Indigenous coating material from palm oil-based polyamide

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Polyurethane coatings are based on polymers, which contain two or more urethane groups per molecule. Other groups such as ester, ether and urea are present in them providing a wide spectrum of properties [1]. Polyurethanes have a unique combination of performance and application properties with excellent abrasion resistance, flexibility, hardness and chemical resistance. Being reactive coatings, their low molecular weight oligomers react and form a polymeric network on a substrate.

Materials such as metals, plastics, woods, clothes, papers and leathers are coated mainly for protection or decoration in both industrial and architectural applications. The oldest types of coatings were applied to substrates using organic solvents. There has been growing interest in the automotive industry in the use of zinc-coated steels of various types to improve the corrosion resistance of the major steel components of cars [2]. The zinc-coated surfaces are generally considered difficult to paint and there have been problems with the use of the technique of aqueous cathodic electrodeposition, which is the method now generally employed for priming car bodies within the industry [3]. Organic esters have long played an important role in coatings applications. They are either used as a one-component system or a two-pack components system to form urethane coatings.

The wide application of polyurethanes, however, is restricted because of their high cost of manufacturing. One way of reducing the cost of raw materials is by utilization of palm oil, which is found in abundance in Malaysia at very low price, to synthesize the polyol. This process was reported broadly in the literature and is acknowledged by experts [4, 5]. The feasibility of using vegetable oil, namely the palm oil, in synthesizing liquid polyols and their reaction with isocyanate adduct to form urethane coatings have been studied. Three types of substrates were used: mild steel, alloy (mixture of 30% stanum with 70% copper) and copper. Observations on the water absorption, hardness and heat stability were carried out. The present work is an attempt to make use of such biological materials for polyol synthesis for the end use in urethane coatings. This may further economize the cost of coating material without risking the quality.

A two-pack polyurethane coating system is based on palm oil-based polyol resin (base component) and isocyanate adduct (hardener component). The two components were mixed at the time of application on the tested panels, which were allowed for complete curing and conditioning (24 h) before testing their performance properties.

Mild steel panels, alloy (mixture of tin and copper) panels and copper panels conforming to IS (Indian Standard Methods of Test for Readymade Paints and Enamels 1964), with size of $150 \times 100 \times 1.25$ mm were cleaned with xylene to remove grease, and then with emery cloth to remove surface imperfections. Emery dust was removed by wiping with a linen rag. Panels were dried to remove traces of solvent and moisture, allowed to return to room temperature and then coated without delay with a bar applicator [1].

The expected structure of polyurethane was confirmed by FTIR spectroscopy. Fig. 1 shows the sharp bands at 1710 to 1610 cm^{-1}, which are due to urethane linkages. The band at 3388 cm^{-1} is the NH deformation. The band at 2932 to 2864 cm^{-1} is the CH stretching.

The hardness of the polyurethane coatings was determined after 24 h of application as suggested by Edgar *et al.* [6]. Coating evaluation of the curable urethane coatings is as shown in Table I. Pencil hardness scale in order of increasing hardness is as below:

$$5B < 4B < 3B < 2B < B < HB < F < H < 2H < 3H < 4H < 5H$$

The coating on alloy showed the highest scratching hardness indexes of 5H followed by copper (3H) and mild steel (H). Scratch marks on coated panels may be used as an indication of the adhesion or bonding of the coating layer to the substrates. The coatings on alloy were only scratched when 4H–5H pencils were used. They were not easily peeled off (by scratching with the pencils). Urethane film on copper started to leave scratch marks when 2H–3H pencils were introduced, whilst for mild steel, scratches were formal when the H pencil was used.

The coated panels were immersed in water at room temperature for a week. The percentage of water absorption for each panel for each individual day was taken and plotted as shown in Fig. 2. Day 3 showed the highest percentage of thickness swelling for mild steel and alloy, which was then followed by decrease in percentage of thickness swelling.

The coating on mild steel absorbed water the most with the percentage of thickness swelling per day as high as 1.53%. On average, the accumulated thickness swelling almost reached a plateau for alloy and copper with percentage of accumulated thickness swelling of 2.72 and 1.15% respectively, as shown in Fig. 3. Until

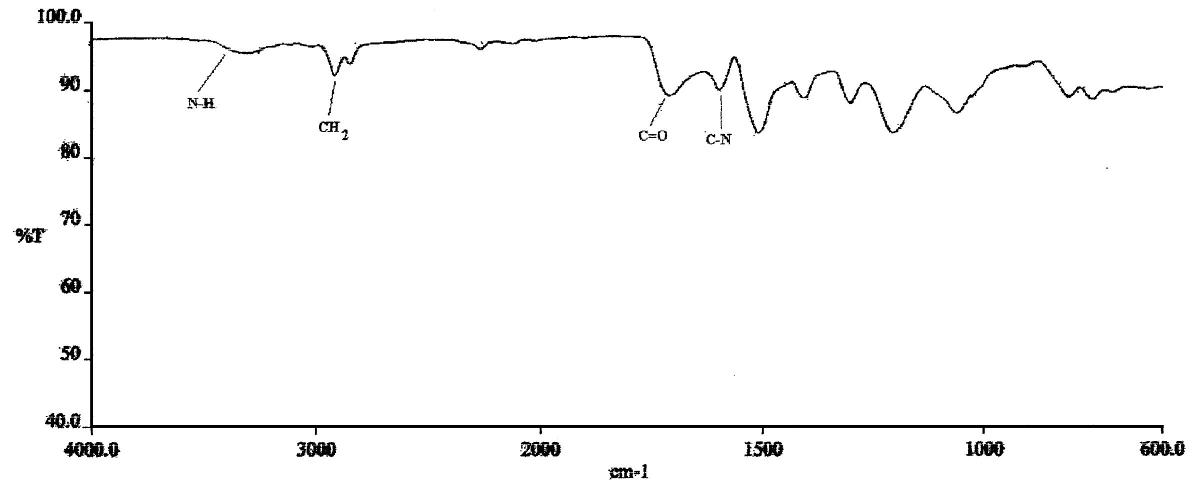

Figure 1 FTIR spectra of the urethane coating.

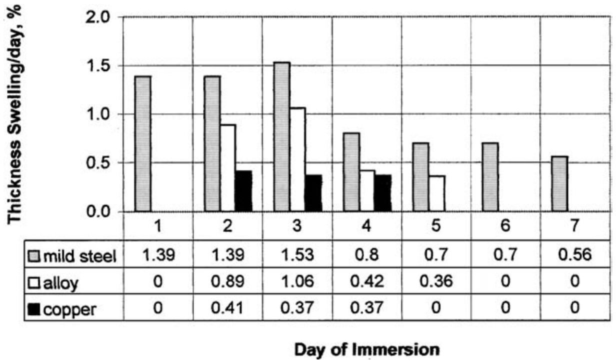

Figure 2 Percentage of thickness swelling of the urethane layer per day.

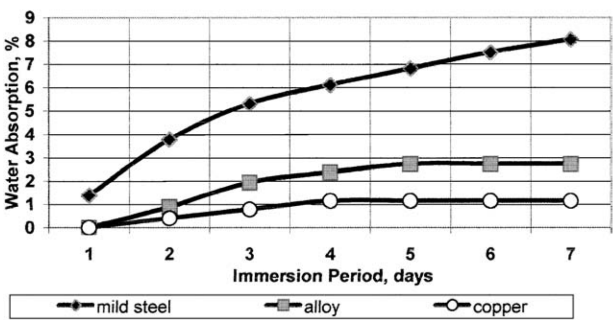

Figure 3 Rate of water absorption of the coating layer.

day 7, the urethane layer on mild steel still absorbed water but at reducing level. Though mild steel did not show the same trend as the other two metals, none of the panels showed any significant changes in thickness until the end of the seventh day. The coating layer is water-resistant with very minimal thickness swelling.

The coated panels were placed in an oven at four different temperatures: 70, 80, 90 and 100 °C for 24 h. Observation at room temperature was also included for comparison. The coated panels were observed in term of glossiness, cracking of urethane layer, film expansion or reduction and color.

TABLE I Pencil hardness of the curable urethane coatings

Type of panel	Pencil hardness
Mild steel	H, H, H, H, HB, H, HB, H, H, H
Alloy	5H, 4H, 5H, 3H, 5H, 5H, 5H, 5H, 5H, 5H
Copper	3H, 2H, 2H, 2H, 3H, 3H, 3H, 2H, 3H, 2H

Fig. 4 showed that the coating film expanded to an extent and lost some thickness as the test temperature increased. These changes may involve simple bond-rupturing dissociation or reaction reversals and provide more volatile components (VOC) [7]. These volatile components were discovered to form on the surface of the urethane film only for the coated mild steel panel. Mild steel oxidized upon contact with moisture and heating. The oxidation process contributed to the release of the VOCs by entrapment of moisture between the panel and the urethane film. It has been reported that urethane decomposed to amine and water vapor on exposure to high temperature for a long period [8].

No change in film thickness was observed at room temperature for all type of substrates. Coating on copper is the most stable with no changes at 70 and 80 °C, while coating on mild steel is the least stable at high temperatures. The coating on mild steel peeled off at 100 °C. Coating layers on all substrates turned yellow (aging) at 100 °C, however, without losing glossy appearance.

Urethane resins with good coating properties can also be synthesized successfully from palm oil-based polyol. Use of palm oil for synthesizing urethane coatings may reduce the cost without compromising on quality. Coating quaity however much depends on the adhesion to the substrates, which at present is being

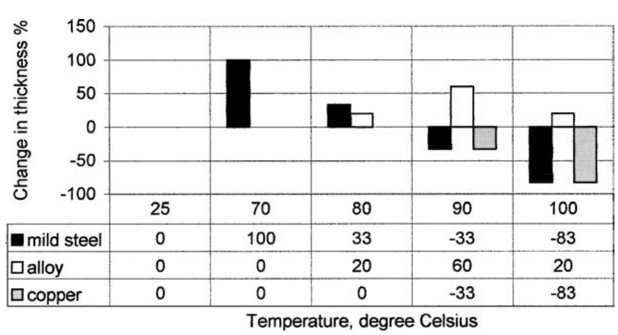

Figure 4 Thermal stability of the urethane layer on the panels.

studied extensively. Initial findings on the correlation study of water absorption and hardness as well as heat stability of the urethane film coated on mild steel, alloy and copper showed that these parameters are much dependent on the type of substrates used. Surface properties of the substrates used should be studied in order to improve the adhesion between the substrate and the urethane coating.

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