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Technical Paper

Development of an ASTM E 84 Class 1 Fire and Smoke Vinyl Ester Resin

Abstract

A unique new fire retardant vinyl ester resin that meets ASTM E 84 Class 1 flame spread and **smoke** rating has been developed. This paper will review resin properties including specific details on the cast resin properties, fire testing results, laminate physical properties, corrosion resistance and end uses.

Introduction

A highly brominated bisphenol-A epoxy based vinyl ester (Vipel® K022-AAA-00) meets the current ASTM E84 Class 1 rating for flame spread and **smoke** development. In order to meet the class 1 criteria the laminate must have a flame spread of 25 or less and a smoke development of 450 or less. The unique aspect is that the ASTM E84 Class 1 smoke requirement is met. This paper reviews the cast mechanical properties, ASTM E 84 test results, UL 94 results, mechanical properties at elevated temperatures, corrosion resistant data, and some applications for this resin. Cast properties of a typical general-purpose fire retardant resin and a non-fire retardant bisphenol-A epoxy vinyl ester resin are included for reference.

Experimental

1) Casting Preparation

Resins were catalyzed and poured between two 63.5 mm/¼ inch thick glass plates. A 0.130 inch/33 mm thick thermoplastic gasket is used as a spacer so that the final cured casting is 0.125 inch/32 mm thick. Table #1 details how the Vipel® K022-AAA-00 casting was catalyzed and cured.

2) Laminate Preparation

Table #2 describes how the Vipel® K022-AAA-00 laminates were prepared. This includes the promotor catalyst, reinforcement used in the construction, glass content, thickness and the post cure schedule.

3) Mechanical Properties

Woven roving /chopped strand laminates were prepared with the Vipel® K022-AAA-00 and an alternative product (competitive brominated bisphenol-A epoxy fire retardant vinyl ester resin) according to table #3.

4) Corrosion Resistance

a) Test Coupons

Laminate corrosion of Vipel® K022-AAA-00 and an alternative product were compared. Test coupons of Vipel® K022-AAA-00 and an alternative product were produced according to ASTM C 581. Solutions were changed every month except for the sodium hypochlorite which was changed every two weeks. In caustic environments, a polyester veil was used instead of a glass veil. Details of the promoter, catalyst, laminate construction and the post cure schedule are given in table # 4.

b) Chemical Environments

The resins were tested in nine environments. The concentration of each chemical and the temperatures are listed in table # 5.

Results

Cast Properties

The cast resin mechanical properties of Vipel® K022-AAA-00 are listed in table #6. The mechanical values of a typical general-purpose fire retardant and a non-fire retardant vinyl ester are included for reference.

Fire and Smoke

ASTM E 84 and UL 94 test results for Vipel® K022-AAA-00 laminates are listed in *Table #7*

Mechanical Properties

Flexural properties at elevated temperatures of Vipel® K022-AAA-00 and an alternative product are shown in *Table #8* and *Table #9* respectively.

Figure #1 compares the flexural strength of the of the Vipel® K022-AAA-00 and alternative product in graphic form.

Figure #2 compares the flexural modulus of the of the Vipel® K022-AAA-00 and alternative product in graphic form.

Corrosion Resistance
The mechanical properties are plotted with time in each of the chemical environments for Vipel® K022-AAA-00 and an alternative product.

Mechanical strength is the average of the retention of flexural strength and retention of flexural modulus:
Mechanical strength = Retention flexural strength + Retention flexural modulus

Figure # 3: Retention of mechanical strength after 1 year of exposure in 5% nitric acid at 100°C/212°F

Figure # 4: Retention of mechanical strength after 1 year of exposure in 10% sulphuric acid at 100°C/212°F

Figure # 5: Retention of mechanical strength after 1 year of exposure in 15% hydrochloric acid at 100°C/212°F

Figure # 6: Retention of mechanical strength after 1 year of exposure in 100% demineralised water at 100°C/212°F

Figure # 7: Retention of mechanical strength after 1 year of exposure in 5.25% sodium hypochlorite at 50°C/122°F

Figure # 8: Retention of mechanical strength after 1 year of exposure in 5% sodium hydroxide at 100°C/212°F

Figure # 9: Retention of mechanical strength after 1 year of exposure in 100% toluene at 20°C/68°F

Figure # 10: Retention of mechanical strength after 1 year of exposure in 100% aniline at 20°C/68°F

Figure # 11: Retention of mechanical strength after 1 year of exposure in 100% methanol at 20°C/68°F

Application

Vipel® K022-AAA-00 vinyl ester resin is now being used in theme parks such as the "Men in Black" ride at Universal Studios in Orlando, FL. Vipel® K022-AAA-00 was used to manufacture the ferocious giant alien that won the "Peoples Choice Award" at the CFA conference in Las Vegas in September 2000. Thereason that Vipel® K022-AAA-00 was chosen for this theme park is that the heat distortion and elongation were higher than typical general-purpose fire retardant resins. (Fire retardant properties were required for the theme park).

Also Vipel® K022-AAA-00 has been used to manufacture ventilation fans for chemical plants, pulp and paper mills and mines because of the combination of fire, smoke and corrosion properties.

Conclusion

1) The cast mechanical properties of the fire retardant and non-fire retardant version of Vipel® K022-AAA-00 resins are similar. The elongation and heat distortion properties of Vipel® K022-AAA-00 are higher than typical general-purpose fire retardant resins.

2) Vipel® K022-AAA-00 meets the ASTM E 84 Class 1 fire and smoke requirements.

3) Vipel® K022-AAA-00 meets UL 94 HB, 5V and V-0 requirements.

4) The elevated temperature mechanical properties of both Vipel® K022-AAA-00 and an alternative product begin to significantly decrease above 105°C/221°F.

5) The corrosion resistant properties of Vipel® K022-AAA-00 laminates are similar to the corrosion resistant properties of an alternative product.

6) The unique combination of good flame and smoke resistant properties combine With the inherently good mechanical properties contribute to Vipel® K022-AAA-00 being an excellent resin for these and many more fire retardant applications where fire and smoke resistance are required.

TABLE #1

CURE SYSTEM AND POST CURE SCHEDULE FOR PREPARATON OF CASTING

CATALYST AND CURE SCHEDULE	QUANTITY AND TIME
Catalyst system	
Benzoyl Peroxide (BPO), %	1
Cure schedule	
60°C/160°F, hours	4
93°C/200°F, hours	1
116°C/240°F, hours	1
138°C/280°F, hours	2

TABLE #2

CURE SYSTEM, CONTRUCTION AND POSTCURE SCHEDULE FOR ASTM E 84 and UL 94 TESTING

Promoter system	0.1% Cobalt 12% solution
Catalyst system	1.25% MEKP
	(9% active oxygen)
Laminate build-up	2 plies of 2 ounce chopped glass strand mat
Glass content, %	30-32
Thickness, mm/inches	2.4/0.095
Postcure	hrs at 100°C/212°F

TABLE #3

CURE AND POSTCURE SCHEDULE FOR MECHANICAL TESTING

Resins	HBVE
Promoter system	0.33% Co* 6% solution
Catalyst system	2% MEKP (9% active oxygen)
Laminate Construction	v**/csm***/csm/Wr****/
	csm/wr/csm
Postcure	3 hrs at 100°C/212°F

* Co - Cobalt
** v - glass veil
*** csm - 1.5 ounce chopped glass strand mat
**** wr - 24 ounce glass woven roving

TABLE #4

CURE AND POSTCURE SCHEDULE FOR CORROSION TESTING

Promoter system	0.33% Co* 6% solution
Catalyst system	2% MEKP (9% active oxygen)
Laminate Construction	2 plies of glass veil and 2 plies of 1.5 ounce chopped strand glass mat
Postcure	3 hrs at 100°C/212°F

* Co - Cobalt

TABLE #5

CHEMICAL RESISTANCE ENVIRONMENTS

CHEMICAL	CONCENTRATION	TEMPERATURE
Nitric acid	5%	100°C/212°F
Sulphuric acid	10%	100°C/212°F
Hydrochloric acid	15%	100°C/212°F
Demineralised water	100%	100°C/212°F
Sodium hypochlorite	5.25%	50°C/122°F
Sodium hydroxide	5%	100°C/212°F
Methanol	100%	20°C/68°F
Toluene	100%	20°C/68°F
Aniline	100%	20°C/68°F

TABLE #6

MECHANICAL PROPERTIES OF CASTINGS

Mechanical Properties	General Purpose Fire Retardant	Non-Fire Retardant Vinyl ester	HBVE
Tensile strength, psi	10,700	13,800	11,600
Tensile modulus, psi	580,000	540,000	490,000
Elongation, %	2.2	4.6	4
Flexural strength, psi	15,400	22,000	21,300
Flexural modulus, psi	590,000	570,000	550,000
Heat Distortion, °C/°F	90/194	112/234	119/246
Barcol Hardness	45	40	41

TABLE #7

ASTM E 84 AND UL 94 TEST RESULTS

TEST	RESULTS
ASTM E 84	
Flame spread	20
Smoke development	450
UL 94	
HB	PASS
5V	PASS
V-0	PASS

TABLE #8

FLEXURAL PROPERTIES OF Vipel® K022-AAA-00 AT ELEVATED TEMPERATURES

Property	Glass Content %	20°C/68°F	20°C/68°F	90°C/194°F	105°C/221°F	120°C/248°F
Flexural Strength, psi	34	25,300	25,300	25,300	17,400	5,100
Flexural Modulus,Psi x 106	34	1.2	1.2	1.2	0.7	0.45

TABLE #9

FLEXURAL PROPERTIES OF AN ALTERNATIVE PRODUCT AT ELEVATED TEMPERATURES

Property	Glass Content %	20°C/68°F	20°C/68°F	90°C/194°F	105°C/221°F	120°C/248°F
Flexural Strength, psi	33	24,700	23,200	24,700	21,800	6,500
Flexural Modulus,Psi x 106	33	1.2	1.1	0.99	0.81	0.45

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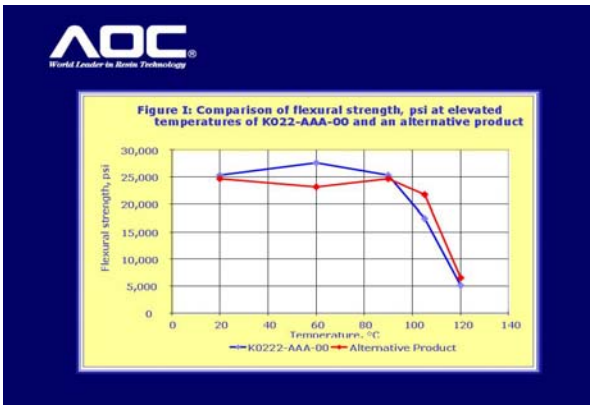

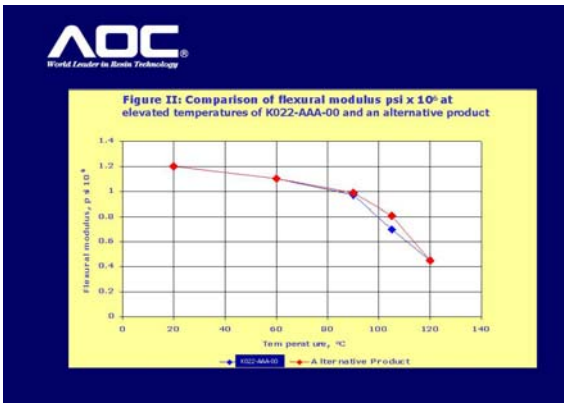

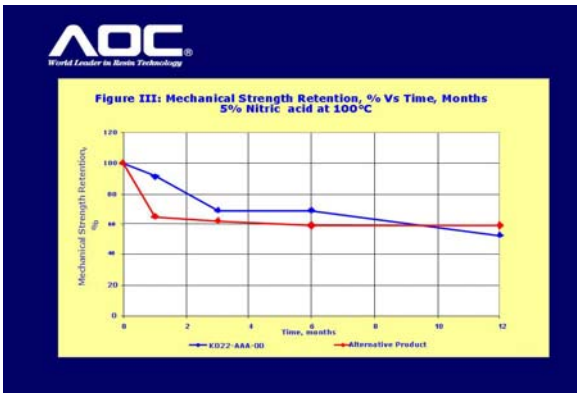

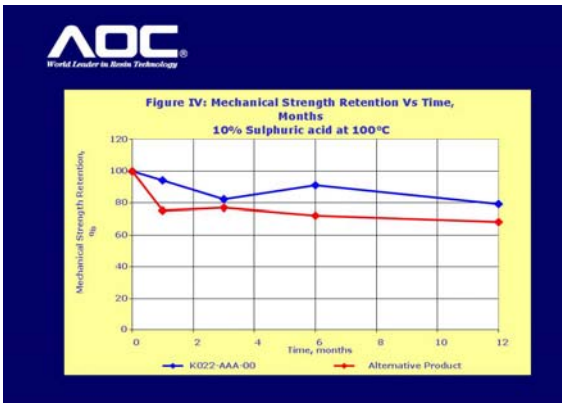

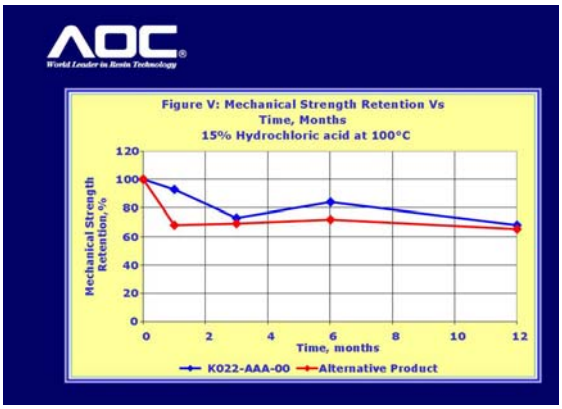

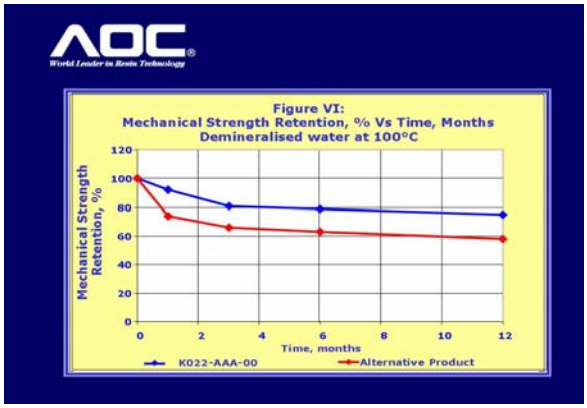

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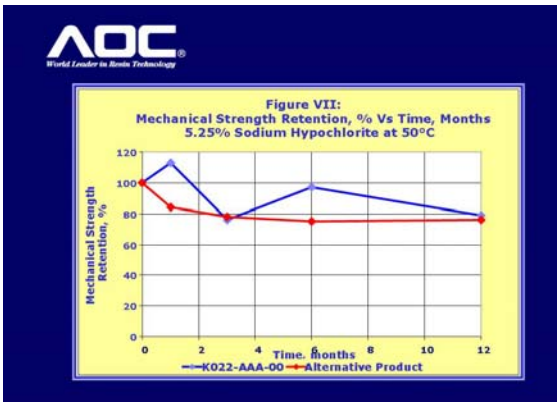
Figure VII:
Mechanical Strength Retention, % Vs Time, Months
5.25% Sodium Hypochlorite at 50°C
Mechanical Strength Retention, %
Time, months
K022-AAA-00
Alternative Product

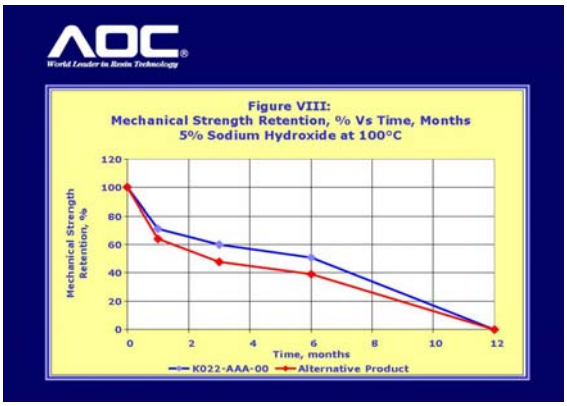
Figure VIII:
Mechanical Strength Retention, % Vs Time, Months
5% Sodium Hydroxide at 100°C
Mechanical Strength Retention, %
Time, months
K022-AAA-00
Alternative Product

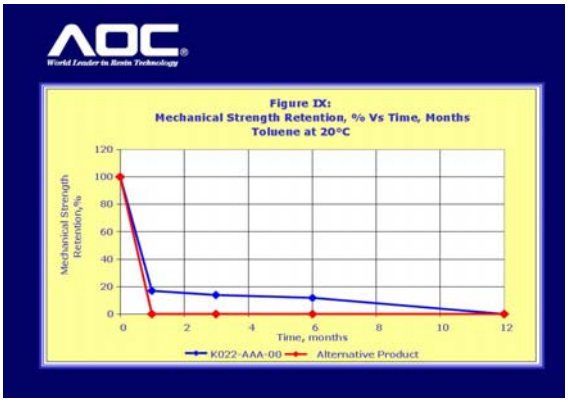
Figure IX:
Mechanical Strength Retention, % Vs Time, Months
Toluene at 20°C
Mechanical Strength Retention,%
Time, months
K022-AAA-00
Alternative Product

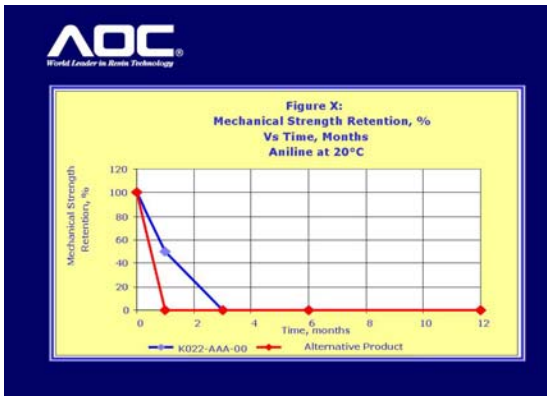
Figure X:
Mechanical Strength Retention, %
Vs Time, Months
Aniline at 20°C
Mechanical Strength Retention, %
Time, months
K022-AAA-00
Alternative Product

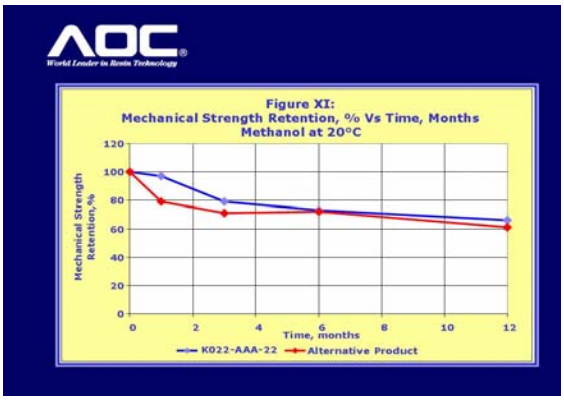
Figure XI:
Mechanical Strength Retention, % Vs Time, Months
Methanol at 20°C
Mechanical Strength Retention,%
Time, months
K022-AAA-22
Alternative Product