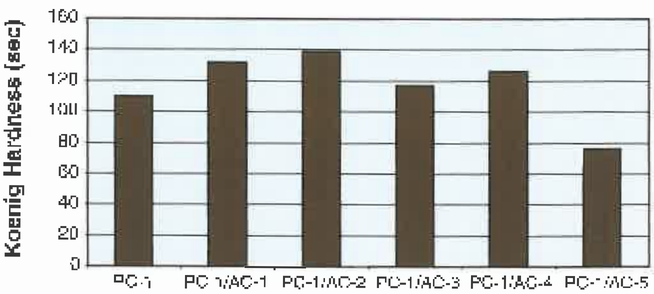
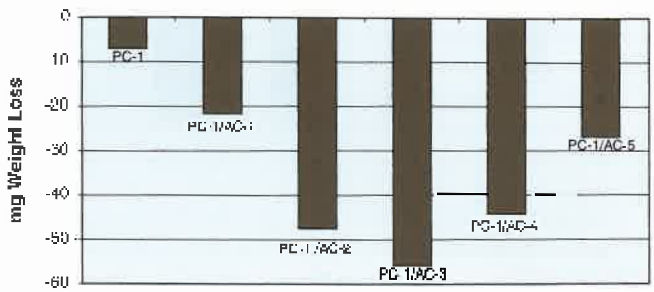


Figure 7—Abrasion resistance of acrylics with PC-1.



minute recovery, the final rating is given. The rating scale ranges from a maximum of 5 being the best with no effect on the film, to 0, indicating complete failure of the film, usually dissolving through to the substrate. *Table* 2 summarizes the results.

It is apparent that each coating performs very well with the milder water-based chemicals. Ethyl alcohol and ammonia provide the best differentiation. The polyester-based PUDs yield slightly better chemical resistance than the polycarbonate-based and castor-based products. This is not necessarily a universal trend, but one that has been noted in much of the author's work.

These data indicate that one could choose any of these as appropriate for use in 1K floor coatings. The best balance of hardness, abrasion resistance, and chemical resistance is achieved with the PC-1 polycarbonate based PUD with the self-crosslinking acrylic AC-1.

ACRYLIC COMPARISON

Is the acrylic AC-1 the optimum for use in a floor coating? To answer this question, a separate study was conducted to evaluate four acrylics in blends with the PC-1 PUD. These acrylics differ in terms of hardness and self-crosslinking type. *Table* 3 gives a description of the acrylics used.

Compatibility of PUD and Acrylic

One of the first factors to evaluate is the initial compatibility of PUDs with the specific acrylic. Simple experiments such as viscosity changes in time or appearance (particularly gloss development) in cast films are good indicators of stability. All acrylics evaluated exhibited good viscosity stability over time with PC-1, however differences did arise in terms of gloss development (see *Figure* 5).

Four of the five resins showed extremely good compatibility with PC-1. AC-5 showed significantly lowered gloss. No further studies were done to determine the cause of incompatibility, but it is speculated that excessive solvent content in formulation was the culprit.

Shown in *Figures* 6 and 7 and in *Table* 4 are the results of hardness, Taber abrasion, and chemical resistance comparisons of the different acrylic modifications versus unmodified PC-1.

The effect of acrylic modification is very evident from increased film hardness and chemical resistance to the decrease in abrasion resistance versus 100% PC-1 PUD. At issue, though, is the VOC of the coatings. The 100% PC-1 coating had a theoretical VOC of 370 g/L while the acrylic modified formulations were below 270 g/L.

Table 2—Chemical Resistance of PUD Comparison

	Chemical Resistance				
	PC-1/AC-1	PC-2/AC-1	PES/AC-1	C-1/AC-1	C-2/AC-1
16 hr—Coca-Cola	5	5	4	5	5
16 hr—water	4	5	5	3	5
16 hr—red wine	4	5	5	5	5
16 hr—hot coffee	5	5	5	4	5
1 hr—dibutylphthalate	5	5	5	5	5
1 hr—acetone	5	5	4	5	5
1 hr—vegetable oil	5	5	5	5	5
1 hr—NH_3 3.5%	3	3	4	2	5
1 hr—Et-OH (50%)	3	4	4	0	3

Table 3—Acrylic Descriptions

Acrylic Code	MFFT	Koenig Hardness	Self-crosslinking Type
AC-1	45	104	A
AC-2	50	130	B
AC-3	50	130	None
AC-4	55	140	C
AC-5	8	35	A

Table 4—Chemical Resistance Acrylic Comparison

	Chemical Resistance					
	PC-1	PC-1/AC-1	PC-1 /AC-2	PC-1/AC-3	PC-1/AC-4	PC-1/AC-5
16 hr—Coca-Cola	5	5	5	5	5	5
16 hr—water	4	4	5	4	5	4
16 hr—red wine	5	4	5	5	5	4
16 hr—hot coffee	3	5	4	4	5	4
1 hr—dibutylphthalate	5	5	4	4	5	5
1 hr—acetone	4	5	3	4	5	4
1 hr—vegetable oil	5	5	5	5	5	5
1 hr—NH_3 3.5%	2	3	3	3	4	4
1 hr—Et-OH (50%)	0	5	3	2	3	2

Table 5—Chemical Resistance Comparisons to Commercial Products

	Chemical Resistance								
	PC-1/AC-1	A	B	C	D	E	F	G	H
16 hr—Coca-Cola	5	5	5	5	4	3	5	5	5
16 hr—water	4	5	5	5	4	3	5	5	5
16 hr—red wine	4	5	5	4	4	5	5	4	5
16 hr—hot coffee	5	4	5	3	3	3	3	4	4
1 hr—dibutylphthalate	5	5	5	5	5	5	5	5	5
1 hr—acetone	5	5	5	5	5	5	5	5	5
1 hr—vegetable oil	5	5	5	5	5	5	5	5	5
1 hr—NH_3 3.5%	3	2	3	2	2	2	4	4	4
1 hr—Et-OH (50%)	3	4	4	3	0	2	5	5	5

In looking at the data, any of the acrylic modifications would be viable aside from the gloss differences noted previously with AC-5. Interestingly, the increased hardness of the AC-1 in combination with PC-1 at 130 sec versus 100% PC-1 at 105 sec and AC-1 at 104 sec is significant due to the increased crosslink density of the two in combination. This can be further supported by the bump in chemical resistance for both ammonia and ethanol.

A balanced view of the data would suggest the best choice of acrylic would be AC-1, giving rise to the best composition of the new coating being PC-1 PUD/AC-1. Comparing data to commercial products on the market currently suggests indeed that this approach is worth investigating.

SUMMARY AND CONCLUSIONS

Although new resins are being developed that will meet or exceed the expectations of formulators, a blend approach using already familiar resins is still a viable option given the known performance attributes of each. This article discussed the utilization of various polyurethane-acrylic blends in developing a wood floor coating that achieves a VOC target of less than 275 g/L, a balance of hardness development with very good Taber abrasion, and excellent chemical resistance.

The best composition involved use of a polycarbonate-based PUD, such as PC-1, in combination with a medium-hard self-crosslinking acrylic, AC-1. This composition also performed very comparably to the commercial wood coatings formulations currently available in the marketplace.

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