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ORIGINAL ARTICLE

Preparation, Characterization, and Evaluation of New Alkyd-vinyl Acetate Grafted Copolymer for Water-based Coating

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Abstract

Alkyd emulsion is one of the solutions to the problem of the legal limit value for volatile organic content. In the present work, we discuss the synthesis of different grafted alkyd-vinyl acetate copolymers using the emulsion polymerization technique. The prepared polymers were characterized in terms of particle size, fourier-transform infrared (FTIR), differential scanning calorimetry (DSC), and gel permeation chromatography. The synthesized polymers showed enhancements in nanometric properties (70 nm) as compared with commercial vinyl acetate copolymer resins. The spectra of the blank resins and hybrid resins showed some spectral differences, as shown by fourier-transform infrared spectroscopy. The differential scanning calorimetry test revealed that the hybrid resin's glass-transition temperatures are lower than those of that based on vinyl acetate copolymer, and the gel permeation chromatography results showed that the average molecular weight (M.wt) of hybrid resin is higher than both vinyl acetate copolymer and alkyd resins, further confirming the chemical formation of hybrid resin. The characterized copolymers were evaluated as binders in water-based coating formulations and showed an increase in wet scrub to 2930 cycles for the hybrid resin, compared with the vinyl acetate copolymer resin of 1600 cycles. These improvements may be one of the most promising opportunities to replace solvent-based alkyd with alkyd-vinyl acetate emulsion in waterborne coating.

Keywords: Alkyd emulsion, Alkyd, Emulsion polymer, Polymer, Vinyl acetate copolymer, Water-based coating

1. Introduction

Solvent-based coatings are coming under increasing legal pressure as a result of current environmental and labor protection standards, and some countries already have strict legal requirements. As stated by those requirements, the allowed limit value for volatile organic content (VOC) can be achieved with water-based or solvent-reduced coating technology, even in the absence of regulation, water-based coatings have more advantages than solvent-based types, as they have a lower odor level and are inflammable [1,2]. To overcome this problem, alkyd emulsions are developed as a solution. Understanding the meaning of alkyd emulsions requires knowledge of both alkyd resin [3] and emulsion polymer [4], alkyd resins are polyester modified with oil or oil's fatty acids, they come from dicarboxylic acids such as phthalic anhydride and polyols such as glycerol and fatty acid or vegetable oil. [5,6], while the emulsion polymerization technique is a versatile and widely used method in the production of polymer dispersions. This technique involves the synthesis of polymers in the form of colloidal particles suspended in an aqueous medium, facilitated by the presence of surfactants and emulsifiers [7].
Alkyd emulsions represent a type of waterborne coating that combines the desirable properties of alkyd resins with the advantages of water-based systems. They often utilize long alkyds due to their low viscosity, which is very suitable for the emulsification. Conversely, there is less chance of emulsifying medium and short alkyds, as those types of alkyds have a high degree of viscosity, making emulsification more challenging. Alkyd emulsions are primarily utilized in the production of paints; the key characteristics of alkyd emulsions include excellent adhesion, durability, and abrasion resistance. They also provide a smooth finish and can be used on various surfaces, including wood, metal, and masonry [8]. Additional benefits of using alkyd emulsions in coating applications include a reduced volatile organic content (VOC), environmental considerations, the absence of high levels of organic solvents can result in more cost-effective formulations, less energy during production and remaining equipment is easier to clean [9,10].

The emulsification of alkyd resins encompasses several techniques, leading to the categorization of products into three generations, in the first generation the hydrophilic properties of alkyd resins are adjusted by the introduction of carboxyl groups into the resin structure, resulting in high acid values of ~45–75 mgKOH/g, followed by neutralization of the resin with amines to increase the water-solubility of the resin, with the addition of co-solvents (e.g., butyl glycol) still necessary to reduce viscosity to an applicable level [11]. The second generation of alkyd emulsions is produced by the addition of an external emulsifier to a mixture of alkyd resin and water followed by emulsification process. This results in an emulsion consisting of tiny droplets of alkyd resin dispersed in water, stabilized by emulsifying agents. Compared with emulsions of the first generation a higher molecular weight of the resin is applicable [12]. While the third generation of alkyd emulsions is based on emulsion polymerization of alkyd resins modified with hydrophilic monomers [13]. In the present study, the third generation is used to prepare a series of new alkyd-vinyl acetate grafted copolymers by using the emulsion polymerization technique, comparing them with vinyl acetate copolymer in water-based coating application. The chemical structure of the prepared resins was instrumentally verified by Fourier-transform infrared spectroscopy (FTIR), while surface morphology and physical properties (e.g., viscosity, pH, and solid contents) of prepared polymers were investigated in detail. Application tests (e.g., wet scrub resistance, gloss, and mechanical properties) on prepared coatings were also extensively discussed.

2. Experimental work

2.1. Materials

Long alkyd was sourced from Eagle, Egypt. Vinyl ester of versatic acid (VEOVA), Vinyl acetate monomer (VAM) were purchased from Sigma Aldrich, Germany. Emulsogen LCN 287 (a nonionic emulsifier which is Alkyl polyethylene glycol ether with 28 mol ethylene oxide), and Hostapal Conc (an anionic emulsifier which is Tributyl phenol polyethylene glycol ether sulfate sodium salt) were purchased from Clarinet, Germany. Sodium bicarbonate, Tylose (which is hydroxyethyl cellulose as a protective colloid), and Sodium per-sulfate (SPS) were purchased from Merck, Germany. Texanol CS12 (2, 2, 4-trimethyl-1, 3-pentanediolmonoisobutyrate as Coalescing agent) from Sunmaxx, Vietnam. EBCCA Burst 200 (an antifoam agent which is

<table>
<thead>
<tr>
<th>Table 1. Composition of different formulations.</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Composition</em></td>
</tr>
<tr>
<td>-----------------------------------------------</td>
</tr>
<tr>
<td><em>Wt. (g)</em></td>
</tr>
<tr>
<td>H2O</td>
</tr>
<tr>
<td>VAM</td>
</tr>
<tr>
<td>VEOVA</td>
</tr>
<tr>
<td>Alkyd</td>
</tr>
<tr>
<td>LCN 287</td>
</tr>
<tr>
<td>Hostapal</td>
</tr>
<tr>
<td>NaHCO₃</td>
</tr>
<tr>
<td>Tylos</td>
</tr>
<tr>
<td>Burst 200</td>
</tr>
<tr>
<td>SPS</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 2. The recipe for latex paints preparations.</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Raw material</em></td>
</tr>
<tr>
<td>-----------------------------------------------</td>
</tr>
<tr>
<td>Water</td>
</tr>
<tr>
<td>Anti-bacterial (Actomax C41)</td>
</tr>
<tr>
<td>EBCCA Burst 200</td>
</tr>
<tr>
<td>EBCCA COAT N50</td>
</tr>
<tr>
<td>Texanol</td>
</tr>
<tr>
<td>Di-Octyl Phthalate (DOP)</td>
</tr>
<tr>
<td>Ammonia (30%)</td>
</tr>
<tr>
<td>Calcium carbonate EJ2 (25 μm)</td>
</tr>
<tr>
<td>Titanium dioxide tione128</td>
</tr>
<tr>
<td>Talk powder ET2</td>
</tr>
<tr>
<td>Tylose</td>
</tr>
<tr>
<td>Polymer latex (50%)</td>
</tr>
<tr>
<td>Acrylic thickener EBCA THICK 30</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>

Note: high PVC formula was used only for wet scrub resistance test.
nonionic emulsifiers with a small amount of silicones), EBCA THICK 30 (as acrylic thickener), EBCA COAT N50 (as dispersing agent which is sodium polyacrylate), Di-Octyl phthalate from EBCA, Egypt. Titanium dioxide from Wuxi, China. Calcium carbonate, Talc powder ET2 were supplied from Green Egypt, Egypt. Actomax C41 (as biocide) from Active, Egypt. The above materials were used as received from its sources without any further purification.

2.2. Procedures

2.2.1. Synthesis of alkyd-vinyl acetate copolymer

The synthesis of the alkyd-vinyl acetate copolymer involved preparing a series of samples referred to as L1-4, including the blank sample B, which is the vinyl acetate copolymer, according to the formulations in Table 1. The process commenced by mixing the long alkyd and both monomers (VAM and VEOVA) in a 1 L picker, a mixture of variable amounts of distilled water, both emulsifiers LCN 287 as a nonionic emulsifier, and Hostapal Conc as an anionic emulsifier, NaHCO₃ as polymerization medium buffer, and the remaining components Tylose as protective colloid and EBCA Burst 200 as anti-foaming agent.
are charged into a 2 l stainless steel reactor using a mechanical stirrer fitted with a condenser, thermometer, and water bath. The reactor contents were purged with a nitrogen blanket to remove any oxygen that may be present in the reaction mixture. The reaction mixture was allowed to stir at 280 rpm for 20 min to ensure good mixing, and the temperature was regulated over the range of 80–85 °C. Both the monomer’s mixture and initiator solution 5% Sodium per-sulfate were added dropwise into the reactor within 6 h. The reaction temperature was held for an additional 1 h to ensure a high percentage of monomer conversion, then the product was cooled to less than 40 °C and filtered [15].

2.2.2. Polymeric film preparation

The polymeric film is produced by solution-casting the aqueous dispersion onto a glass surface that has been leveled. The sample first undergoes a 7-day period of room-temperature drying, followed by a 12 h period of increasing temperature to 60 °C. To create a dried film with a thickness of between 25 and 30 μm, the film is cast using a 90 μm applicator from the emulsion onto the surface of the glass (diameter: 7 cm by 2 cm), after which it is placed in a desiccator to eliminate any remaining moisture [16].

2.2.3. Physical properties of synthetic resins

The physical properties of the prepared polymers, specifically solid content, pH, and viscosity, are assessed using a drying oven, pH meter (PL-700 PV), and viscometer (Brookfield RVDVE-II Pro), respectively, in accordance with the accepted ASTM D2369, ASTM D1293, and ASTM D 2196-99 methodologies [17].

2.2.4. Gravimetric conversion

The following equation is used to gravimetrically compute the general conversion for the produced...
polymers based on the dried polymer and total monomer content in the reaction formulation [18]:

\[
\text{Conversion} \% = \frac{\% \text{ of solids} - (\text{wt fraction of emulsifiers} + \text{wt fraction of buffer} + \text{wt fraction of initiator})}{\text{weight fraction of monomer}}
\]

2.3. Instrumental characterization

2.3.1. The spectrum of FT-IR

Utilizing an Inevio S-BROCKER FT-IR spectrometer, the chemical structure of the produced polymers was examined. Within a range of 4000–400 cm\(^{-1}\), all data were collected. A thin film is applied to the glass surface to prepare the sample wafer, which is subsequently dried [19].

2.3.2. Determination of the glass transition temperature

To determine the glass transition temperature of the prepared polymers, we use a Perkin–Elmer differential scanning calorimeter (DSC 6000) with a flow rate of nitrogen 50 mL/min at 10 \(^\circ\)C/min rate of heating. The thermogram was recorded from room temperature up to 800 \(^\circ\)C [20].

Fig. 7. The particle size of (B) vinyl acetate copolymer.

Fig. 8. The particle size of (L2) the hybrid alkyd resin.
2.3.3. Particle size analysis

For the characterization of the particle size of prepared polymer particles, the particle size analyzer Model Master Sizer 3000 (Malvern) was used [21].

2.3.4. Gel permeation chromatography (GPC)

The average molecular weight distribution of the produced polymers is determined using a Waters Alliance 2695, Waters Corporation, USA. Using gel permeation chromatography (GPC) analysis [22].

2.4. Evaluation of characterized polymers as binder in water-based coating formulations

To evaluate the resulting prepared polymers for application in a water-based coating formula, we prepared two types of paint: low PVC and high PVC, which are present in Table 2, and we did the following tests.

2.4.1. Contact angle for water droplets on the coating surface

In this test, droplets of water are placed on the surface of a film sample, and the contact angle values are measured and then averaged according to ASTM D5946 [23].

2.4.2. Wet scrub resistance

According to ASTM D4213, paint samples were applied on plastic panels, and the wet scrub tester Ref 903/2 (binder content 7%, wet film thickness 200 μ, curing time 7 days) was used [24].

2.4.3. Gloss test

According to ASTM D523 test, paint samples were applied on glass panels, and the gloss-meter manufactured by the Sheen Company (binder content 50%, wet film thickness 120 μ, curing time 1 day) was used [25].

2.4.4. Hiding power test (Opacity) and whiteness test

The ability of a coating film to completely mask the underlying substrate is determined by the opacity of the coating, using an opacity tester on the prepared paint samples, and the whiteness of the prepared paint samples was tested using a whiteness meter.

2.4.5. Cross hatch adhesion test

The cross-hatch adhesion test was done using Elcometer 1542 Cross Hatch Adhesion Tester and according to ASTM D3359-17 test methods. Six-cut cutter wheels, 1 mm and 2 mm in sizes were used for films with thickness 0–50 and 50–125 μm, respectively [26].

2.4.6. Bending test

A bending test of cured samples was performed on a TQC Sheen conical mandrel bending tester over a range of diameters between 1 and 30 mm.

2.4.7. Mechanical properties of the prepared coating

We used the Elongation testing machine (BGD570), to determine the ability of a coating to stretch or elongate before break [27].

3. Results and discussion

(Table 1) lists the components of the various formulations. According to the conditions of grafted

| Table 4. Results of particle size results of the prepared copolymers emulsions. |
|-------------------|---|---|---|
| Formulation       | B | L2 | L3 |
| Particle size (nm)| 117| 71 | 72 |
emulsion polymerization, the vinyl monomers are polymerized in the company of long alkyd resin. Both hybrid resins and vinyl acetate copolymers are produced. All prepared polymers are stable milky emulsions and after 7 h at room temperature, the films of the prepared polymer were dried without any extra loss of weight or thickness. The expected chemical structure is shown in (Figs. 1 and 2), and the properties of the produced polymers are discussed in the following paragraphs.

3.1. Physical properties: solid percentage and viscosity

By measuring the concentration of the active matter, we noticed that with an increase in the

<table>
<thead>
<tr>
<th>Formulation</th>
<th>Retention Time</th>
<th>Mn</th>
<th>Mw (g/mol)</th>
<th>MP</th>
<th>Mz</th>
<th>Poly-dispersity</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>7.548</td>
<td>2373</td>
<td>23181</td>
<td>2599</td>
<td>145609</td>
<td>9.770</td>
</tr>
<tr>
<td>L3</td>
<td>6.414</td>
<td>9059</td>
<td>64979</td>
<td>34765</td>
<td>165278</td>
<td>7.173</td>
</tr>
<tr>
<td>alkyd</td>
<td>8.124</td>
<td>3114</td>
<td>57703</td>
<td>–</td>
<td>217062</td>
<td>18.528</td>
</tr>
</tbody>
</table>

Fig. 10. The gel permeation chromatography of (B) the polyvinyl acetate copolymer.

Fig. 11. The gel permeation chromatography of (L3) the hybrid alkyd resin.
percentage of alkyd, the monomer to polymer conversion decreased. On the other hand, the viscosity of the resulting polymers increased with an increase in alkyd percentage, as shown in (Table 3). The higher viscosity of the hybrid resins, compared with the vinyl acetate copolymer may be due to the formation of hydrogen bonding, which can be considered a proof of the composition of the hybrid structure. The gravimetric conversion, which reached 98.58%, indicated that the produced hybrid resins had undergone extensive copolymerization.

3.2. FTIR spectra

The FTIR spectra obtained from the L3 alkyd modified copolymer in comparison to the incorporated long alkyd and the blank copolymer (B) sample are shown in (Fig. 3). The spectrum of the alkyd-modified copolymer is an integration of the blank copolymer and the long alkyd structure, which confirms the existence of both structures, especially considering the peaks around 1731, 1580, 1450, and 1100 cm⁻¹. In the case of the three chemical structures, the three bands at 1731 cm⁻¹ are related to the carbonyl group C=O stretching, and the peaks associated with the B sample were shown to be weaker than the peak associated with the L3 hybrid resin, which was weaker than the peak associated with the alkyd resin. The bands observed at about 2853:2923 cm⁻¹ are associated with asymmetric CH₂ stretching, while the relevant bending vibration is evident at 1226 cm⁻¹.
Furthermore, the bands observed at about 3432 cm\(^{-1}\) related to the O–H stretching vibration [28]. Moreover, the spectrum of the long alkyd resin shows a band at 3007 cm\(^{-1}\) which is related to C–H alkene, and 1599 cm\(^{-1}\) which is related to C=C [29], these two bands are absent in L3, which can be considered evidence for the chemical formation of a grafted hybrid structure [30].

3.3. Glass transition temperature

The glass transition temperature (Tg) is a critical parameter in coating applications, influencing the performance and characteristics of the coating material. The glass transition temperature can impact the application conditions of the coating. For instance, coatings with a lower Tg may require lower temperatures for proper curing, making them more suitable for certain application methods or conditions [31]. The Tg influences the adhesion and cohesion of the coating. A coating with an appropriate Tg can adhere well to the substrate, ensuring good bonding. Additionally, it contributes to the coating’s internal cohesion, preventing cracking or delamination over time.

The differential scanning thermal analysis of the Tg is reported in (Figs. 4–6). The Tg of the alkyd and vinyl acetate copolymer (B) are about –10 °C and 12.29 °C, respectively. The hybrid resin’s thermal behavior differs from that of the long alkyd and vinyl acetate copolymer resins. The prepared polymers represent (L2) around 12.1 °C and (L3) around 8.76 °C. It can be considered that hybrid resins have more free volume as compared with vinyl acetate copolymer. This finding supports the formation of the hybrid structure as well [32].

### Table 6. Contact angle values.

<table>
<thead>
<tr>
<th>Formulation</th>
<th>Contact angle</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>71°</td>
</tr>
<tr>
<td>L2</td>
<td>78°</td>
</tr>
<tr>
<td>L3</td>
<td>82°</td>
</tr>
</tbody>
</table>

3.4. Particle size analysis

The distribution of particle size of the synthesized hybrid resins compared with vinyl acetate copolymer is reported in (Figs. 7–9). As can be seen from (Table 4), the particle size of the prepared polymers is mostly located around 70 nm, which indicates the high stability of the prepared emulsions of the grafted alkyd and coating enhancements [33].

3.5. Gel permeation chromatography (GPC)

(Figs. 10 and 11) exhibit a high average molecular weight and a narrow molecular weight distribution, demonstrating a significant degree of polymerization. From (Table 5) we note that the L3 copolymer shows a higher molecular weight (64979 g/mol) than that of the vinyl acetate copolymer and alkyd resin. This might be due to the grafted reaction of the alkyd resin into the skeleton of the vinyl acetate copolymer Figs. 12 and 13.

### Table 7. Results of wet scrub resistance, gloss, whiteness and hiding power.

<table>
<thead>
<tr>
<th>Test</th>
<th>B</th>
<th>L2</th>
<th>L3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wet scrub resistance</td>
<td>1600</td>
<td>2500</td>
<td>2930</td>
</tr>
<tr>
<td>Gloss</td>
<td>45</td>
<td>54</td>
<td>58</td>
</tr>
<tr>
<td>Whiteness</td>
<td>31.7</td>
<td>31.7</td>
<td>31.9</td>
</tr>
<tr>
<td>Hiding power</td>
<td>58.9</td>
<td>58.1</td>
<td>57.1</td>
</tr>
</tbody>
</table>

![Fig. 15. Scrub resistance test for prepared resins.](image-url)
3.6. Contact angle for water droplets on the coating surface

The water repellency properties of the hybrid alkyd resins were evaluated by measuring the contact angle formed between water droplets and the surface of the coating film obtained after drying without the addition of a drier additive (Fig. 14) shows the water droplets images on the prepared coatings, and (Table 6) gives the contact angle values. We note that the contact angle increased with the increase in the alkyd content in the prepared polymer, which exhibits good water resistance for coatings prepared by hybrid resin. This can be attributed to the fact that as the contact angle increases, the surface tension increases, leading to less contact between the water droplet and the paint surface, which enhances water repellency [34].

3.7. Influence of alkyd hybrid resins on the wet scrub resistance of emulsion coatings

Wet scrub resistance refers to a paint film’s ability to withstand wet abrasive cleaning without removing paint from the surface. The resistance is often directly related to the type of binder. According to reports, polyvinyl acetate copolymer has good specifications as binders in the coating formulation; however, a few limitations can be assumed, such as rising water absorption and scrub resistance. As can be seen from (Table 7) vinyl acetate copolymer has less wet scrub resistance. On the other hand, the wet scrub resistance was proportionally related to the grafted alkyd proportion, as it was shown to be enhanced to 2500 and 2930 cycles for L2 and L3, respectively, as compared with vinyl acetate copolymer at 1600 cycles. Additionally, considering the Tg, the hybrid alkyd resin exhibits a lower Tg compared with the B sample, this is related to the mobility of alkyd to penetrate deeper into the polymer phase of the coating and the degree of coalescing of polymer particles improved. This suggests that the alkyd hybrid resin has an advantage for enhancing the wet scrub resistance of emulsion coatings; this result further supported by the contact angle for water droplets on the coating surface, which indicates increasing the resistance of the paint surface to water when prepared by hybrid alkyd resin Figs. 15 and 16.

3.8. Influence of alkyd hybrid resins on gloss, whiteness, and hiding power of prepared coatings

The grafted alkyd copolymers have an observed effect on the films and coatings. Based on (Table 7) it can be shown that the hybrid resins have gloss values better than the polyvinyl acetate copolymer. May be this is due to the particle size of hybrid resins is less than that of the polyvinyl acetate copolymer. The smaller the particle size, the higher the gloss of the coating film. This effect might be explained by the improved film smoothness and reduction in surface roughness after a film formation process, as the particle size is reduced. Smaller polymer particles are subjected to higher Laplace

<table>
<thead>
<tr>
<th>Formulation</th>
<th>Bending test</th>
<th>Scratch test</th>
<th>Adhesion test</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>10 mm</td>
<td>1.2 Kg</td>
<td>1B</td>
</tr>
<tr>
<td>L2</td>
<td>5 mm</td>
<td>2 Kg</td>
<td>3B</td>
</tr>
<tr>
<td>L3</td>
<td>1 mm</td>
<td>1.5 Kg</td>
<td>5B</td>
</tr>
</tbody>
</table>
pressure than large particles, and better film leveling and smoothness should be observed in the presence of nano-sized polymer particles. These latter lead to a uniform specular reflection and a better gloss appearance [35].

3.9. Results of adhesion test and bending test on the prepared coating

It was found that the adhesion test of the coated films was significantly improved by increasing the concentration of alkyd, and this is due to the hydrogen bond formed through the polar OH groups present in the alkyd resin. Also, a higher alkyd concentration may lead to better adhesion to substrates. This is because, at a lower degree of crosslinking, a reduced shrinkage of the coating may occur, and thus adequate wetting of the substrate occurs, which leads to improved adhesion to the substrate.

And in the field of coating industry, it is necessary to know the elasticity of water cured polymer films by using steel panels and bending over 1 mm diameter a cylindrical mandrel. Formulations B, L2, and L3 have excellent flexibility and have passed the bending test at 5 mm diameter, except formula B has passed at 10 mm and scratch resistance at a certain weight on the steel surface. The results of these tests are presented in (Table 8), Fig. 17.

3.10. Mechanical properties of the prepared coating

The mechanical properties of modified emulsion films for each formulation can be seen in (Table 9). Depending on these results, the increase in alkyd percentage in the emulsion structure causes a decrease in stress at break values. Modification of the emulsion polymer backbone with alkyd, increases the volume of side groups and branching, which increase the movement of the polymer chain. The elongation increases due to the flexibility movement in the backbone of the hybrid resin and the increasing functional groups on it. Thus, the highest elongation (29%), and the lowest stress at break (1.5 MPa), were recorded for the alkyd hybrid resin L3 [36].

4. Conclusion

The alkyd-vinyl acetate grafted copolymer was synthesized successfully by using the emulsion polymerization technique. All prepared polymers formed stable milky emulsions. After 7 h at room temperature, the prepared polymer films were dried without any extra loss of weight or thickness. The prepared polymers were characterized with FTIR, which showed some differences between the long alkyd resin, vinyl acetate copolymer, and the resulting hybrid resins. The absent bands in L3, which are present in alkyd resin like C–H alkene and C=C, are evidence for the formation of grafted structures. Moreover, these findings were

<table>
<thead>
<tr>
<th>Formulation</th>
<th>Elongation (%)</th>
<th>Stress at Break (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>16</td>
<td>6.5</td>
</tr>
<tr>
<td>L2</td>
<td>25</td>
<td>4</td>
</tr>
<tr>
<td>L3</td>
<td>29</td>
<td>1.5</td>
</tr>
</tbody>
</table>
confirmed by GPC, which showed that the L3 sample has a higher molecular weight (64979 g/mol) than both the vinyl acetate copolymer and alkyd resin. This increased molecular weight might be due to the formation of the grafted structure. The reduction in particle size value is due to the grafting of the alkyd into the backbone of the vinyl acetate copolymer. These results improve the gloss values of the prepared coatings. Moreover, the results of the evaluation of characterized polymers as binders in water-based coating formulations showed that the hybrid resins formulations have excellent properties in terms of gloss, mechanical properties, adhesion, and especially wet scrub resistance, which was enhanced with the degree of grafted alkyd copolymer since it increased to 2500 and 2930 cycles for L2 and L3, respectively. On the other hand, the blank copolymer was shown to give 1600 cycles.

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