CHAPTER 2

PU Coatings Based on Neem Oil Fatty Amide and IPDI Trimers
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ABSTRACT

This chapter shows an entirely new application of *Azadirachta indica juss* (neem oil) i.e. the preparation of polymeric resin from it. In the regards, we have attempted to synthesize the neem seed oil based poly (urethane fatty amide) by reaction of neem oil fatty amide (AIJFA) with trimer of isophorone diisocyanate (IPDI). Initially fatty acid composition of neem seed oil was obtained by gas chromatographic (GC) method and then we synthesized AIJFA. Spectral study of synthesized AIJFA was done by FT-IR and $^1$H NMR techniques. Molecular weight of AIJFA was determined by gel permeation chromatography (GPC). The prepared polyurethane was applied as a coating on mild steel plates and evaluated for its coating performance, chemical and corrosion resistances.

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INTRODUCTION

Now day's natural feed stock of fossil fuel is reducing continuously and due to this, there is emergent interest in developing new feed stocks to prepare polymers. [1-3] For preparation of polymers, renewable resources such as cellulose, carbohydrates, polysaccharides, starch, fatty acids and vegetable oils have been focused in the literature. [4-8] Amongst all of these, vegetable oil is having more importance in polymer sectors by considering the sustainable energy resource and easy availability. Vegetable oils such as linseed, tall, palm, nahar, cotton, jatropa, karanja, tung and castor oils were used to prepare the polymeric resins according to their characteristic properties. [9-13] Tons of vegetable oils are having their uses as renewable raw materials for other industrially important chemicals such as soaps, surfactants, cosmetic products, lubricants, inks, diluents, plasticizers, agrochemicals, food industry, composite materials, etc. [14-16] In addition to this, vegetable oils have also been used for decades in paint formulations and as binders for different types of coatings. The most important parameters influencing on properties of oil based coatings are their composition with respect to presence of fatty acids of different saturated and unsaturated types, degree of unsaturations, the position and stereochemistry of the double bonds and extent of oil content. [17] Types of binders used in coatings and prepared from vegetable oils include alkyds, diethanolamides, polyesteramides, polyetheramides and polyurethanes (PU). [18] In addition to above mentioned applications of oil based polymers, PU are also having incredible significant applications for adhesives, elastomers and foams. [19] For the preparation of PU, vegetable oil need to convert into hydroxyl terminated polyols by chemical modification or reaction on triglyceride molecules.
Numbers of experimental reports are available in the literature for conversion of vegetable oils into polyols by chemical modifications such as ozonolysis, epoxidation, hydroformylation, esterification and amidation. PU obtained from vegetable oils (e.g. castor oil) and copolymers of them with styrene, methyl methacrylates and other monomers have noticed with much attention over the last decades due to their remarkable properties. Preparation of epoxidized plant oils (canola, sunflower, soybean, linseed and corn) were also used to prepare polyols. Meshram et al developed the polyetheramide resin from cottonseed oil and utilized it in moisture curing coatings after reacting it with TDI and shown cottonseed oil is a good source of renewable material for preparing high performance coatings. Oils have also been reported for preparation of PU coatings by Gite et al from the combination of monoglycerides (dehydrated castor, linseed, soybean and sesame oils) with trimer of isophorone diisocyanate (IPDI). The overall study shown that the PU prepared from the four monoglycerides and IPDI trimer exhibited significant enhancement and have a strong potential to be used in the application as binder for surface coatings.

*Azadirachta indica juss* (neem oil) is present in plentiful amount with annual production rate of 88, 400 tons in the India and the Indian continent. Neem seed contains 33 - 38 % oil, which possesses total five fatty acids such as palmitic, stearic, arachidic, oleic and linoleic acids. However their application in the preparation of polymer is not studied and majority of the earlier applications of neem seed oil reported are in agrochemical and pharmaceutical sectors. In other application of neem tree, Peter et al investigated use of tree extracts as corrosion inhibitors and found high inhibition efficiency to the surface of metal from corrosion comparing with root and...
leaf extracts of it. [34] Chaudhari et al first time reported preparation of polymeric resins from neem oil. [33]

This chapter represents development of the poly (urethane fatty amides) from neem oil by reaction of its fatty amide with trimer of IPDI. Initially, we have prepared neem oil fatty amides (AIJFA) by the reaction of neem oil with diethanol amine. The prepared AIJFA was treated with laboratory synthesized and commercially obtained IPDI trimers for the preparation of PU coatings. All the prepared PU coatings were tested for their coating properties by standard experimental methods. Use of neem oil in the development of PU coatings may definitely show environmental rewards like declination in the requirement of fossil or petroleum resources and configuration of very low greenhouse gas emission. The prepared PU coatings by this route may be suitable for maintenance coatings for petrochemical refineries and tank linings in the future.

EXPERIMENTAL

Materials and Methods

Neem (*Azadirachta indica*) seed oil was obtained from local supplier and subjected for its characterization such as specific gravity, refractive index, saponification and iodine values. These values of neem oil were matched with the standard values and therefore it was used without any further chemical modification. IPDI was purchased from Merk, Germany and used as such for the synthesis of its trimer. Commercial IPDI trimer was purchased from Bayer Material Science, Mumbai and characterized for its isocyanate content by ASTM D-2572-97 before use. Laboratory grade dibutyltin dilaurate (DBTDL) was purchased from Aldrich Chemicals, UK. Cylcohexanone, tetrahydrofuran (THF) and diethanolamine of
analytical grade were obtained from SDFCL, India. Remaining chemicals and solvents used for synthesis or analysis were of either synthesis or of analytical grade as per their need.

**Synthesis of *Azadirachta indica* juss Fatty Amides (AIJFA)**

AIJFA was synthesized by the base-catalyzed amidation of neem seed oil with diethanolamine as shown in Figure 1. In the experimental process three-necked round bottom flask of 500 mL capacity was used. Diethanolamine (0.3 mol, 31.8 g) and sodium methoxide (0.05 %) based on an amount of oil were introduced in the flask and heated with agitation by a over head motor stirrer at temperature of 80 °C for 20 min. After maintaining inert atmosphere (purging of N₂ gas for 20 min), the assembly was immersed in an oil bath having arrangement of temperature controller. Neem seed oil (0.1 mol, 90.4 g) was added drop-wise into the reaction mixture over a period of 60 min with gradual increase in temperature to 120 °C and continued for next three hours under constant agitation. The formation of product was tested by two ways viz. checking solubility of the reaction mass in methanol and determining amine value. Completion of reaction was confirmed by the complete solubility of reaction mass in methanol and or the amine value near to zero. The obtained product was dissolved in a solvent diethyl ether and washed with 15 % aqueous NaCl (salt) solution.

![Reaction for Synthesis of AIJFA](image)

*Figure 1: Reaction for Synthesis of AIJFA*
The upper organic ethereal layer containing product AIJFA was separated from aqueous layer by separating funnel. The trace amount of solvent present in AIJFA was evaporated in a rotary vacuum evaporator.

**Synthesis of IPDI Trimer**

General structure of trimer and the reaction for trimerization of IPDI is as shown in Figure 2. For the trimerization of IPDI, the catalyst choline hydroxide was synthesized in the laboratory according to the method reported in the literature. [35] Trimerization reaction of IPDI was carried in a three-necked round bottom flask equipped with thermometer, dropping funnel, mechanical stirrer, condenser, nitrogen purging system and maintained at 75-80°C in an oil bath. Catalyst was added drop-wise in to the round bottom flask containing IPDI. The reaction was continued for next 5-7 h until the isocyanate content of the reaction mixture reach to half of the initial value. At last catalyst deactivation was carried out by adding appropriate quantity of p-toluene sulphonic acid.

![Figure 2: Synthesis of IPDI trimer](image)

**Preparation of PU Coatings**

The general reaction for the preparation of PU is given in Figure 3. The prepared neem oil based AIJFA was reacted with IPDI trimer by varying an NCO/OH ratio (1:1, 1.1:1 and 1.2:1). Mixture of cyclohexanone and THF (80:20) was mixed with AIJFA (1 mole) to obtain required solid content (50%) solution of AIJFA.
Initially DBTDL (0.05 %) as a catalyst was added to AIJFA part in order to control the rate of urethane formation. Then appropriate amount of trimer was added to the 50 % solid AIJFA solution. The reaction mixture was stirred for next 5 min at 27 °C temperature to attain pourable viscosity. After attaining pourable viscosity, the mixture was used to prepare coating samples using bar applicator (Raj Scientific Company, Mumbai, India) with a wet film thickness of 120 µm on MS panels of 4 x 6 inch dimensions. Different PU coated samples were prepared by changing the ratios of NCO/OH as mentioned earlier. The prepared coating panels were allowed to cure at room temperature under visual examination, until the coatings were dry to touch. Before application of the coatings, steel panels were pretreated with sand paper, washed with acetone and dried in an air-circulated oven.

![Figure 3: Preparation of PU Coatings](image-url)
CHARACTERIZATION

Characterization of Raw Materials

Oil was characterized by the standard experimental methods such as specific gravity (ASTM D5355-95), refractive index (ASTM D1747-09), saponification value (ASTM D464-05), acid value (ASTM D5768-02) and iodine value (ASTM D-5768-02). The fatty acid composition of neem oil was determined by gas chromatography (GC) using methyl esters of it. Neem oil fatty acid methyl esters (FAME) were prepared by refluxing neem oil in a dry methanol in the presence of sodium methoxide as a catalyst. Analysis of FAME was carried on gas chromatography (GC) (Shimadzu GC-14B) having specially designed program for oven temperature starting from 180 to 250 °C, injection temperature 230 °C, column (Restek, Rtx-Wax) and FID detector. Isocyanate content of the synthesized IPDI trimer was determined by the n-butyl amine method as per ASTM D-2572-97 standards. The hydroxyl value of neem oil and AIJFA was determined by acetylating reagent method as per experimental procedure recommended by ISI: 354 (1987) and amine value was determined by IS 354 (Part-5), 1986.

Gel Permeation Chromatography (GPC)

Molecular weights of AIJFA were measured by a gel permeation chromatography (GPC) with Agilent GPC-Addon Rev A02.02 series HPLC system. The experimental conditions required an injection volume upto 20 μL and flow 1 mL/min using a column PL-Gel Agilent with RI detector and tetrahydrofuran as a solvent.
Fourier Transfer Infrared (FT-IR) Spectroscopy

The FT-IR spectra were scanned 50 times on a FT-IR spectrometer (Perkin-Elemer 2000 FTIR spectrometer) in the range of 4000 to 500 cm\(^{-1}\) by making the pellets of AJFA using KBr.

\(^1\)H NMR Analysis

The \(^1\)H NMR measurements were performed on a \(^1\)H NMR spectrometer (Varian Mercury 300 MHz spectrometer). The reported chemical shifts were against tetramethyl silane (TMS) and deuteriated chloroform (CDCl\(_3\)) as a solvent.

Thermal Analysis of PU Coatings

Thermal analysis of the prepared PU coating samples was performed in a Mettler Toledo TGA/SDTA- 85 instruments in the range of 40-700 °C. Samples (about 2 mg) were placed in a platinum pan and heated under N\(_2\) atmosphere (20 mL/min) at a heating rate of 10 °C/min. During the heating, the weight loss versus temperature curve was recorded and analysed further.

PU Coatings Characterizations

Gloss

Gloss measurement is important for finding the capacity of a surface or coating to reflect light. Precautions taken during the measurement in such a way that the coated samples should not contaminated by any chemical or oil. A digital gloss meter (Model BYK Additive & Instruments, Germany) was kept on the coated samples with on auto calibration mode at an angle of 60 ° after calibration of it as per the procedure given by the manufacture.

Flexibility

Flexibility of film or coating is measured to check the ability of the coatings for elongation under bent condition or it is test that gives tolerance of the coatings against
cracking when elongated. The flexibility of the coated samples was performed on a conical mandrel instrument (Raj Scientific Company, Mumbai). While performing the test, mandrel was freed to rotate on its axis and then coated sample was kept in between the rotating axis. The handle of conical mandrel was lowered in a vertical direction to obtain specific angles.

**Pencil Hardness**

To determine the hardness of polymeric coating films, pencil hardness measurements is essential. The pencil hardness of the coating was measured by using a pencil hardness tester (Model BYK Additive & Instruments, Germany). In this test pencils having different grades were used to move over the surface of the coated panels from the distance of 6 mm at fixed 45° by using a standard holder. The force were applied on the pencil and moved over the surface of the test sample at a fixed angle. The coated panels were checked for the removal of the film. The same procedure was repeated with pencil of higher grades of hardness until the film is scratched or penetrated. The pencil which does not remove the coating denoted the pencil hardness of the particular coating.

**Cross Cut Adhesion**

In this test a cross cut adhesion tester consisting of a die with 11 number of closed set of parallel blades was passed and pressed on the coated panel in two directions at right angle to each other so that the lattice of 100 squares of 1 mm² area each were formed. The adhesion tape was placed at the centre over of lattice pattern made on the panel. After 5 min, self adhesive tape was removed by pulling it steadily in 2 seconds at an angle close to 60°. Then the sample was examined carefully with the help of magnifier to determine the percentage of cubes remained on the coating panel.
Scratch Resistance

Scratch hardness of the coated panel studied by a ‘Automatic Scratch Tester’, (Rajdhani Pvt. Ltd., India).

Impact Resistance

The impact resistance test of the prepared coatings was carried out for evaluating the load carrying capacity of them. During this test the dried PU coating panels were placed on hock properly and movable weighted indenter (1.818 lb) was lifted from the certain height starting from 0 - 40 inch until the film cracked. After falling the weighted indenter peeling, cracking and film detachment from the coated substrate was examined. If there are any cracks on coatings test is considered as failed otherwise it is passed.

Mar Resistance

The mar resistance of the prepared PU coating was evaluated in the laboratory using a mar resistance tester of BYK Instruments, Mumbai. Mar resistance is express in gram, the term of load that fails to spoil the coating film.

Chemical Resistance and Anticorrosive Properties

The chemical resistance of sample was measured by dipping the coated panel in alkali solutions (10 % NaOH and 10 % NH₄OH), acid solutions (25 % H₂SO₄ and 25% CH₃COOH) and xylene as a solvent for 7 days. Periodic visual inspection was taken for 7 days to find any evidence of softening, deterioration or development of cracks.

Anticorrosion properties of the prepared PU coatings were also evaluated through immersion studies and compared coated (crossed and uncrossed) and uncoated steel panels with each other. The crossed panels were obtained by crossing panels with sharp razor blade. Immersion study of these coatings was carried out in an aqueous solution of NaCl (3.5 wt. %). The sample panels were tested for a total exposure time
of 144 h and further extend to 192 h. The panels were continuously monitored time to
time by visual inspections and recorded using a digital camera (Sony, 16 mega pixels).

RESULTS AND DISCUSSION

Characterization of Raw Materials

The chemical analysis of neem oil and AIJFA is furnished in Table 1. The isocyanate content of the synthesized trimer of IPDI was found to be 15.60 %. Molecular weight of the AIJFA was measured by GPC and it was found to be 520 (\( M_w \), weight average) and 431 (\( M_n \), Number average) with polydispersity index (PDI) of 1.20. The amine value of AIJFA was found to be 0.37 indicated almost all secondary amines present in diethanol amine have been converted into amide groups during formation of the AIJFA.

Table 1: Chemical Analysis of Neem Oil and AIJFA

<table>
<thead>
<tr>
<th>Properties</th>
<th>Specific gravity ( @ 30,^\circ\mathrm{C} )</th>
<th>Refractive index ( @ 40,^\circ\mathrm{C} )</th>
<th>Acid value (mg of KOH/g)</th>
<th>OH value (mg of KOH/g)</th>
<th>Iodine value (g of ( I_2 )/100g)</th>
<th>Amine value (mg of KOH/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neem oil</td>
<td>0.920</td>
<td>1.503</td>
<td>0.5</td>
<td>0.0</td>
<td>64.55</td>
<td>0.0</td>
</tr>
<tr>
<td>AIJFA</td>
<td>0.927</td>
<td>1.542</td>
<td>0.6</td>
<td>205</td>
<td>59.82</td>
<td>0.37</td>
</tr>
</tbody>
</table>

Fatty Acid Composition of Neem Oil

Table 2 is representing the composition of fatty acids for the utilized neem oil which was determined by GC. Total five fatty acids were found in the gas chromatogram of neem oil FAME. These fatty acids included palmitic, stearic and arachidic acids as saturated fatty acids, while oleic and linoleic acids as unsaturated fatty acids. The obtained qualitative and quantitative fatty acid composition of the
neem oil (utilized in preparation of PU coatings) is in agreement with the values available in the literature. [36]

Table 2: Composition of Fatty Acids in Neem Oil

<table>
<thead>
<tr>
<th>Name of fatty acids</th>
<th>Structure</th>
<th>Composition % by weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oleic acid</td>
<td>![Structure of Oleic Acid]</td>
<td>50.04</td>
</tr>
<tr>
<td>Stearic acid</td>
<td>![Structure of Stearic Acid]</td>
<td>29.96</td>
</tr>
<tr>
<td>Palmitic acid</td>
<td>![Structure of Palmitic Acid]</td>
<td>11.90</td>
</tr>
<tr>
<td>Linoleic acid</td>
<td>![Structure of Linoleic Acid]</td>
<td>05.15</td>
</tr>
<tr>
<td>Arachidic acid</td>
<td>![Structure of Arachidic Acid]</td>
<td>02.94</td>
</tr>
</tbody>
</table>

**FT-IR Spectroscopy**

![FT-IR Spectrum of AIJFA of Neem Oil](image)

**Figure 4:** FT-IR Spectrum of AIJFA of Neem Oil

The results of FT-IR analysis of AIJFA is represented in Figure 4. FT-IR spectra of AIJFA showed the absorption broad band at 3487 cm\(^{-1}\) for presence of OH stretching. Absorption bands at 2837 and 2941 cm\(^{-1}\) were attributed to symmetrical and asymmetrical stretching’s of –CH\(_2\) and –CH\(_3\) groups respectively. The characteristic
band at 1645 cm\(^{-1}\) indicated the presence of C=O stretching of amide carbonyl groups.

Presence of absorption bands at 1361 and 1460 cm\(^{-1}\) in the FT-IR spectra revealed the CH\(_2\)\(\_\) bending vibrations and band at 1300 cm\(^{-1}\) was a result of C–O stretching. The medium absorption band at 1250 cm\(^{-1}\) was assigned to presence of C–N stretching in AIJFA. Overall result showed absence of –COOH group and appearance of >N–C=O group which confirmed the formation of AIJFA.

\(\text{\textsuperscript{1}H NMR Analysis}\)

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure5.png}
\caption{\textsuperscript{1}H NMR of AIJFA of Neem Oil}
\end{figure}

\(\text{\textsuperscript{1}H NMR spectrum of AIJFA (Figure 5) showed the peak at 0.88 - 0.9 ppm of terminal CH\(_3\) group of fatty acid chain, 2.04 -2.06 ppm for –CH\(_2\)–C= and 2.37 - 2.41 ppm for –CH\(_2\)–C=O protons. It also showed peak at 1.27 ppm for presence of protons of –CH\(_2\)– in fatty acid chain. The protons of –CH\(_2\) attached to amide nitrogen appeared at 2.86 - 2.97 ppm, while –CH\(_2\)– attached to –OH occurred at 3.71-3.88 ppm and alcoholic –OH at 5.24 ppm. For C=C–H proton of fatty acid chain was observed at 5.43 ppm. The results of \textsuperscript{1}H NMR spectra confirmed the proposed structure of neem oil fatty amide.}\)
Thermal Analysis (TGA)

Initially the TGA curve (Figure 6) of polyurethane coating sample showed about 4% of weight loss at 200 °C that may be due to entrapped moisture and solvent moiety. Then it went through three steps degradation. The first step occurred with 17% of weight loss at 300 °C, the second with 37% of weight loss at 420 °C and the last with 30% of weight loss at 600 °C. Normally it is observed that decomposition of urethane bond starts between 150 and 200 °C depending on the type of substituent like isocyanate and polyol as reported in the literature. [37] In our case urethane bond decomposition started at higher temperature range than mentioned in the literature revealed higher thermal stability of urethane linkage. Second and last decomposition step corresponded to decomposition of amide and hydrocarbon chains. Thermal stability of neem oil based fatty amide and trimers of IPDI based PU system is higher in comparison to urethane fatty amide of linseed oil. [10] (27.7 wt% at 260 °C, 21.11 wt% at 360 °C and 40.62 wt% at 505 °C), alkyd and uralkyd (10 wt% at 95.4 °C, 20 wt% at 147.6 °C and 50 wt% at 367.12 °C). Cross-linked structure of polyurethanes

![TGA Curve of AIJFA Based PU Coatings](image)

**Figure 6:** TGA Curve of AIJFA Based PU Coatings
synthesized from trimers of IPDI and presence of isocyanurate heterocyclic ring may also be responsible for higher thermal stability.

**PU Coating Properties**

The coating properties tested for the prepared PU coated samples include dry to touch, gloss, scratch resistance, mar resistance, pencil hardness, impact resistance, flexibility and cross cut adhesion. These coating properties are furnished in Table 3a and 3b.

**Table 3a:** Coatings Properties of PU from AIJFA and Synthesized IPDI Trimer

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Samples/ Property</th>
<th>PU Coatings with ratio of NCO/OH</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1:1</td>
</tr>
<tr>
<td>1)</td>
<td>Cross cut adhesion (%)</td>
<td>99</td>
</tr>
<tr>
<td>2)</td>
<td>Gloss</td>
<td>94.3</td>
</tr>
<tr>
<td>3)</td>
<td>Mar resistance (g)</td>
<td>100</td>
</tr>
<tr>
<td>4)</td>
<td>Impact resistance (lb.inch)</td>
<td>33</td>
</tr>
<tr>
<td>5)</td>
<td>Pencil hardness</td>
<td>1H</td>
</tr>
<tr>
<td>6)</td>
<td>Flexibility at 180 °</td>
<td>Pass</td>
</tr>
<tr>
<td>7)</td>
<td>Scratch resistance (Kg)</td>
<td>3.5</td>
</tr>
<tr>
<td>8)</td>
<td>Dry to touch (h)</td>
<td>40</td>
</tr>
</tbody>
</table>

**Table 3b:** Coatings Properties of PU from AIJFA and Commercial IPDI Trimer

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Samples/ Property</th>
<th>PU Coatings with ratio of NCO/OH</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1:1</td>
</tr>
<tr>
<td>1)</td>
<td>Cross cut Adhesion (%)</td>
<td>99</td>
</tr>
<tr>
<td>2)</td>
<td>Gloss</td>
<td>96.3</td>
</tr>
<tr>
<td>3)</td>
<td>Mar resistance (g)</td>
<td>110</td>
</tr>
<tr>
<td>4)</td>
<td>Impact resistance (lb.inch)</td>
<td>33</td>
</tr>
<tr>
<td>5)</td>
<td>Pencil hardness</td>
<td>1H</td>
</tr>
<tr>
<td>6)</td>
<td>Flexibility at 180 °</td>
<td>Pass</td>
</tr>
<tr>
<td>7)</td>
<td>Scratch resistance (Kg)</td>
<td>3.5</td>
</tr>
<tr>
<td>8)</td>
<td>Dry to touch (h)</td>
<td>40</td>
</tr>
</tbody>
</table>
Gloss of the PU samples of ratio 1.1:1 (NCO/OH) was found better for both types of PU coatings. The flexibility of all prepared samples of PU coatings were excellent with adhesion (measured by pencil hardness tester) of 1H. Mar, scratch and impact resistances of the synthesized IPDI trimer based PU coating prepared from same ratio were found to be higher compared with samples prepared from other ratios. Similarly properties of the coatings prepared from commercial IPDI trimer based PU coatings were also higher than the samples prepared from other ratios. It concludes that the PU coatings were almost similar for synthesized as well as commercial IPDI trimer and 1.1:1 NCO/OH ratio was the best amongst all three.

**Corrosion Resistance of PU Coatings**

It has been noticed that no significant change in the physical appearance of the PU coating samples was found after exposing them to acids, alkalis and solvent. In H$_2$SO$_4$, specimens upto some extent became deteriorated and showed slightly loss in gloss when dried. Corrosion properties of the PU coated, uncoated and cross-cut coated panels were done by immersion of the panels in an aqueous solution of NaCl (3.5 wt. %) for 144 h (6 days). The results of study are shown in Figure 7. The panel without PU coating quickly corroded within 144 h, while slight corrosion was observed to the cross-cut coated panel even though the metal surface exposed to a salt solution. It has been found that coated panels were free from corrosion and blister even after 144 h. After achieving excellent results from the immersion study of AIJFA based PU coatings after 144 h, we extended the test upto 192 h and we found no cracking or any physical damage to coated panels and only little deterioration was observed to cross-cut film. Good corrosion resistance to the PU coatings may be due to the presence of excellent adhesion of coatings with the substrate (as reported by cross cut adhesion in
earlier part of the report). This study conclusively revealed the presence of extensive corrosion resistance to the AIJFA based PU coatings in salt solution.

![Anticorrosive Test of the Prepared PU Coatings](image)

**Figure 7**: Anticorrosive Test of the Prepared PU Coatings

**CONCLUSIONS**

The *Azadirachta indica juss* (neem oil) based fatty amide has been prepared and characterized by physical properties as well as by spectroscopic techniques. Further, AIJFA was used as a polyol in the preparation of the PU coatings. The impact resistance, flexibility and adhesion test showed excellent results for the prepared PU coatings. The results also showed that the polyurethanes prepared from AIJFA and trimers of IPDI were of similar coating properties and chemical resistance in comparison with commercial IPDI trimer based PU coatings. Thermal stability of AIJFA based PU coatings was also better over normal urethane and alkyd coatings.
From this study it can be concluded that the neem seed oil is one of the important renewable material for the synthesis of PU to be used for the application in coatings.

**REFERENCES**


