A Review on Synthesis and Characterization of Castor Oil Based Polyurethane Adhesive

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Abstract—This review paper gives the idea about use of raw materials from renewable sources to synthesis polyurethane adhesive which is important from social, environmental and economic view as compared to those produced from petrochemical sources. Polyurethanes based on castor oil were synthesized with polyols and toluene diisocyanate, and amine as a catalyst. The degree of swelling, mechanical properties, and polymerization kinetics was greatly affected by the diisocyanate nature. The aim of this review paper is to give a fundamental description of castor oil and various application of polyurethane adhesive like wood, metal, etc.

Keywords—Adhesive, Polyols, Castor oil, Isocyanate, Polyurethane.

I. INTRODUCTION

Adhesive are used from long time. The scientist Otto Bayer first invented polyurethanes in 1940. Polyurethane adhesives have excellent adhesion and wetting properties on wood substrates. PU is prepared by reacting polyols with isocyanates in the presence of suitable additives, such as cross-linker, catalyst and curing agent. NCO/OH ratio higher than 1.0 produced PU adhesives with greater strength due to more complete reaction between the polyol and isocyanate additives. Besides, free isocyanates penetrate into wood top layer giving more adhesive bonding strength and a more rigid three-dimension networking by reacting with naturally occurring hydroxyl groups of the wood cellulose. At present, most of the commercially available PU adhesives were produced from non-renewable petroleum-based polyols. Renewable resources of raw materials such as starch, cellulosic wastes, agricultural wastes, saw dust and vegetable oils had been used for polyol synthesis. Among these, vegetable oils have advantages due to its availability, versatilities and technical feasibilities in polyols production. Furthermore, PU adhesives prepared from castor oil was reported to have superior lap shear strength and good chemical resistance than petroleum-based polyols. Polyurethanes based adhesive used by a wide range of application like transport, building, packing, goods and furniture industries.

II. LITERATURE REVIEW

Bianca et al., worked on A Solventless Castor Oil based PU adhesive for wood and foam substrates they were prepared the solventless castor oil-based PU adhesives were prepared with NCO/OH molar ratios of 1, 2, or 3 having dibutyltin dilaurate (DBTL) and triethylenediamine (TEDA) as catalysts. The solventless PU adhesive foam joints showed peeling strength values 75% higher than that of a solvent-based commercial adhesive. The solventless PU adhesive wood joints showed lap shear strength values 20% higher than that of a commercialized solvent-based adhesive used for wood.

Keyur et al., worked on Castor oil based polyurethane adhesive for wood-wood bonding and they found that most adhesives are polymeric adhesives and if made from renewable sources they will have low cost and biodegradability which are of importance.

Patel et al., found that modification on active sites of castor oil to utilize double bond of unsaturated fatty acid and carboxyl group yields new modified or activated polyols, which can be utilized for polyurethane adhesive formulation. The NCO/OH ratio (1.5) was optimized for adhesives as the higher NCO/OH ratio (2.0) increasing cross-linking density and decreases adhesion. Lower NCO/OH ratio (1.0) provides low cross-linking density and low strength of adhesives.

III. MATERIAL

The raw materials used are castor oil, Toluene Di-isocyanate, Polypropylene Glycol are used as a reactant and amine is used as a catalyst.

A. Castor Oil

Castor oil, a triglyceride of ricinoleic, is a naturally occurring and suitable monomer for polyurethane production, whose viscosity depends on the chain length and unsaturation degree of the fatty acid. The –NCO groups of the diisocyanate compound react with the –OH group of the castor oil, which become part of the network and will therefore not vaporize out of the adhesive as a solvent.
Castor oil is a vegetable oil obtained by pressing the seeds of the castor oil plant \((Ricinus communis)\).

India is the leading producer and exporter of castor oil in the world, followed by China and Brazil. The states of Gujarat & Rajasthan contribute 90% of the total castor produced in India. The major importers of castor oil in the world market are European Union, US and Japan. The world demand for castor oil is estimated to grow at the rate of 5 to 7% per annum. The present demand for the castor oil product is estimated at 1,250 tonnes per annum. The demand is expected to reach at 2,947 tonnes by the year 2017.

TABLE I
Composition of Castor Oil

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Acid Name</th>
<th>Average % range</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Ricinoleic acid</td>
<td>95 to 85 %</td>
</tr>
<tr>
<td>2</td>
<td>Oleic acid</td>
<td>6 to 2%</td>
</tr>
<tr>
<td>3</td>
<td>Linoleic acid</td>
<td>5 to 1%</td>
</tr>
<tr>
<td>4</td>
<td>Linolenic acid</td>
<td>1 to 0.5%</td>
</tr>
<tr>
<td>5</td>
<td>Stearic acid</td>
<td>1 to 0.5%</td>
</tr>
<tr>
<td>6</td>
<td>Palmitic acid</td>
<td>1 to 0.5%</td>
</tr>
<tr>
<td>7</td>
<td>Dihydroxystearic acid</td>
<td>0.5 to 0.3 %</td>
</tr>
<tr>
<td>8</td>
<td>Other</td>
<td>0.5 to 0.2 %</td>
</tr>
</tbody>
</table>

TABLE II
Characterization of castor oil

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Properties</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Acid Index (mg/KOH/g)</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>Gardner colour-max</td>
<td>Pale Yellow</td>
</tr>
<tr>
<td>3</td>
<td>Hydroxyl Index (mg/KOH/g)</td>
<td>160-170</td>
</tr>
<tr>
<td>4</td>
<td>Specific Gravity</td>
<td>0.954-0.967</td>
</tr>
<tr>
<td>5</td>
<td>Index of Reflection</td>
<td>25°C 1.4764-1.4778</td>
</tr>
<tr>
<td>6</td>
<td>Saponification index</td>
<td>176-178</td>
</tr>
<tr>
<td>7</td>
<td>Moisture &amp; Volatility</td>
<td>0.5% max.</td>
</tr>
<tr>
<td>8</td>
<td>Boiling Point</td>
<td>313°C</td>
</tr>
<tr>
<td>9</td>
<td>Melting Point</td>
<td>5°C</td>
</tr>
<tr>
<td>10</td>
<td>Molecular Weight</td>
<td>248</td>
</tr>
</tbody>
</table>

B. Isocyanate

Isocyanates are very reactive materials which makes them useful in making polymers. Most of the isocyanates are difunctional that is they have exactly two isocyanate groups per molecule. Toluene di-isocyanate (TDI) is aromatic which react faster with hydroxyl containing compound than aliphatic isocyanates and has good stability to U.V. light and also the cyanate group present 48%. Diphenylmethane di-isocyanate (MDI) is extremely durable, stable to U.V. exposure and the cyanate group present 3- 30%. Hexamethylene di-isocyanates (HDI) is aliphatic, react slower with hydroxyl containing compound than aromatic. It is used mostly for coating purpose, flexible coating obtained and the cyanate group present 3-30%

C. Polyols

Naturally occurring polyols are:-

1. Polyether polyols

Polyether polyols are mostly made by co-polymerizing ethylene oxide and propylene oxide with a suitable polyol precursor. Eg. Glycerol, Adipic acid, Diethylene glycol. Properties of Polyether polyols

- Polyether polyols molecular weight required (1000-4000) are commonly used in coating
- Softer
- More flexible
- More resistance to hydrolysis
- Resistance to oxidative degradation

2. Polyester polyols

Polyester polyols are made similarly to polyester polymers. Eg. Ethylene oxide (PEOX), Propylene oxide (PPOX). Properties of Polyester polyols

- Linear and branch polyester polyols molecular weight required (500-5000)
- It is used for adhesive
- Low cost

IV. MECHANISM

Polyurethanes are prepared by treating polyols with a slight excess of diisocyanates. The linear chains can be obtained by treating low functional polyols \((i.e.\ diols)\) with diisocyanates to form urethanes. The following reaction is called the urethane reaction:

\[ R'OH + R''NCO \rightarrow R''NH \cdot CO \cdot OR' \]
Castor oil based polyurethane is synthesized by the reaction between polyol and an excess of isocyanate. The syntheses were performed in a three necks round bottom flask with electrically operated stirrer for mixing of components. In one neck condenser is fitted while through side neck the rod of temperature indicator is dip in the solvent and middle neck is used for mechanical stirrer. The molar ratio of chemicals NCO/OH is [1:1] to [1.5:1] for adhesive. Increase in NCO in formulation is increasing the adhesive property. The reaction is carried out about 40\(^0\) C to 50\(^0\) C for one hour with continuous stirring. The reaction is carried out under condensation polymerization. After polymerization viscosity builds up and eventual gelations take place. This viscous solution is directly use as adhesive.

V. CONCLUSION

In this review paper a brief idea of increasing concern over environmental pollution has forced the industry to develop environmentally friendly adhesive have been undestude. Castor oil based polyurethane adhesive from renewable sources are greatly appreciated by the research since they can be produced at low prices and can be biodegradable, as compared to those produced from petrochemical sources. By use of this method biodegradable castor oil based polyurethane adhesive made.

REFERENCES


