

Polyvinyl Acetate and Vinyl Acetate-Ethylene Hybrid Adhesive: Synthesis, Characterization, and Properties

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How to cite this paper: Gadhave, R.V. (2024) Polyvinyl Acetate and Vinyl Acetate-Ethylene Hybrid Adhesive: Synthesis, Characterization, and Properties. *Open Journal of Polymer Chemistry*, 14, 1-18. <https://doi.org/10.4236/ojpchem.2024.141001>

Received: December 30, 2023

Accepted: February 6, 2024

Published: February 9, 2024

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Abstract

The goal is to develop a hybrid IPN network of polyvinyl acetate (PVAc) and ethylene-vinyl acetate (VAE). In this research work, the vinyl acetate (VAc)/VAE hybrid emulsion and polyvinyl acetate emulsion (PVAc) were effectively synthesized. Emulsions with various characteristics have been developed by adjusting the weight ratios between the vinyl acetate monomer and the VAE component. The impacts on the mechanical, thermal, and physical properties of the films were investigated using tests for pencil hardness, tensile shear strength, pH, contact angle measurement, differential scanning calorimetry (DSC), and viscosity. When 5.0 weight percent VAE was added, the tensile shear strength in dry conditions decreased by 18.75% after a 24-hour bonding period, the heat resistance decreased by 26.29% (as per WATT 91) and the tensile shear strength decreased by approximately 36.52% in wet conditions (per EN 204). The pristine sample's results were also confirmed by the contact angle test. The interpenetrating network (IPN) formation in hybrid PVAc emulsion as primary bonds does not directly attach to PVAc and VAE chains. The addition of VAE reduced the mechanical properties (at dry conditions) and heat resistance as per WATT 91. Contact angle analysis demonstrated that PVAc adhesives containing VAE had increased water resistance when compared to conventional PVA stabilised PVAc homopolymer-based adhesives. When compared to virgin PVAc Homo, the water resistance of the PVAc emulsion polymerization was enhanced by the addition of VAE.

Keywords

Ethylene-Vinyl Acetate Dispersion, Polyvinyl Acetate, Hybrid, Wood, Adhesive

1. Introduction

One of the most significant applications for polyvinyl acetate (PVAc) emulsions is the adhesive sector, which benefits greatly from its low cost, convenience of use, and environmental friendliness. On the other hand, a few drawbacks restrict the scope of its uses [1] [2] [3] [4]. PVAc emulsions do, however, have certain intrinsic drawbacks that restrict their use in applications. Since the PVAc homopolymer often lacks heat and water resistance and the stability of the emulsion is low in the absence of a protective colloid like polyvinyl alcohol (PVA), it is frequently changed using specific techniques to enhance emulsion performance [5] [6] [7] [8]. Numerous scientific techniques, including silane grafting, hydrophobic monomer crosslinking, PVA modification, nanomaterial use, and crosslinking by comonomer, have been utilised to enhance the performance of polyvinyl emulsions [9] [10]. Combining two distinct polymers can result in the development of hybrid polymers. They usually involve mixing an organic or inorganic material with a polymer. These combinations incorporate certain properties of both components that were not achievable in a single polymer alone. Several hybrid systems have been introduced to the market as a result of the advancements in hybrid polymer technology. Numerous academic institutions and the polymer industry are conducting research, and new findings are frequently published. Due to their unique and frequently unusual properties as well as their simple and inexpensive production processes, which result in significant cost savings over comparable silicon-based systems, hybrid polymers are becoming more and more common. Adhesives based on PVAc emulsion can have their performance attributes enhanced in a number of ways [11].

Aqueous polyurethane dispersions (PUD) are widely used in adhesives and coatings. Aliphatic di-isocyanate, which has a low reactivity with water, is the most prevalent form of polyol in commercial PUD. Enhancing urethane/acrylic dispersion adhesion to plastic surfaces, resilience to chemicals and solvents, abrasion resistance, and cost effectiveness are the main goals of recent advancements in this technology [12]. The synthesis of composite dispersions of water-based polyurethane-acrylic (PU-AC) physical blends yielded results that show the PU-acrylic hybrid systems' characteristics do not behave linearly as the concentration of AC increases. But the physical mixes' properties indicate a gradual transition from PU to AC [13]. A possible method for introducing the best characteristics of vinyl-acrylics and alkyds in a low volatile organic compound water-based system is the use of hybrid systems [14] [15]. The synthesis of hybrid binders by free radical polymerization of acrylic monomers in the presence of an unsaturated alkyd resin was studied using an emulsion polymerization approach [16] [17]. Among the polymerization methods are interpenetrating network (IPN) development and seeded emulsion polymerization. Research is being done on hybrid emulsions made of polyurethanes and acrylic polymers [18] [19] [20]. According to certain sources, there are advantages to hybridising these two materials to generate a network that is physically cross-

slinked [21]. There are numerous methods of producing aqueous acrylic-polyurethane hybrid emulsions [22] [23]. To produce hybrid emulsions, the most representative method is to polymerize acrylic monomers in the presence of polyurethane dispersion [24]. Alternatively, acrylic and polyurethane polymers can develop simultaneously using the *in-situ* process. The components resembling IPN are then transformed into hybrid emulsions of acrylic and polyurethane. Waterborne one-pack crosslinking systems comprising acrylic emulsions and polyurethane dispersions with distinct reactive groups are the subject of another proposal [25]. Through surfactant-free emulsion polymerization, PVAc/MMT hybrid adhesives have been developed by adjusting the kind and loading of MMT nanoclay. The final characteristics of the hybrid films and latexes were contrasted with those of pure PVAc that were produced in comparable circumstances. When comparing PVAc/MMT hybrid materials to pure PVAc, notable improvements were seen [26] (Figure 1).

Another way to enhance the qualities of PVAc is to combine it with other adhesives or polymers. Due to its simplicity of obtaining new qualities and inexpensive processing costs, mixing or blending is the recommended method [27] [28] [29] [30] [31]. Vinyl acetate and ethylene co-polymers are available commercially for various uses. They are referred to as EVA and VAE when the ethylene concentration is more than 50% and vinyl acetate is more than 50% [32]. Because of the internal plasticizing impact of ethylene, VAE is more flexible than a typical PVAc emulsion, offering numerous benefits. The permanent plasticizing effect of ethylene is well-known because its molecules are bonded to the vinyl acetate's backbone. VAE works incredibly well in coating, adhesives, and other applications when used without any modifiers or additions. Because of its numerous industrial applications among end users, this polymer is growing in popularity [33]-[38]. Compared to PVAc, VAE polymers exhibit stronger and higher adhesive properties as well as superior heat resistance. These polymers have the potential to be highly effective PVAc enhancers due to their superior compounding and creep resistance properties [39] [40]. Combining hard and soft polymers can improve adhesive qualities in a complementary way. When combining several components in a synergistic way to develop hybrid materials, better performance can be achieved [41] [42] [43].

PVAc and hybrid water-based polyurethane/vinyl acetate (WPU) emulsions were investigated. Various weight percentages of polyurethane components were used to create emulsions with various characteristics. The loading of WPU in PVAc emulsion is related to thermomechanical and mechanical parameters such as damping factor, storage modulus, loss modulus, tensile strength, and lap shear strength to build a physical crosslinked network. When comparing the hybrid emulsion to the PVAc emulsion, the results indicated a slight change in the heat response of the hybrid emulsion qualities but an improvement in lap shear strength. Abdel-Wakil *et al.* [44] synthesised novel aqueous polyurethane-vinyl ester-vinyl acetate terpolymers with a high solid content using efficient nano-scale emulsion synthesis in one of their recent investigations. Studies on the effects of different

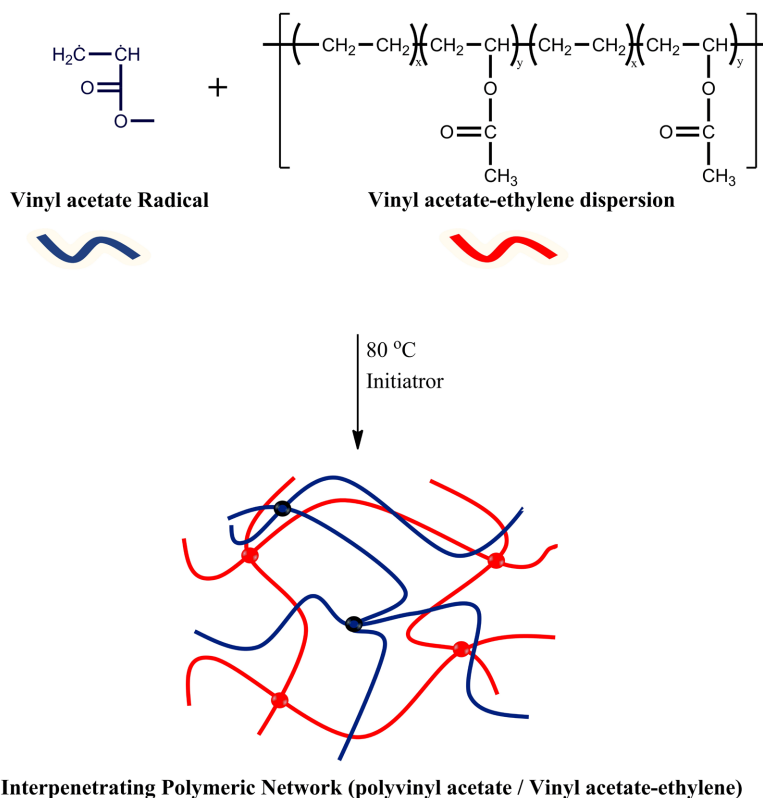


Figure 1. PVAc-VAE hybrid interpenetrating polymeric network.

vinyl monomers and diisocyanates on the properties of the resulting emulsion coatings have been conducted. Similar scientists found in another study that the vinyl acetate copolymer's polyurethane moiety enhanced heat stability based on TGA measurements [45].

This paper reports a novel route to improve the performance of PVA-stabilized PVAc emulsion by forming a physical IPN network with Vinyl acetate-ethylene copolymer dispersion. In this research, VAE dispersion was used at the time of polymerization of vinyl acetate monomer. VAE is well known for its balanced properties. VAE have a wide range of applications because of their excellent adhesion to low surface energy substrates, mechanical, abrasion, and chemical resistance properties. The physical and thermal properties and performance of adhesives prepared through this route have been studied in detail.

2. Experimental

2.1. Materials

Cold water so polyvinyl alcohol (CWS PVA) (CAS No. 9002-89-5, % degree of hydrolysis 88% - 89%, Molecular weight 90,000 - 100,000 g/mol) was obtained from Kuraray Cooperative Limited, India. Vinyl acetate (VAc, CAS No. 108-05-4), sodium lauryl sulfate (SLS, CAS No. 68585-34-2), vinyl acetate ethylene copolymer (VAE, CAS No. 24937-78-8), potassium persulfate (PPS, CAS No. 7727-21-1), and sodium benzoate (CAS No. 532-32-1) were acquired from Sigma Aldrich.

2.2. Preparation Method

Polymer emulsions were synthesized in a flat-bottom glass reactors equipped with condenser, stirrer, temperature indicator, metric pump, and glass funnel for addition of additives. Semi-continuous emulsion polymerization process was adopted with continuous supplying thermal energy using water heating bath. **Table 1** shows the polymer emulsion recipes.

Colloid solution preparation

CWS PVA was first put into a glass reactor. The water was added to them, and the mixture was kept for continuous stirring at 175 rpm. The temperature was slowly raised up to 94°C - 96°C and the final temperature was kept at 94°C - 96°C. The cooking was carried out for 2.5 hr. Then, the solution was cooled down to 25°C and added sodium benzoate. It is used in PVAc.

PVA- VAE solution preparation

VAE in VAc-VAE Hybrid-01 and VAc-VAE Hybrid-02 and PVA were first put into a glass reactor. The water was added to them, and the mixture was kept for continuous stirring at 175 rpm. The temperature was slowly raised up to 94°C - 96°C and the final temperature was kept at 94°C - 96°C. The cooking was carried out for 2.5 hr. Then, the solution was cooled down to 25°C and added sodium benzoate.

PVA stabilized emulsion (PVAc)

CWS PVA solution was used as protective colloid for stabilization of emulsion. Sodium lauryl sulphate was used as an anionic surfactant. Sodium bicarbonate used as buffer. Initiator solution was prepared by dissolving potassium persulfate in deionised water. Polymerization was carried out by controlled addition of vinyl acetate (VAc) monomer. After complete addition of monomer, potassium persulfate solution in water was added and temperature was maintained at 90°C for 1 hr. Then, the emulsion was cooled down to 25°C and added sodium benzoate.

Table 1. Composition of the emulsions.

Components	PVAc (g)	VAc-VAE Hybrid-01 (g)	VAc-VAE Hybrid-01 (g)
VAc	48.73	45.73	44.73
VAE	0	3	5
DIW	43.61	43.61	42.61
CWS PVA	2.00	2.00	2.00
SBC	0.12	0.12	0.12
SLS	0.01	0.01	0.01
DIW	1.53	1.53	1.53
PSS	0.1	0.1	0.1
DIW	3.5	3.5	3.5
Sodium benzoate	0.1	0.1	0.1
DIW	0.3	0.3	0.3
Total	100	100	100

PVA and VAE stabilized emulsion (VAc-VAE Hybrid-01 and VAc-VAE Hybrid-02)

CWS PVA + VAE solution was used as protective colloid for stabilization of emulsion. Sodium lauryl sulphate was used as an anionic surfactant. Sodium bicarbonate used as buffer. Initiator solution was prepared by dissolving potassium persulfate in Deionised water. Polymerization was carried out by controlled addition of monomer VAc. After complete addition of monomer, potassium persulfate solution in water was added and temperature was maintained at 90 °C for 1 hr. Then, the emulsion was cooled down to 25 °C and added sodium benzoate.

3. Characterization and Testing

3.1. Solid Content

Solids content of emulsion was checked by heating sample (around 1 g) at 120 °C for 120 min in a hot air oven. Measurements were done in triplicate to minimize error. To measure the solid content the following equation was used:

$$\text{Solid content (\%)} = (W_3 - W_2) / (W_2 - W_1) \times 100\%$$

W_1 = Weight of empty weighing pan;

W_2 = Weight of Pan with sample before heating;

W_3 = Weight of pan with residue after drying till constant weight.

3.2. Viscosity and pH

Viscosity was measured by using Brookfield DV1 Viscometer as per ASTM D1084. The values were taken at 20 rpm and sample stored at a temperature of 30 °C. pH of the samples was analysed using a digital pH meter, CL 54 + Toshcon Industries, India according to ASTM E70 [7]. To reduce the error, viscosity and pH measurements were taken for 5 times.

3.3. Dry-Out Period on Teflon Sheet

Use of notched bar film applicator, 200 µm wet coatings were drawn over a Teflon sheet and at the same time a stopwatch was triggered. For recording the dry-out periods, time from casting step to completely dry was recorded using stopwatch. This test was carried out at 30 °C ± 2 °C [23].

3.4. Pencil Hardness Test

The pencil hardness test was done using a QHQ-A portable pencil hardness tester, having lead pencils of varying hardness numbers. Using an applicator, 200-micron films were casted over a glass plate. After the films are dried at 30 °C ± 2.0 °C for 1 day, the test was conducted following ASTM D 3363 standard [7].

3.5. Differential Scanning Calorimetry (DSC)

A Perkin Elmer instrument Q 100 DSC has been used for estimating the glass transition temperature (T_g) of the samples. During the measurement, an oxy-

gen-free nitrogen stream of 40 mL/min was maintained through the cell. Sample film casted on Teflon was dried at 105 °C for 90 min. 5 mg film was analysed directly on DSC by cyclic heating-cool-heat method. The DSC analyses were done within a range of -10 °C to 200 °C at a heating rate of 10 °C min. Drying time on glass plate Using an applicator, 200- μ m films were casted over a glass plate and the time for drying was measured using a stopwatch. Time taken for full drying of films is noted at 30 °C \pm 2.0 °C.

3.6. Water Contact Angle Measurement

The water contact angle was measured using a Kruss Easy Drop (FM40Mk2, Kruss GmbH, Germany) at 30 °C and 50% relative humidity. To measure the contact angle, the samples are cast over glass substrates with an applicator of 100 μ m. The test was conducted for 5 times to reduce the error. Contact angle measurement gives an idea of the behaviour of prepared samples with respect to water. Moreover, variations in the hydrophobicity in formulations can be analysed using contact angle measurements.

3.7. Tensile Shear Strength-Wet and Dry

Shear strength was evaluated at different intervals in joints prepared by gluing beech specimens in normal climate. Bonded assemblies were tested after keeping them at 30 °C and 50% relative humidity after 6 hr, 24 hr and 7 days. In this case, strength was calculated in MPa. Wet strength tests were performed according to condition D3-3 of EN 205 after 7 days in a normal climate. Specimens were soaked in water for an additional 24 hr and then tested water resistance.

3.8. Heat Resistance of Adhesives

Adhesive was applied to step-cut unsteamed beech wood substrates with a bonding area of (2 \times 2) sq. cm followed by applying static pressure of 1 MPa. The adhesive was applied on the substrates at 25 °C \pm 2 °C and 60% \pm 5% relative humidity, followed by the conditioning of the substrates for 7 days at the same temperature and humidity condition. After 7 days, samples were released from the clamps. The substrates were conditioned as per DIN 14257/WATT 91 [10], respectively. For each sample, at least five bonded specimens were prepared, and standard deviations were calculated. Bond strength evaluation was carried on a universal testing machine (UTM) of making Amil technologies. Load cell capacity of UTM was 25 KN, and crosshead speed was 5 mm/min. **Figure 2(a)** shows bonded specimens as per EN 204-205 and **Figure 2(b)** shows specimens dipped in water to test wet strength as per EN 204-205. Finally, wood failure percentage was visually determined.

4. Results and Discussions

All the test findings are combined and collated in order to bring together different observations from the characterization and analysis. **Table 2** provides the

overall test findings for the research. The next section contains thorough discussions of each analysis.

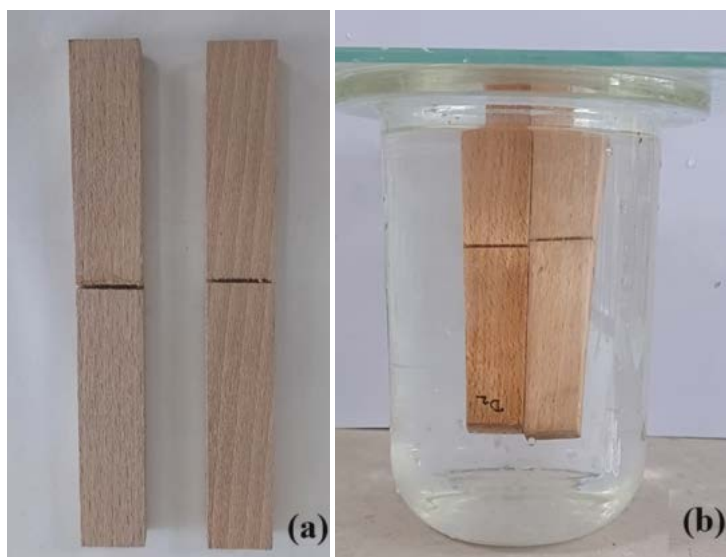


Figure 2. (a) Bonded specimens as per EN 204-205; (b) Specimens dipped in water to test wet strength.

Table 2. Various test results.

Sr. No	Properties	PVAc Homo	VAc-VAE Hybrid-01	VAc-VAE Hybrid-02
1	% Solid	47.0 ± 0.1	47.1 ± 0.1	47.3 ± 0.1
2	Viscosity (P)	400 ± 10	345 ± 10	300 ± 10
3	pH	4.90 ± 0.1	4.50 ± 0.1	4.50 ± 0.1
4	Drying time on glass plate (min.) (% relative humidity- 70% Temperature- 30°C)	35 - 37	33 - 35	30 - 33
5	Film Hardness	2H	2H	H
6	Glass transition temperature (°C)	39.4	33.76	32.43
7	Contact angle (°)	45.7 ± 1.29	59 ± 1.29	63 ± 1.29
	Tensile share strength (Dry) (MPa)			
	6 hr	3.27 ± 0.4	2.94 ± 0.4	2.50 ± 0.4
		100%BF	100%BF	100%BF
8	24 hr	6.08 ± 0.4	5.62 ± 0.4	4.94 ± 0.4
		50%SF	50%SF	50%SF
	7 Days	6.39 ± 0.4	6.53 ± 0.4	5.92 ± 0.4
		100%SF	100%SF	100%SF
9	Wet strength (7 days RT + 24 hrs in cold water) (MPa)	1.15 ± 0.3	1.35 ± 0.3	1.57 ± 0.3
		100%BF	100%BF	100%BF
10	Heat resistance as per DIN EN 14257 (MPa)	2.7 ± 0.3	2.33 ± 0.3	1.99 ± 0.3
		100%BF	100%BF	100%BF

BF: Bond failure; SF: Substrate failure.

4.1. Solid Content

Solids content of adhesives was checked by heating sample (around 1 g) at 120°C for 120 min in oven. It was found that the solid for all the samples are approximately same (Table 2).

4.2. Viscosity and pH

Viscosity and pH of the prepared samples are shown in Table 2. Presence of VAE in modified PVA-VAE based stabilizer in VAc-VAE Hybrid-01 and VAc-VAE Hybrid-02 samples maintain the pH constant.

Compared to the PVAc Homo, decrease in viscosity was observed in with increase in the concentration of VAE modification in PVAc Homo. Overall concentration of free hydroxyl of PVA decreased. This is due to less grafting of VAc monomer on hydroxyl group of PVA and resulted in decreased in viscosity as compare to PVAc Homo which is shown in Figure 3.

4.3. Dry-Out Period on Teflon Sheet

The drying time test was conducted on a Teflon sheet at controlled conditions (% RH 70% \pm 5% Temperature 30°C \pm 2°C). In comparison to PVAc Homo, VAc-VAE Hybrid-01 and VAc-VAE Hybrid-02 both required less time to dry. As showed in Table 2, the low water loss from adhesive film is caused by presence of unreacted hydroxyl group of PVA which acts as a humectant resulted into high drying time for pristine sample.

4.4. Pencil Hardness of Film

Pencil hardness of adhesives evaluates the mechanical strength property. As the addition of VAE in PVA stabilized PVAc adhesives VAc-VAE Hybrid-01 and

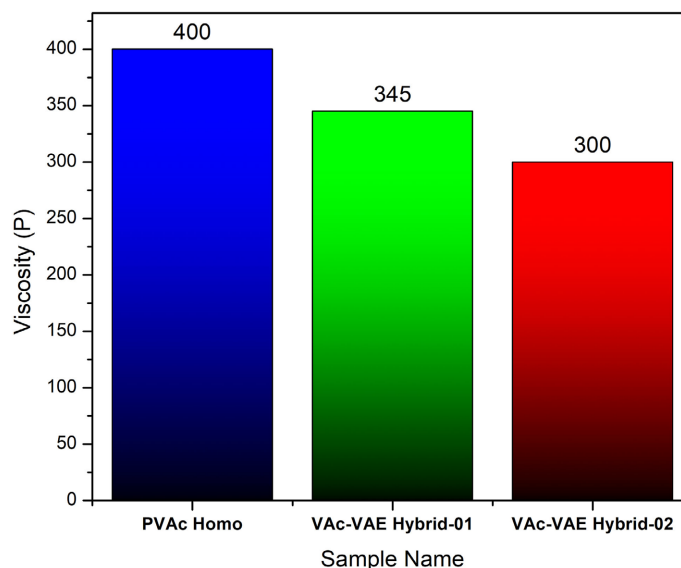


Figure 3. Viscosities of PVAc Homo, VAc-VAE Hybrid-01 and VAc-VAE Hybrid-02.

VAc-VAE Hybrid-02, hardness of film was decreased as compared to PVAc Homo as shown in **Table 2**. Due to less grafting of VAc on PVA resulted into less dense structure. Slip from sharp pencil due to needle like structure and VAE modified PVAc decreased, hence the VAc-VAE Hybrid-01 and VAc-VAE Hybrid-01 samples showed lower value of pencil hardness than PVAc HOMO.

4.5. Differential Scanning Calorimetry (DSC)

DSC thermograms quantify the thermal stability of samples. In DSC, the first heating cycle was considered for analysing the Tg value. The glass transition of PVAc homo and VAc-VAE Hybrid-01 and VAc-VAE Hybrid-01 samples was diagnosed with the help of DSC to observe the effect of VAE addition on the thermal characteristic of hybrid emulsion. The DSC thermograms for PVAc homo and VAc-VAE Hybrid-01, and VAc-VAE Hybrid-02 are shown in **Figure 4**.

PVAc-VAE hybrid emulsion develops a physical interpenetrating network as shown in **Figure 1** with reduced or unchanged Tg value compared to PVAc emulsion film. It is scientifically well known that a lower Tg value provides better flexibility of thin film with improved adhesion properties on the substrate. Due to flexible nature of VAE (Tg = 0°C) and hydroxyl functional group of PVA of VAE undergone grafting reaction with VAc monomer in VAE Hybrid-01, and VAc-VAE Hybrid-02 led to the decreased of Tg and make them flexible as compare to PVAc Homo. The same is validated from the film hardness test.

4.6. Water Contact Angle

In general water contact angle correlates the water resistance properties of the samples. Moreover, to correlate with the water resistance properties of VAE Hybrid-01, and VAc-VAE Hybrid-02 with the PVAc Homo, water contact angle measurement was studied. Distilled water is made in contact with the adhesive surface. The contact angle of the sample with water is shown in **Figure 5** and the values are labelled in **Table 2**. It is observed that the contact angle value is higher for VAc-VAE Hybrid-01 and VAc-VAE Hybrid-02 as compare to PVAc Homo. This is due to PVAc-VAE hybrid emulsion develops a physical interpenetrating network as shown in **Figure 1** and hydroxyl functional group of PVA of VAE undergone grafting reaction with VAc monomer in VAE Hybrid-01, and VAc-VAE Hybrid-02. Due to ethylene group in VAE hydrophobicity of the film increased. Sight reduction in strength of bonded wood specimen in wet condition in PVAc Homo provides evidence for the same observation.

4.7. Tensile Shear Strength Testing: Wet and Dry

The bonding strength of adhesives were tested on the substrates in dry condition and another set of samples in wet conditions as per EN 204 for water resistance and conditions for wet strength is shown in **Figure 2(b)**. From **Table 2**, it was observed that by the addition of VAE-PVA solution in VAc-VAE Hybrid-01 and VAc-VAE Hybrid-02, water resistance was increased.

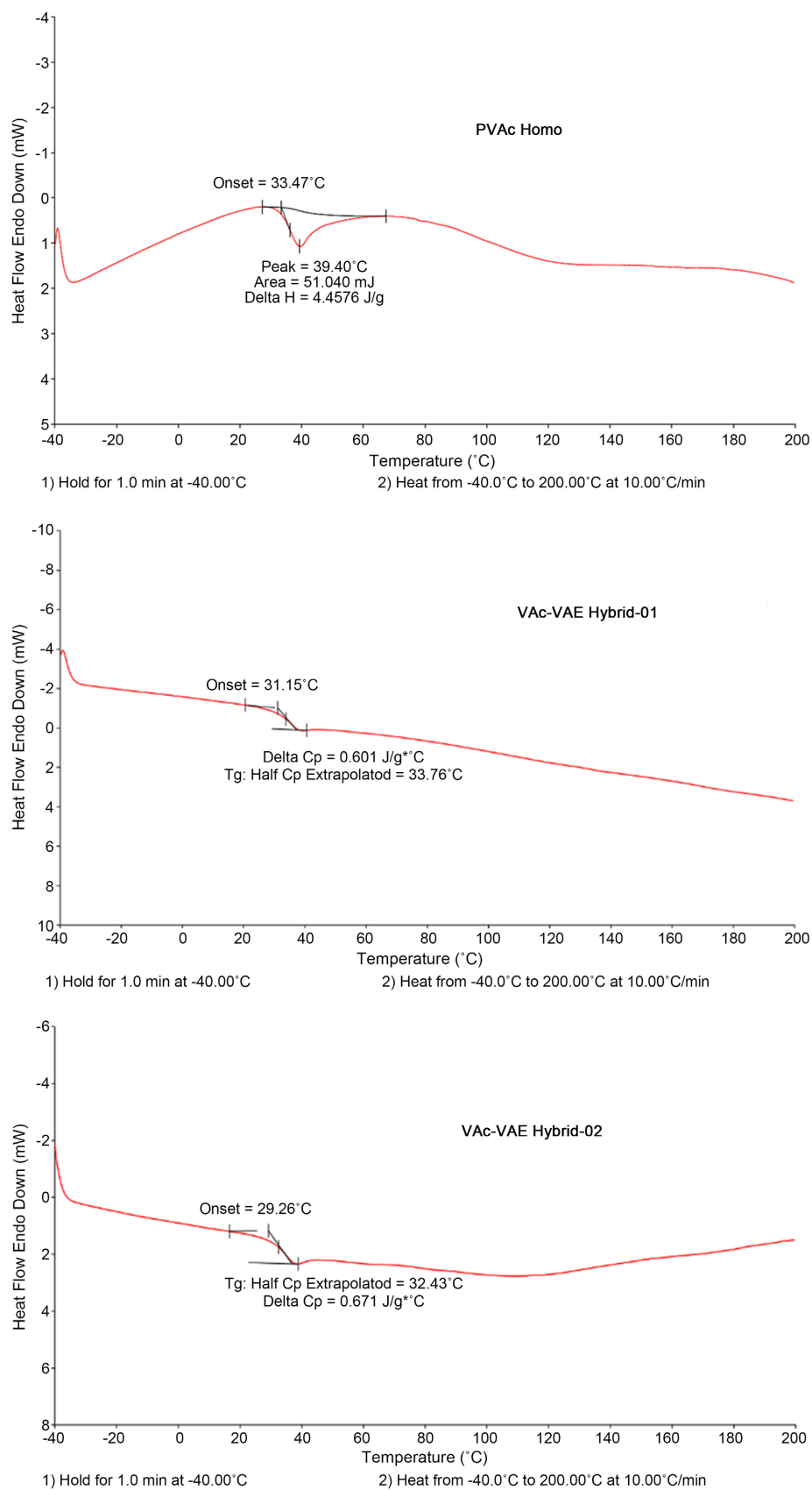


Figure 4. DSC thermograms for PVAc Homo, VAE Hybrid-01, and VAc-VAE Hybrid-02.

After 24 hr immersion in water, PVAc Homo has lower strength as compare to VAc-VAE Hybrid-01 and VAc-VAE Hybrid-02 as shown in **Figure 6**. This is due to PVAc-VAE hybrid emulsion develops a physical interpenetrating network as shown in **Figure 1** and hydroxyl functional group of PVA of VAE undergone grafting reaction with VAc monomer in VAE Hybrid-01, and VAc-VAE Hybrid-02. Due to ethylene group in VAE hydrophobicity of the film increased.

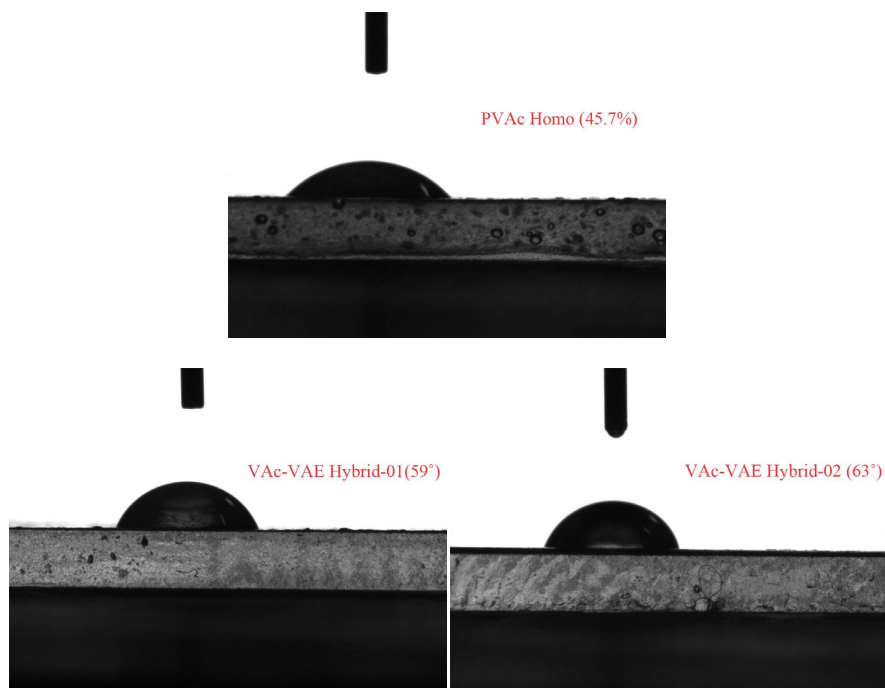


Figure 5. Water contact angle images for PVAc Homo, VAc-VAE Hybrid-01, and VAc-VAE Hybrid-02.

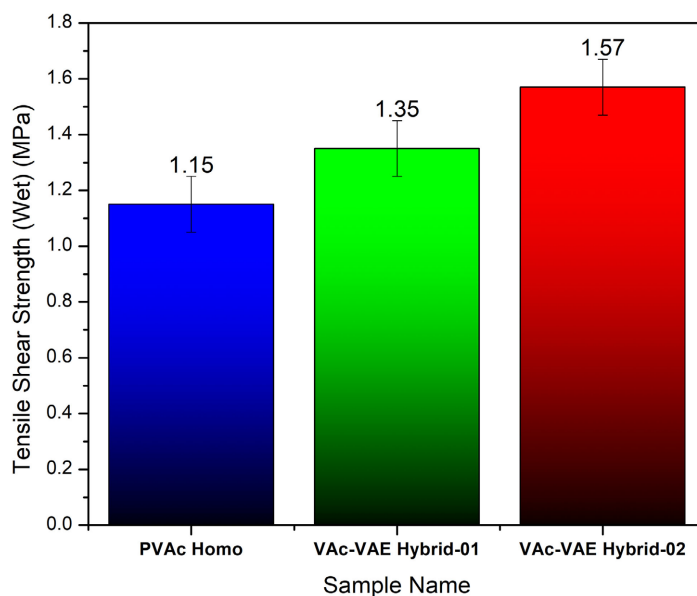


Figure 6. Tensile shear strength in wet conditions.

As addition of VAE, dry strength decreased in VAc-VAE Hybrid-01 and VAc-VAE Hybrid-02 as compare to PVAc Homo. This is due to PVAc-VAE hybrid emulsion develops a physical interpenetrating network as shown in **Figure 1** with reduced or unchanged Tg value compared to PVAc emulsion film. It is scientifically well known that a lower Tg value provides better flexibility of thin film with improved adhesion properties on the substrate. Dry strength was shown in **Figure 7**.

4.8. Heat Resistance of Adhesive (WATT 91)

The heat resistance of adhesives was assessed on the substrates conditioned as per WATT 91. From **Figure 8** and **Table 2**, we observed variation in bonding

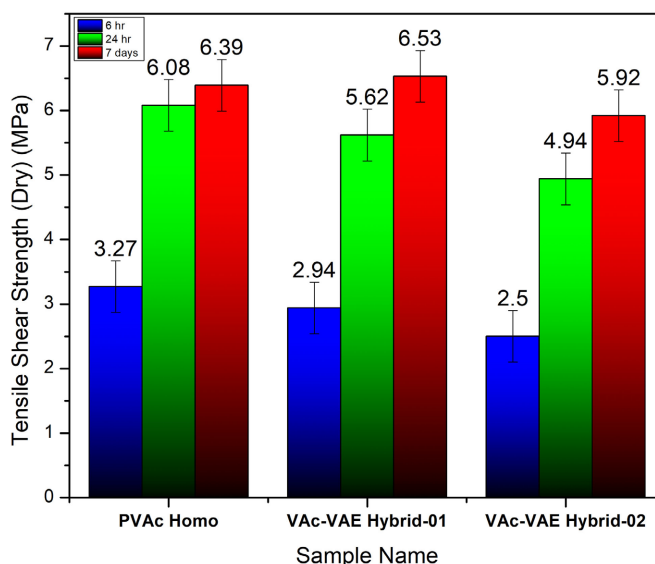


Figure 7. Tensile shear strength in dry condition.

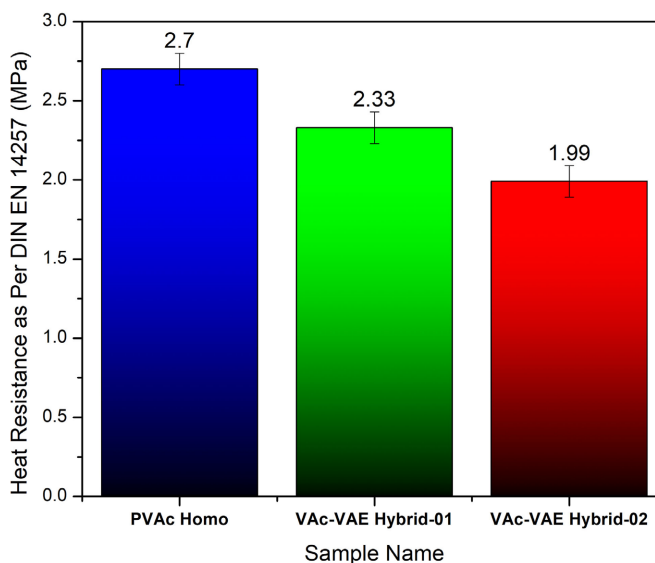


Figure 8. Trend of adhesive strength measure for the specimen conditioned as per WATT 91.

strength test for assessing heat resistance property of the hybrid. With 5.0 wt% of VAE dispersion, the heat resistance showed reduction by 26.29% (as per WATT 91) compared to that of PVAc Homo. PVAc-VAE hybrid emulsion develops a physical interpenetrating network as shown in **Figure 1** with reduced or unchanged Tg value compared to PVAc emulsion film. It is scientifically well known that a lower Tg value provides better flexibility of thin film with improved adhesion properties on the substrate. Due to flexible nature of VAE (Tg = 0°C) and hydroxyl functional group of PVA of VAE undergone grafting reaction with VAc monomer in VAE Hybrid-01, and VAc-VAE Hybrid-02 led to the decreased of Tg and make them flexible as compare to PVAc Homo.

5. Conclusion

PVAc-VAE hybrid adhesives were prepared by adding VAE at different concentrations 3.0%, and 5.0%, during *in situ* polymerization of PVAc adhesive. PVAc-VAE hybrid emulsions were prepared using various proportions of VAE dispersion, and its effect on physical properties was studied. VAE dispersion was found to influence the adhesion property of PVAc positively in wet conditions. Lap shear strength in wet conditions was increased significantly with the proportion of VAE dispersion. The interpenetrating network (IPN) formation in hybrid PVAc emulsion as primary bonds does not directly attach to PVAc and VAE chains. The addition of VAE reduced the mechanical properties (in dry conditions) and heat resistance as per WATT 91. Water resistance was enhanced in PVAc adhesives with VAE addition as compared to conventional PVA stabilized PVAc Homopolymer based adhesive which was confirmed by contact angle study. The VAE added to *in situ* emulsion polymerization of PVAc improved the water resistance as compared to virgin PVAc Homo.

Acknowledgements

We would like to thank Institute of Chemical Technology, Mumbai, India, for the support throughout this work.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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