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Synthesis and Optimization of PVA based paper lamination adhesives

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ABSTRACT: Polyvinyl alcohol (PVA) and polyvinyl acetate (PVAc) are the polymers of great interest because of many desirable characteristics. They can be used for many purposes. One of the major uses of these polymers is they can be used to produce adhesives for paper converting, packaging and laminating. The purpose of this work is to develop a suitable process for producing PVA based adhesives. In this work, both polyvinyl acetate and polyvinyl alcohol adhesives were prepared. Adhesives were prepared by the polymerization and alcoholysis of vinyl acetate monomer (VAM). Different performance tests were conducted after preparing these adhesives. In this study it was found that better quality adhesives can be prepared from polyvinyl alcohol. Different performance tests were conducted on the adhesives prepared. It was found from the performance tests that polyvinyl alcohol adhesive is the best adhesive that can be used for lamination. Drying time for polyvinyl alcohol was found 12.9 minutes which was better than polyvinyl acetate adhesives. Moreover, pull-off test shows that maximum allowable pressure for PVA adhesive is higher than PVAc adhesives and the value is 195 psi.

KEYWORDS: Polyvinyl alcohol, polyvinyl acetate, Vinyl acetate monomer, Adhesive, Polymer.

1 INTRODUCTION

An adhesive is any substance applied to the surfaces of materials that binds them together and resists separation [1]. The importance of using paper lamination adhesive is increasing day by day. In Bangladesh, all the adhesives used for different purposes such as, paper lamination, book binding, book cover preparing is imported from different countries. Using imported adhesive is costly. This study work is based on producing foreign quality adhesive at low cost.

The use of adhesives offers many advantages over other binding techniques such as sewing, mechanical fastening, thermal bonding, etc. These include the ability to bind different materials together, to distribute stress more efficiently across the joint, the cost effectiveness of an easily mechanized process, an improvement in aesthetic design, and increased design flexibility [2]. Properties of adhesive and applications may vary depending on the raw materials used to prepare those adhesives. Vinyl ester family is the most important polymers that can be used to produce different adhesives [3]. Vinyl ester is a synthetic polymer. PVA adhesives are water based adhesives [4]. They are mainly used for mounting paper, paper products canvas etc. Polyvinyl acetate latexes were the first synthetic polymer latexes made on an industrial scale, beginning in Germany in the 1930s [5]. With the addition (and/or generation in situ) of PVA as an emulsifier, PVA latexes became one of the major products of the adhesive and surface coating industries.

PVA based adhesive preparation is a complex process. It shows complexity of polymerization reaction such as initiation, propagation, termination and is time consuming [6]. It is, therefore, an object of this invention to provide a practical and economical process for producing polyvinyl acetate adhesives having a lower degree of crystallizability. A further object is to provide an improved method of polymerizing vinyl acetate to yield polyvinyl acetate that may be converted to polyvinyl alcohol having a low degree of crystallizability. Optimization of different methods of adhesive preparation and the selection of most cost effective method is another motto of this study.

2 MATERIALS AND METHODS

2.1 MATERIALS

The main materials used here are Polyvinyl Alcohol and Vinyl acetate monomer. Sodium Hydrogen Carbonate was used as a buffer solution and Potassium persulfate as initiator. Detergent was used surfactant solution and all of these were found from local market.

2.2 METHODOLOGY

Different types and grades of binders can be produced from polyvinyl Alcohol (PVA) and polyvinyl acetate (PVAc). Paper converting, packaging wood, tile and home handyman adhesive can be produced from polyvinyl Acetate. On the other hand polyvinyl alcohol binders are mainly used for paper applications and in textile industries. Synthesis processes of these adhesives are different depending on the use of the adhesives. Our goal is to study a process for producing commercial grade paper lamination binder. To achieve this goal, we have prepared both PVA and PVAc based adhesives.

2.3 POLYVINYL ACETATE PREPARATION

Two different tests were conducted to prepare polyvinyl acetate adhesive. The basic difference between the two experiments was in the use of raw materials. In the first experiment no polyvinyl alcohol was used while polyvinyl alcohol was used in the second experiment. Adhesives of two different grades have been found from two different experiments. Polyvinyl alcohol is a water soluble polymer and it was used to partially hydrolyze polyvinyl acetate. Thus, adhesive prepared in the second experiment has better bonding characteristics than the one prepared from the first experiment.

2.4 METHOD 1

The raw materials used for this method was vinyl acetate monomer (VAM), potassium persulfate, sodium bicarbonate and surfactant solution. Potassium persulfate was used as the initiator of the polymerization reaction. Sodium persulfate was used as buffer solution. 0.12 g sodium bicarbonate and 0.12 g potassium persulfate was dissolved in 5ml water respectively. 0.2 g surfactant solution was dissolve in 20 ml water. 40 ml water was added to 30 ml vinyl acetate monomer solution. All the prepared solutions were mixed together in a polymerization bottle. Then the solution it was heated using magnetic stirrer for 8 hours. The temperature was kept at 70-80^{o}C. After 8 hours of heating, polyvinyl acetate was found. The problem with this method is plastic was formed with prepared adhesive and this plastic formation was found as precipitation. The quality of the prepared adhesive was decreased because of the plastic formation. Another problem of this plastic formation is that it hindered the movement of magnetic stirrer and thus the proper mixing of the solution.

2.5 METHOD 2

Method 2 is a modification of the first method as; plastic was formed in the first method. In this method additional polyvinyl alcohol was used in the solution. 0.2 g PVA was dissolved in water and added to the polymerization bottle. PVA partially hydrolyzes polyvinyl acetate and the adhesive produced in this method has a better binding quality. All procedures are same as the previous method. The adhesive found in this process has no plastic precipitation, has a better binding quality than the previous one. The reason behind this better quality is polyvinyl alcohol was used in this method. But still, the desired quality couldn’t be achieved. So, another experiment was conducted to produce polyvinyl alcohol (PVA) adhesive.

2.6 POLYVINYL ALCOHOL PREPARATION

Polyvinyl alcohol cannot be prepared directly from vinyl alcohol monomer [7]. So, it was prepared from vinyl acetate monomer. PVAc was prepared from vinyl acetate monomer. The procedure is just as discussed in the previous section. Then PVA was prepared by the alcoholysis of PVAc. Methanol was used for the alcoholysis of PVAc. NaOH was used as the catalyst. The solution was refluxed for 1 hour at 80°C. PVA was found as precipitate. It was separated by filtration and the PVA binder was prepared by hydrolyzing the solid PVA. The adhesive prepared in this method has very good binding characteristics. Its quality is almost same as the imported adhesives used in the local market.

3 PERFORMANCE TESTS

After preparing adhesives using three different methods, different performance tests were conducted to measure their strengths. The tests we have conducted were:

1. Pull-off test
2. Peel test
3. Drying time test

The results found from these tests have shown the strength and quality of the different adhesives prepared. The tests were conducted to conclude whether the adhesives prepared in this work is good or not.

3.1 PULL OFF-TEST

Pull-off adhesion testers measure the force required to pull a specified diameter of coating away from its substrate [8]. This test provides a direct indication of the strength of adhesion between the coating and the substrate. Equipments required for this test were pressure source, pressure gauge and actuator. The flat surface of a paper is adhered to the coating to be evaluated. A coupling connector from the actuator was attached to the paper, after allowing for the bonding adhesive to cure. Pressure is slowly increased to the actuator within the system. Separation occurs when the pressure in the actuator becomes greater than the bond strength between the coating and the substrate. The pressure at which separation occurs is the maximum allowable pressure for the adhesive used.

3.2 DRYING TIME

Drying time is the period of time recommended for the adhesive to set after it is covered with the substrate. Drying time was calculated manually. A stop clock was used to measure the drying time of the adhesives. The time required for each sample to complete drying is observed.

3.3 T-PEEL TEST

Peeling is the most important test conducted for adhesives [9]. Because, paper lamination binders are applied in a way that papers can be separated by peeling easily rather than tearing. An Admet eXpert 7600 series machine was used for the t-peel test. High frequency data points were captured by the tester and a characteristic curve was found for each of the samples. Each end of the sample was loaded into opposite tensile grips. The grips were separated at a constant rate and the average load and the peak load were noted.

4 RESULTS AND DISCUSSION

4.1 PULL OFF-TEST

Maximum allowable pressures found from the pull-off test were different for all the samples. Maximum pressures for all the samples are shown in table-1.

Table-1: Pull-off test result for different samples

Name of the sample	Sample 1	Sample 2	Sample 3	Market product
Maximum pressure (psi)	55	80	195	210

The maximum allowable pressure is different for different samples (Figure 1).

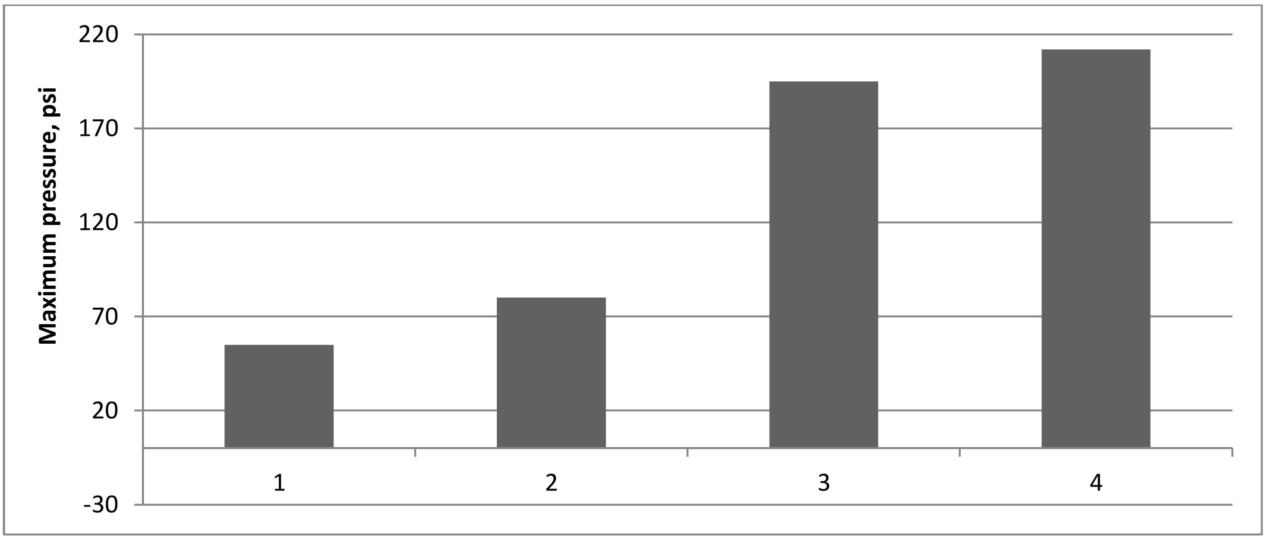

Figure 1: Graphical representation of pull-off test result

From the bar diagram it can be said clearly that the adhesive prepared in the third experiment has the best adherent quality and the maximum allowable pressure is nearly equal to that of the market product.

4.2 DRYING TIME

The drying time was calculated manually. Using the stop clock, the drying time for the adhesive to set after it is covered with the substrate. Drying time for different samples is shown in table-2.

Table-2: Drying time for different samples

Sample name	Sample1	Sample 2	Sample 3	Market product
Drying time (min)	23.4	21.1	12.9	10.1

The drying time is noted for different samples and market product and it is found that Sample 3 is close to market adhesive (Figure-2)

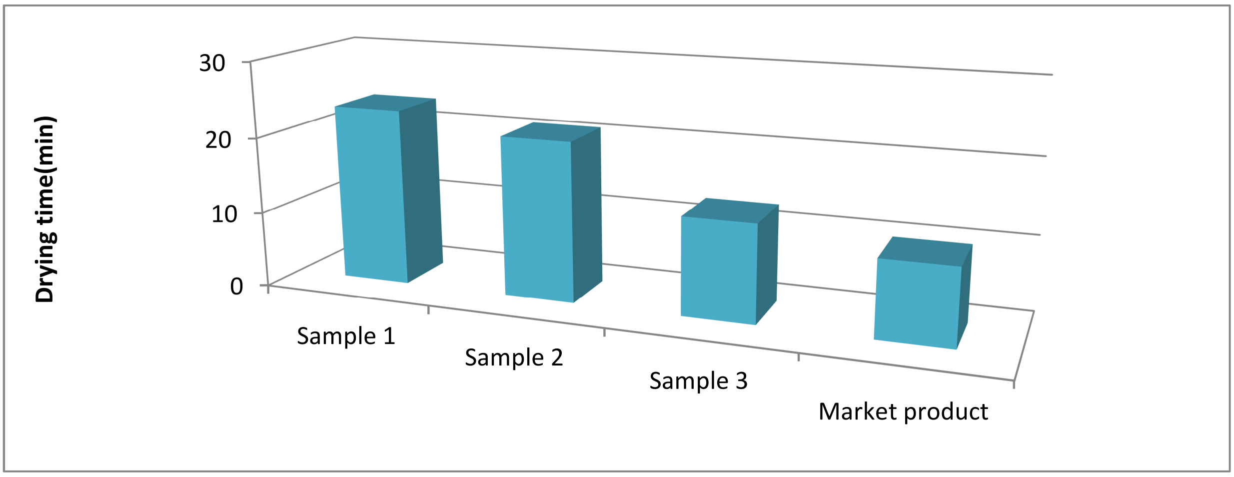

Figure 2: Drying time of various samples

4.3 T-PEEL TEST

In T-peel test, laminating films are detached by the pneumatic tension grip. Different loads need to separate the films and displacements of the arms were observed.

Table-3: T-peel test result for different samples

Sample 1		Sample 2		Sample 3		Market product	
Displacement (mm)	Load (N)	Displacement (mm)	Load (N)	Displacement (mm)	Load (N)	Displacement (mm)	Load (N)
0	10	0	10	0	10	0	10
2	55	2	75	2	129	2	168
4	41	4	32	4	67	4	72
6	25	6	28	6	76	6	70
8	31	8	28	8	64.5	8	68
10	25	10	27.5	10	65	10	68

The grips were separated at a constant rate and the average load and the peak load were noted (figure-3).

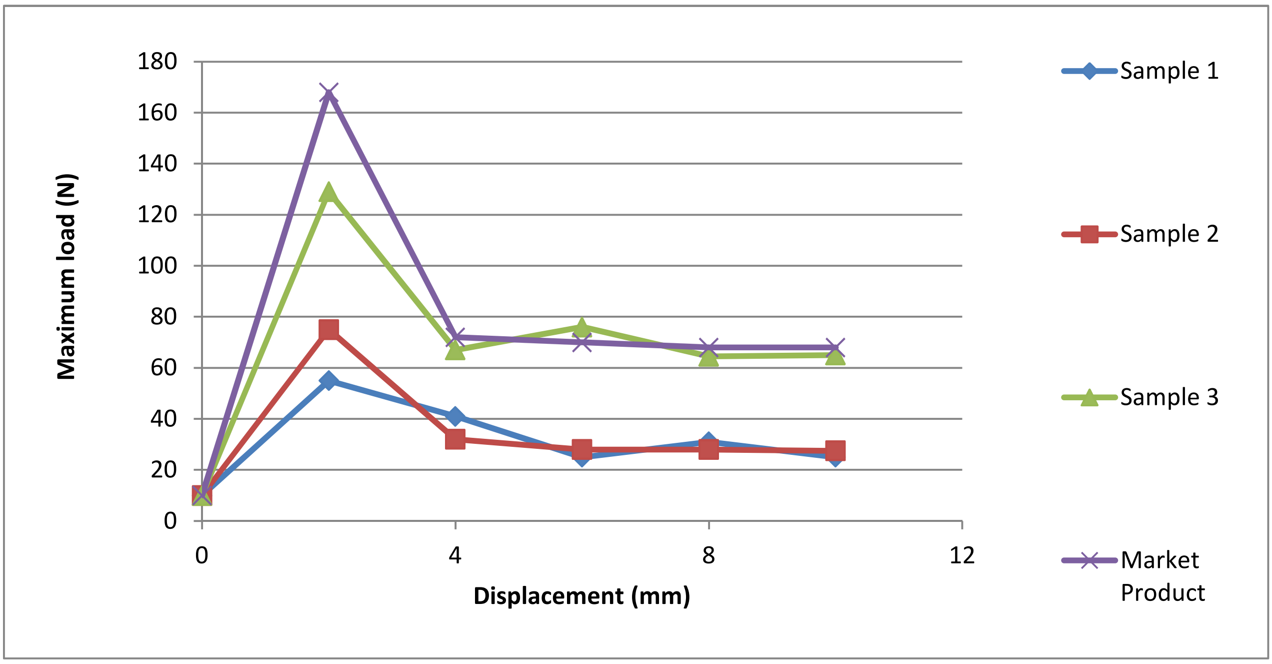

Figure 3: T-peel test for various samples

From analyzing all the results it is clearly stated that market product is still better than ours. Some reasons are liable for that such like: Using local detergent instead of AMA, AOT which caused foam during PVA synthesis, using Vinyl acetate monomer in fist two sample tests which formed plastic during operation, running semi batch instead of batch system, presence of air bubble in the final product etc.

5 CONCLUSION

It can be stated that the synthesis and optimization of PVA based adhesive constitutes a mature field of research with commercial opportunities and a promising future in the forthcoming years. The objective of this study was to establish a simplified and economically feasible process for PVA adhesive production. From analyzing the results it is concluded that method 3 is the optimized method. It is clearly mentioned that using polyvinyl acetate will not be feasible for this study. PVA adhesive has less drying time of 87s which confirms that it dries faster. From pull off test it is proved that PVA adhesive can tolerate up to a pressure of 195 psi which is approximate to existing market adhesive. Drying time and T peel test also proved its properties as a fine quality adhesive. Experimental study showed that it was a time consuming process and needs great inspection.

REFERENCES

[1] A. J. Kinloch *Adhesion and Adhesives: Science and Technology*, illustrated, *reprint Ed*. Springer Science & Business Media, 1987.

[2] Allen, J.P. *Biophysical Chemistry*: John Wiley & Sons, 2009.

[3] Kim, J.K. and Pal, K, *Recent Advances in the Processing of Wood-Plastic Composites,* Springer, 2010.

[4] T.E. Rolando, *Solvent-Free Adhesives, Ismithers* Rapra Publishing, 1998.

[5] J.C. Salamone, *Polymeric Material Encyclopedia*, CRC Press, 1996.

[6] Fried, J.R. *Polymer Science and Technology*, 2nd, illustrated, reprint Ed. Prentice Hall Professional Technical Reference, 2003.

[7] Sakurada, I. *Polyvinyl Alcohol Fibers*, illustrated Ed. CRC Press, 1985.

[8] Silva, L., Dillard, D., Blackman, B. and Adams, R. *Testing Adhesive Joints: Best Practices*, John Wiley & Sons, 2012.

[9] Benedek, I. *Pressure-Sensitive Adhesives and Applications*, 2nd, illustrated, revised Ed. CRC Press, 2004.