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Synthesis and Characterization of Castor Oil based Polyurethane Adhesive for Wood Substrates

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Abstract: ***This project 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 form 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 paper is to give a fundamental description of castor oil and various application of polyurethane adhesive like wood, metal, etc. In the beginning of the 21st century, the increasing concern over environmental pollution has forced the industry to develop environmentally friendly adhesive. 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.***

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

1. Introduction

The preparation of resins from natural renewable raw materials is today's need in order to reduce the dependency on petroleum-based material and provide a sustainable and green solution to the industries. [1]. Polyurethane adhesive are traditionally produced by reacting petroleum- based polyols with diisocyanates. Although for many years research have been trying to develop polyurethane coating and interpenetrating network from natural oils, there are very few studies describing the use of vegetable oil based polyurethane adhesives. Since the beginning of the 21st century, the increasing concern over environmental pollution has forced the industry to develop environmentally friendly adhesive. For such adhesives, the green requirements mainly include: renewability; biodegradability in some application and repulpability.[3]

Polyurethanes are one of the polymeric adhesive, which show excellent adhesion, flexibility, high cohesive strength, low-temperature performance, and amenable curing speed. They effectively wet the surface of most substrates and develop excellent bonding to many materials including textile fibers, metals, plastics, wood, ceramics, rubber, and leather.[3] Generally the adhesive based on polyurethanes used by a wide range of application like transport, building, packing, goods and furniture industries.[1]

The development of commodities derived from petrochemical polymers has brought many benefits to mankind. However, it is becoming more evident that the ecosystem is considerably disturbed and damaged as a result of pollution occasioned by discharge of heavy metals and the non-degradable materials used in disposable items. Therefore, the interest in polymers from renewable resources has recently gained exponential momentum and the use of biodegradable and renewable materials to replace conventional petroleum material for disposable and other industrial applications is becoming popular and necessary.[4] Solventless 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.[1]

2. Polyurethane Adhesive using Castor oil as a polyols source

Castor oil is a vegetable oil obtained by pressing the seeds of the castor oil plant (*Ricinus communis*). The common name "castor oil", from which the plant gets its name, probably comes from its use as a replacement for castoreum, a perfume base made from the dried perineal glands of the beaver (*castor* in Latin).[13]

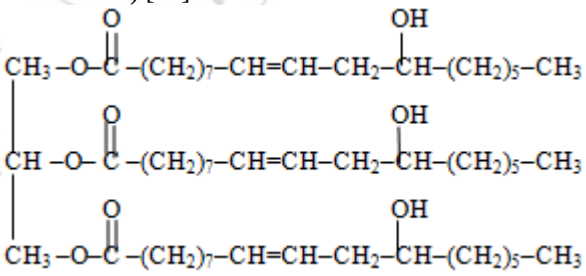

Figure 1: The structure of castor oil[13]

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 diisocynate 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.[1]

Table 1: Composition of castor oil[13]

Sr. No.	Acid Name	Average % range
1	Ricinoleic acid	95 to 85 %
2	Oleic acid	6 to 2%
3	Linoleic acid	5 to 1%
4	Linolennic acid	1 to 0.5 %
5	Stearic acid	1 to 0.5 %
6	Palmitic acid	1 to 0.5 %
7	Dihydroxystearic acid	0.5 to 0.3 %
8	Other	0.5 to 0.2 %

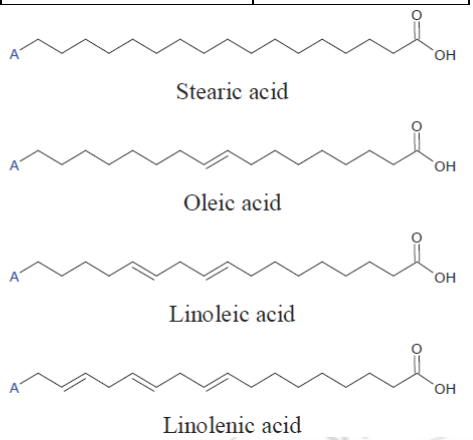

Figure 2: Castor oil substituted fatty acids [13]

3. Material and Methodology

3.1 Selection of Raw Material

The raw materials used for the preparation of castor oil based polyurethane are castor oil which is obtained from the local market, Toluene Di- Isocyanate, Polypropylene Glycol are used as a reactant and amine is used as a catalyst.

Table 2: Physical and Chemical properties of raw material

Raw material	Mol.Wt.	Density	Boiling Point	Melting Point
Castor Oil	248 g/mol	0.9090 gm/cm^3	313^{o}c	-18 ^{o}c
Polypropylene Glycol	76.09 g/mol	1.036 gm/cm^3	188.2 ^{o}c	-59^{o}c
Toluenediisocyanate	174.2 g/mol	1.22 gm/cm^3	250^{o}c	20 ^{o}c
Diethenolamine	105.14 g/mol	1.096 gm/cm^3	268.8 ^{o}c	28 ^{o}c

3.2 Experimental Process

The reaction was carried out in a 250 ml three neck flask equipped with stirrer, reflux condenser and thermocouple. The three neck flask was immersed in a heating mantle.

Table 3: Conditions of the reaction

Batch No.	Ratio (TDI:CO)	Agitation rate (rpm)	Catalyst (Amine) (wt%)	Temperature (^{0}C)	Time (min)
Optimization of molar ratio:					
1	1 : 1	300	1	40	30
2	**1 : 1.2**	300	1	40	30
3	**1 : 1.5**	300	1	40	30
4	**1.2 : 1**	300	1	40	30
5	**1.5 : 1**	300	1	40	30

A calculated amount of Castor Oil was introduced in the reactor. A calculated amount of polyol and amine catalyst (1wt%) were added and heated with agitation for 15 min by keeping the temperature at 40^{0}c. Then calculated amount of Isocyanate was then added into the mixture for 30 min. This feeding strategy was required to avoid overheating the system as the reaction is highly exothermic. The reaction was well mixed and was performed at a stirring speed of 300 rpm under isothermal conditions. The product of the reaction was then cooled. After polymerization viscosity builds up and eventual gelations take place. This viscous solution was directly used as adhesive.

4. Characterization of Polyurethane Adhesive

There are number of general factors that require consideration in the evaluation of an adhesive. These factors pertain to the behavior of an adhesive form the time the adhesive is made to the moment the ultimate bond is accomplished. They are commonly referred to as the working properties and include such characteristics as viscosity or consistency, storage life, working life, coverage, blocking tack, penetration and curing rate or rate of strength development. Testing provides a measure of quality control of the adhesive material, adequacy of the bond formed, acceptability against specifications and other criteria of economic importance.

5. Results

All the batches samples Viscosity ranges from 180 to 230 sec (0.3 to 0.45 Poise 30-45 mPas) As the percentage of Castor oil and TDI increases the density of the adhesive will reduces. No Detachment of Adhesive from the panel is observed by internal chemical resistance. The glass transition temperature Tg (^{o}c) is ranges between 51 to 113 ^{o}c and the Melting Temperature Tm (^{o}c) is rangs between 204 to 270 ^{o}c

6. Conclusion

In this work polyurethane adhesive was synthesized from castor oil and toluene diisocyanate. Curing of this adhesion was done with the different percentage of toluene diisocynate. This resin shows good adhesion properties so can be used for the wood application for furniture industries.

7. Future Scope

Polyurethane adhesive synthesized from castor oil was studied for wood application further study will carried out on leather also. Reaction kinetics study can also be performed.

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