IOP Conf. Series: Materials Science and Engineering **368** (2018) 012026 doi:10.1088/1757-899X/368/1/012026

# Properties of water-borne coating incorporate with nanoclay

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**Abstract.** Water-borne coatings, as well as other coating options, are having advantages and disadvantages besides having different mechanical properties from those of the conventional solvent based coatings. A nanoparticle such as nanoclay (NC) has found its applicability in coatings to meet the mechanical requirements. In this study, a special focus has been given in order to improve the properties of water-borne coating using NC. The optimum percentage of NC mixed into water-borne coating was determined. The samples were prepared by dispersing 2 % of NC in water-borne coating. Both of it were mixed by using homogenizer for a certain duration using high speed rotation. The dispersion process was then repeated for 4 %, 6 %, 8 % and 10 % of NC loading. Whilst water-based coating without NC was used as control for comparison purposed. Effect of using NC on the mechanical properties of coatings on wood such as adhesion (ISO 2409:2007 (E) (BS EN 2007)), impact test (BS3962:Part6 1980 (BS 1980) scratch resistant (ISO 1518-1:2011 (BS EN 2011)) and abrasion (ASTM D 4060-14) were investigated. For adhesion properties, no detectable failure was observed for nanocoating with 2 %, 4 % and 6 % of NC. However, NC 8 % and NC 10 % showed a little detachment, indicating poorer adhesion quality for these samples. There are significant differences for impact and abrasion tests but insignificant for scratch test. It was found that the increasing amount of NC percentage would improve the mechanical properties of water based coating until a certain limit.

## 1. Introduction

Coating is the process whereby a thin layer of material is applied on a substrate. It is primarily used for surface protection and provides a defense against chemical, mechanical and environmental threats by preventing water, oil or air penetration, chemical corrosion, UV penetration and electrical conduction. Water-based coatings was known as sorts of coating which have been around for decades but have demonstrated greatly improved performance characteristics in recent years to meet the high quality standards demanded by customers worldwide [1]. However, there are some issues on properties of water-based coating such as hardness, heat resistance, water and solvent resistance [2]. Thus, attempts have been made to enhance the mechanical properties of water-based coating by incorporating nanoparticles in the water-based coating [3].

Nanoparticles such as nanoclay found applicability in coatings to meet mechanical requirements and improvement in thermal stability of coatings [4]. Researchers have showed that the addition of nanoclay could provide excellent mechanical properties of nanocoatings due to their high surface area to volume ratio [5-6]. The objectives of this study are to determine the effect of nanoclay on adhesion and mechanical properties of water-based coating.

## 2. Materials and methods

Rubber wood timber was purchased from local company located in Selangor. Then it was cut and plane into panels. The panels were cut to size of 400 mm x 500 mm, having a moisture content of 12.

### *2.1 Preparation of nanocoatings*

The water-based coatings, which was waterborne polyurethane contained 30 % clear finish, was purchased from local supplier located in Selangor, Malaysia. The typical characteristics of the coating are shown in Table 1. Nanoclay that have been chosen for this analysis contained octadecylamine and 3-aminopropyltriethoxysilane.

**Table 1.** Coating properties.

| Characteristics | Properties |
|---|---|
| Appearance | Translucent liquid |
| Viscosity | Approximate 30-32 sec at 25°C |
| Solid content | 33±2 % |
| Dilution | No required |

The samples were prepared by dispersing 2 % v/v of nanoclay in 50 ml of water based coating. The solutions were mix by homogenization for 20 minutes at 10, 000 rpm. The dispersion process was then repeated for 4 %, 6 %,8 % of 10 % of nanoclay loading. The samples were compared with control (water-based coating) and referred to as NC 2%, NC 4%, NC 6%, NC 8% and NC 10%. Whilst water-based coating without nanoclay was used as control for comparison purposed. After finishing, the panels were kept at ambient room temperature in the laboratory.

### *2.2 Preparation of wood samples*

The rubber wood panels were sanded with sandpaper with grit number of 80 followed by grit number of 360 along the grain to obtain a smooth surface. Panels were conditioned in a conditioning room at 22 ± 2 °C and relative humidity of 65 ± 5 % for one week. The dimensions of the panels were cut based on standard requirements of the test, in which the size for adhesion, impact and scratch test were 140 mm x 80 mm x 5 mm while for abrasion test was 100 mm x 100 mm x 5 mm. Each panel was coated for 3 layers using 75 µm wire bar coater. Three replicates were prepared for each test. After finishing, the panels were ambient at room temperature in the laboratory.

### *2.3 Adhesion test (cross-cut)*

The adhesion test on the substrate was carried out using cross-cut tape method based on ISO 2409:2013 [7]. A single blade cutter was used to make lattice pattern. The number of cuts for each lattice pattern is six. The spacing between each cut at both directions is 2 mm. An adhesive tape was placed over the lattice area and removed after 5 minutes. The cut area percentage was examined.

### *2.4 Impact test (Resistance to mechanical damage)*

The relative resistance of finishes was carried out based on BS3962:Part6 1980 [8]. whereby a steel ball was dropped from 2 m height on to the test panel. The area was examined and rated based on the assessment code stipulated in the standard.

### 2.5 *Scratch test*
The scratch test was carried out based on ISO 1518-1:2011 [9]. The finished panel was clamped onto the panel holder. A weight with a minimum load of 1000 g load was placed on the stylus. The load weight was increased by 100 g until a maximum load of 2000 g.

### 2.6 *Abrasion test*
The abrasion test was done on the coated rubber wood panels. The surface of the coated panels is abraded by rotating the panel under weighted abrasive wheels. Abrasion resistance is calculated as loss in weight at 1000 and 2000 of abrasion cycles based on ASTM D 4060-14 2014 [10].

## 3. Results and discussion

### 3.1 *Finishing properties of nanocoating*
Finishing properties of controlled and nanocoating were tabulated in Table 2. It showed that the adhesion and mechanical properties of coating with and without nanoclay. Coating adhesion can be evaluated in terms of the force at which the coating layers detached from the substrate surface or serious destruction occurs at the coated layer. No detectable failure was observed for nanocoating with 2 %, 4 % and 6 % of nanoclay loading. Thus, coating layer resided all along the indentation groove without any detachment or destruction. However, NC 8 % and NC 10 % showed a little detachment, showing poorer adhesion quality for these samples due to the agglomeration of the nanoclay. When the amount of nanoclay was increased with the same speed and time of homogenization, there was some nanoclay that was not well dispersed in the coating.

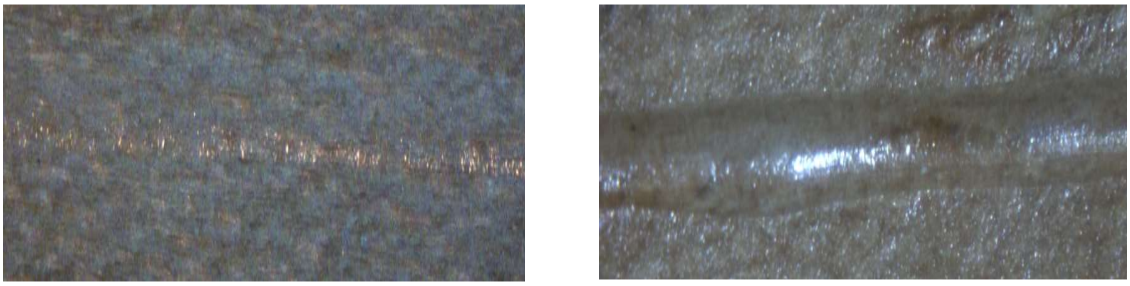
**Table 2**. Adhesion and mechanical properties of nanocoating.

| | Adhesion | Impact | Scratch (N) | Abrasion (mg) at 2000 cycles |
|---|---|---|---|---|
| Control | 0[a] | 2[c] | 19.70 | 274 |
| NC 2% | 0[a] | 3[d] | 19.70 | 241 |
| NC 4% | 0[a] | 3[d] | 19.70 | 290 |
| NC 6% | 0[a] | 3[d] | 19.70 | 294 |
| NC 8% | 1[b] | 2[c] | 19.70 | 396 |
| NC 10% | 1[b] | 2[c] | 19.70 | 561 |

[a]Notes are referenced for none of the lattice is detached.
[b]Detachment is <5 %.
[c]Slight flaking.
[d]Moderate cracking.

For impact test, the results show significant increase in resistance to mechanical damage for NC 2 %, NC 4% and NC 6 %. However, at higher percent of nanoclay, the impact strength decreased at NC 8 % and NC 10 %. However at higher percentage, reason for drop in impact strength is not yet addressed [11]. In this case, the decrement of impact strength was related to the not well dispersed of the nanoclay. There was some part of the panels was not smoothly covered with the nanocoating because of the nanoclay agglomeration.

It can be seen that scratch test results show for all samples of the coating with and without nanoclay can resist load maximum to 19.7 N. Increase of applied load being almost independent with nanoclay content. However, Figure 1 reveals a different penetration depth affected from the scratch test. There is a significant increase of penetration depth happens at NC 10 % compared to the NC 2 %. High of penetration depth as shown in Figure 4b was attributed with the bad adhesion properties. Hence, the penetration depth was highly related with the adhesion of the nanocoating.



(a) (b)

**Figure 1**. Penetration depth of scratch on (a) NC 2% and (b) NC 10% under 18x magnification

Abrasion test was done up to 2000 cycles and the result obtained shows that there is a significant different of weight loss between control and NC 2 %. It reveals the addition of nanoclay in the coating can improve the abrasion resistant. However, the results give a bad effect while the weight loss increases after 2 % nanoclay. Thus, the scratch resistance decreases as the amount of nanoclay increase. The weight lost for control and nanocoating samples were 274 g and 241 g respectively. It reveals that by additional of nanoclay in the water-based coating can improve the abrasion resistant of this material. While having the optimum amount of nanoclay in water-based coating, a good abrasion resistance with smooth surface panels can be achived.

## 4. Conclusion

In the present study, it can be concluded that the addition of nanoclay into water-based coating resulted in an increase in adhesion and mechanical properties. The optimum percentage of nanoclay was found to be 2%, after which there was a decrease in properties due to the particle agglomeration due to the particle that was not well dispersed in the coating. The excessive amount of nanoclay was significantly affecting the adhesion, impact and abrasion resistance while it does not affect the scratch resistance. However, the penetration depth of the coating shows a significant different between the present of the nanoclay in the coating and coating without nanoclay.

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