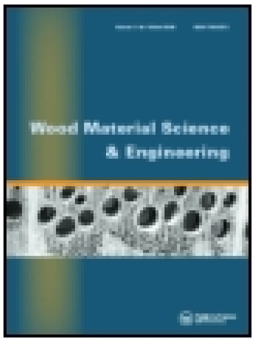

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ORIGINAL ARTICLE

Wettability and adherence of acrylic paints on long and short rotation teaks

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ABSTRACT

The quality of finished wood products depends on the quality of its coating layer. An important indicator for evaluating the quality is Adherence of the paint on the wood surface. The purpose of this research was to analyze the effect of wood surface roughness and the viscosity of acrylic paints (pure acrylic and acrylic copolymer) to the wettability and Adherence for long and short rotation teaks. Wood surface with various degrees of roughness was prepared by sanding with abrasive papers of P120, P240, and P360 grits. Different viscosity of the acrylic paints was prepared composition between paint and water (w/w) of 100:0, 90:10, 80:20, and 70:30. The wettability of the acrylic paints on teak wood surfaces was measured using a sessile drop contact angle method with the S/G model. Adherence of the coating layer was measured using a crosscut test. The results showed that the increase in the roughness (Ra) and the decrease in the viscosity of the paints resulted in the increase in the wettability which leads to better Adherence of acrylic paints on the surface of teak woods. The pure acrylic paint generated better wettability and Adherence compared to the acrylic copolymer.

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Acrylic paints; adherence; surface roughness; teak wood; viscosity; wettability

Introduction

Wood surface coating is an activity to cover wood surfaces with paint materials that aim to protect, beautify, and improve the stability of the wood (Darmawan *et al.* 2011). Wood surface has various roughness degrees. Some species of wood also have a porous surface due to various structure of the cell wall component (Mohammed-Ziegler *et al.* 2004; Inari *et al.* 2006). Teak wood is largely used for structural and furniture products in Indonesia. Due to the increasing demand for teak wood as a raw material, much of teak wood supply has been from community teak plantations which were harvested at short age of 7–10 years (short rotation teak). The quality of products produced by short rotation teak is lower than the quality of similar products made from conventional teak (long rotating teak wood). Therefore, surface coating process would be needed to enhance the quality of teak wood products. The final quality of teak wood products depends on the quality of the paints coating. Acrylic paint has been recently used to coat the wood surfaces because it is ecofriendly water-soluble paint.

An important factor in paint coating performance is good adhesion of coating material on the wood surface (Richter *et al.* 1994). The ability of paint adhesion to wood is influenced by wood materials (wood species, wood structure, wood chemical components, and wood surface roughness), coating materials (types and viscosity of coatings), and also coatings material application (Kamke and Lee 2007). The interaction between wood surface and paint can be analyzed by observing thermodynamic wetting parameters such as contact angle, surface free energy (SFE), and adhesion work force (Wålinder 2002). One important parameter that can be used to characterize the wood surface and evaluate the chemical properties of the wood surface is SFE. The most common way to determine the value of the SFE is the measurement of contact angles of two or more polar and non-polar liquids through the sessile drop method. Several approaches have been taken to calculate the SFE value of a material, harmonic mean equation (Wu 1971), geometric mean equation (Owens and Wendt 1969), and acid–base approach (Van Oss *et al.* 1988; Van Oss and Giese 1995). Investigation of the SFE value and its components has been widely carried out (Gardner 1996; Shen *et al.* 1998; Shi and Gardner 2001; Wålinder and Strom 2001). Differences in SFE values between wood species and in the same wood species have also been reported (Mohammed-Ziegler *et al.* 2004; McConnel and Shi 2011; Rossi *et al.* 2012).

The characteristics of wood material, characteristics of the paint polymers, surface tension, and interaction between wood surface and paint (adhesion mechanism) need to be understood to evaluate the adhesion of paint on wood. The theory of mechanical bonding (mechanical interlocking) has long been used to describe the Adherence of paint on wood. The various degrees of surface roughness in wood contribute to the mechanical bond and change the nature of wood wettability due to the capillary force (Gardner 2005). Surface roughness is closely related to wettability. Wettability is the ability of a liquid to spread and penetrate on a solid surface (Gray 1962). Most studies on wettability have been carried out for adhesive on the wood surface. Wettability of adhesive increases as surface roughness increases (Moita

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and Moreira 2003; Ayrilmis *et al.* 2010; Buyuksari *et al.* 2010; Arnold 2011). On the contrary, few studies on wettability have been carried out for paint coatings on the wood surface. Darmawan *et al.* (2017) reported that the surface roughness is an important factor in determining the wettability and Adherence of alkyd and acrylic varnish on the surface of fast growing jabon and sengon woods. In addition to the surface roughness, the viscosity of paint is thought to also influence the wettability. Suitable wettability due to surface roughness and paint viscosity will be an important indication of adequate Adherence of a paint coating on long and short rotation teak wood surfaces. The wettability of water and glycerol on short rotation teak is better than on long rotation teak (Rizanti *et al.* 2017). This study aimed to analyze the effect of wood surface roughness and viscosity of acrylic paints on wettability and their Adherence on long and short rotation teaks.

Materials and methods

Materials

The materials used were long rotation teak wood of 50 years age with a diameter of 40 cm obtained from KPH Mantingan Tasikagung Village, District Rembang, Central Java and short rotation teak of 7 years age with a diameter of 28 cm obtained from Ciaruteun Village, District Bogor, West Java. Long and short rotation teak trees (3 each) were selected from the plantation sites as representative specimens. After felling the trees, one log section in length of 2.5 m was taken from each tree at the bottom part of the trees stem. The logs were transported to the wood workshop for preparation of test specimens. The sample logs were sawn by band saw in such a manner that flat grained lumbers in thickness of 2.5 cm were produced. The lumbers were carefully air-dried to prevent warping. The lumbers with 12–15% moisture content were surfaced end-cut to produce dimension of test specimen 20 cm (Longitudinal) × 12 cm (Tangential) × 2 cm (Radial). Total samples prepared for each species were 32 pieces.

Paints used in this study were copolymer acrylic (water, acrylic, titanium dioxide, sodium potassium aluminum silicate, anhydrous aluminum silicate) and pure acrylic (water, acrylic, pigments oxide transparent). Paint emulsions with composition between paint and water (w/w) of 100:0, 90:10, 80:20, and 70:30, respectively, were prepared and stirred uniformly. The viscosity of the paint emulsions was measured using a Toki Sangyo TV-10 viscometer tool. Density, solid content, and surface tension in each emulsion were also measured.

Surface roughness measurement

A set of test specimen was kept un-sanded as the control. The other specimen was sanded 50 times parallel to the length with abrasive papers of P120, P240, P360 grits, respectively. The wood dust produced was carefully cleaned by a standard wood shop air spray. The roughness of all test specimens were measured by using the Mitutoyo type SJ-210 tester and characterized by ISO 1997. The arithmetical mean roughness (Ra) value was measured with a diamond tip radius of 5 µm, tracing length of 6 mm, the cutoff of 0.8 mm and speed of 0.5 mm/s. Twenty points of measurement were diagonally made on the surface of the specimen. Measurements were made perpendicular to the fiber direction of the specimen.

Determination of SFE of teak woods

SFE is one of the thermodynamic quantities that describe the state of equilibrium of atoms in the surface layer of material (Żenkiewicz 2007). The basis for determining solid SFE (γ_s) is the size of the contact angle (θ) of the standard liquid droplet (with known γ_l) on the surface of the solid sample area. The method used to calculate the SFE value in this study was the method proposed by Rabel (Rabel 1971). The method uses a regression line modified from the Owens and Wend equation:

$$(1+\cos\theta)\frac{\gamma_l}{(\gamma_l^d)^{1/2}} = (\gamma_s^d)^{1/2} + (\gamma_s^p)^{1/2}\left(\frac{\gamma_l^p}{\gamma_l^d}\right)^{1/2}. \quad (1)$$

In a linear regression line ($Y = A + BX$), as $Y = (1+\cos\theta)\frac{\gamma_l}{(\gamma_l^d)^{1/2}}$, $X = \left(\frac{\gamma_l^p}{\gamma_l^d}\right)^{1/2}$, the slope (B) will be $(\gamma_s^p)^{1/2}$ and the intercept (A) will be $(\gamma_s^d)^{1/2}$. Calculations of both X and Y in this work used four standard liquids as presented in Table 1.

SFE of un-sanded, sanded with P120, P240, and P360 grits for the long and short rotation teaks was calculated. The contact angles of the standard liquids in Table 1 on the surface of the un-sanded and sanded specimens which were used to determine the value of Y were measured. The value of SFE should be $A^2 + B^2 = ((\gamma_s^d)^{1/2})^2 + ((\gamma_s^p)^{1/2})^2$.

Determination of characteristics of paints

Viscosity of the emulsion paints was measured using a viscometer TV-10 Toki Sangyo. Density and solid content of emulsions were also measured. Surface tensions of the emulsions were measured with pendant drop analysis method. The pendant obtained from axisymmetric dropping of 0.02 ml emulsions from a syringe was captured by using CCD camera. The shape of the pendant images was analyzed using Image-J 1.46 software with pendant drop analysis plugin.

Contact angle measurement

The dynamic contact angle of emulsion paints on the surface of the un-sanded and sanded teak woods was measured by a video measuring system with a high-resolution CCD camera.

Table 1. The value of total surface tension, polar surface tension, dispersive surface tension for the standard liquids (in mJ/m^2).

Liquids	γ_l	γ_l^p	γ_l^d
Water	72.8	21.8	51.0
Metanol 50%	35.6	12.9	22.7
Toluena	28.4	2.3	26.1
Gliserin	64.0	30.0	34.0

Note: γ_l, the value of total surface tension; γ_l^p, polar surface tension; γ_l^d, dispersive surface tension.

Wood specimen was placed on the top of a table in front of the CCD camera. The emulsion paint were dropped by syringe with a screw method to obtain the same droplet volume of 20 µl. Video images of the drop shape on the wood surface were captured by the CCD camera and saved for the duration of 180 s. Five drops per sample were captured for measurements of the contact angle. Each of captured video images was cut to an individual image at intervals of 10 s. The contact angle (*θ*) of the individual image of the drop was measured by the Image-J 1.46 software with the dropsnake plugin analysis. The contact angle was measured on both sides of the droplet and then averaged. Nineteen data points were taken for each recorded drop to obtain a curve of contact angle versus time. All of the samples were initially conditioned at temperature 23°C ± 2°C and relative humidity of 50% ± 5%.

Determination of equilibrium contact angle and constant contact angle change rate

The equilibrium contact angle (θ_e) values were determined based on the segmented regression equation between contact angle (*y*) and time (*x*) using the PROC NLIN program in SAS (2004). The contact angle change rate (*K*-value) on the S/G model (Shi and Gardner 2001) was used to quantitatively evaluate the wettability. The S/G model is described in Equation (2).

$$\theta = \frac{\theta_i . \theta_e}{\theta_i + (\theta_e - \theta_i)\exp\left[\left(\frac{\theta_e}{\theta_e - \theta_i}\right)t\right]}, \quad (2)$$

where θ is the contact angle at a given time, θ_i is the initial contact angle, θ_e is equilibrium contact angle, t is wetting time, and K is the constant contact angle change rate. The *K*-value was calculated using defined functions of non-linear regression model to fit the S/G equation by XLSTAT (2007).

Coating application and adherence test

All test specimens were coated by different paint emulsions. Coating was applied using brushes on all sides of the wood surface. Two coats were applied on the wood surfaces to achieve a total application of 150 g/m^2 wet film. The required weight of each coat to achieve these spread rates was calculated based on the surface area of the specimen. Twenty-four hours drying time was allowed before the second coat was applied. When the second coat had dried, the coated specimens were conditioned for a week in a clean room. A crosscut test method was applied to evaluate the resistance of the coating film to separation from wood surfaces. The coating film on each test specimen was then scratched by a cutter of 11 lines with a distance between lines of 2 mm. The same scratch was also made intentionally perpendicular to the first stroke so that a square pattern with a small square of 100 pieces was formed. Pressure-sensitive tape was applied over the crosscut. The tape was removed by pulling it off rapidly back over itself with the direction 45°. The degree of damage indicates the quality of its bonding. The degree of damage can be classified into 6 scales referring to ASTM D 3359-02 standard (1997). The scales of the adhesion were averaged.

Statistical analysis

An analysis of variance, ANOVA was conducted to evaluate the effect of the surface roughness, emulsion, paint types on the wettability and Adherence between the paint and wood specimens. Significant differences among the average value of the factors were determined using Duncan's test.

Results and discussion

Roughness and wood SFE

The value of Ra in Figure 1 shows that the surface roughness of the teak wood specimens decreased as grit number of abrasive paper increased. A higher grit number of the abrasive paper has the finer particles to scratch the wood surface, hence smoother wood surface (lower Ra) was produced. The Ra values of un-sanded, sanded P120, sanded P240, and sanded P360 for long rotation teak wood were 10.55, 6.28, 3.57, 2.18 µm, respectively. While the Ra values of un-sanded, sanded P120, sanded P240, and sanded P360 for short rotation teak wood were 11.10, 8.01, 4.77, 3.17 µm, respectively. This result indicates that the short rotation teak wood was higher in Ra value than the long rotation teak wood for the same grit number of abrasive paper. This could be due to the average pore diameter of the short rotation teak wood (500 µm) higher than that of the long rotation teak (400 µm). Wahyudi *et al.* (2014) reported that a short rotation teak wood has a greater pore sizes than a long rotation teak wood.

The SFE of teak woods after sanding are shown in Table 2. The same phenomena as the Ra value, the SFE decreased as the grit number of abrasive paper increased. The SFE value for long and short rotation teak woods were in the range 29.95–36.54 mJ/m^2 and 50.30–54.37 mJ/m^2, respectively. Polar and dispersive SFE for the un-sanded, sanded P120, sanded P240 and sanded P360 of long and short rotation teak wood are also presented on Table 2. The polar SFE (γ_p^s) was lower than the dispersive SFE (γ_d^s) both for long and short rotation teak woods. It was noted in another study that wood material is an hydrophobic material as the value

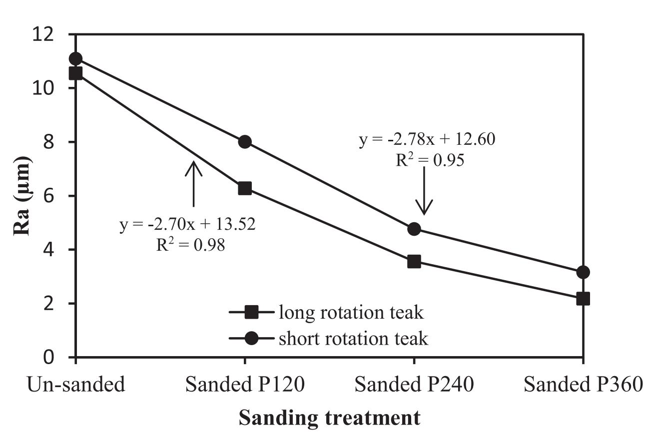

Figure 1. Surface roughness value for long and short rotation teak wood surfaces.

Table 2. The value of total SFE, polar SFE, dispersive SFE for teak woods (in mJ/m[2]).

Sample	Treatment	γ_s	γ_s^p	γ_s^d
Long rotation teak	Un-sanded	36.54	9.06	27.47
	Sanded P120	35.52	8.98	26.54
	Sanded P240	34.44	8.91	25.53
	Sanded P360	29.95	9.21	20.74
Short rotation teak	Un-sanded	54.37	13.18	41.19
	Sanded P120	53.09	13.24	39.85
	Sanded P240	51.95	13.39	38.56
	Sanded P360	50.30	13.61	36.69

Note: γ_s, the value of total SFE; γ_s^p, polar SFE; γ_s^d, dispersive SFE.

of its polar SFE is smaller than its dispersive SFE (Suryadi 2017). The decrease in the roughness of teak wood could cause the decrease in the SFE value. This could due to the contact area on the rougher surfaces higher than that on the smoother surfaces.

Wettability

The values of contact angle should be an important factor in determining the wettability, and Adherence of paint liquid on the surface of wood. The results on contact angle of pure acrylic and acrylic copolymer paint on the teak wood surfaces are presented in Figure 2. The results in Figure 2 show that the equilibrium contact angles (θ_e) decreased as the grit number of abrasive paper and the percentage of solvent in the paint emulsion increased. The θ_e of pure acrylic with 0%, 10%, 20%, and 30% solvent in the emulsion paint on un-sanded long rotation teak was 49.73°, 41.78°, 37.70°, 35.21°, respectively, and on un-sanded short rotation teak was 43.12°, 40.77°, 34.06°, 29.47°, respectively. Otherwise, the θ_e of acrylic copolymer with 0%, 10%, 20%, and 30% solvent in the emulsion paint on un-sanded long rotation teak was 67.50°, 60.10°, 48.73°, 47.36°, respectively, and on un-sanded short rotation teak was 66.82°, 59.66°, 47.93°, 46.19°, respectively. The values of θ_e both for pure acrylic and acrylic copolymer emulsions were proportionally increased as the teak woods were sanded by P120, P240, and P360. This result indicates that pure acrylic paint produced a lower θ_e than acrylic copolymer paint.

The constant contact angle change rate (*K*-value) is a value that describes the wettability. The average *K*-values of five measurements for all wood specimens are shown in Figure 3. The *K*-value for all experimental data was calculated using the least squares method to fit the S/G equation by XL-STAT. Figure 3 also showed that the un-sanded wood samples had the highest *K*-value and it decreased as the grit number of the abrasive paper increased both for paints type. The *K*-value decreased as the emulsion paint more viscous. Pure acrylic paint generated larger *K*-value compared to acrylic copolymer paint. Analysis of variance of paint type, paint emulsion and sanding factors on *K*-value are presented in Table 4.

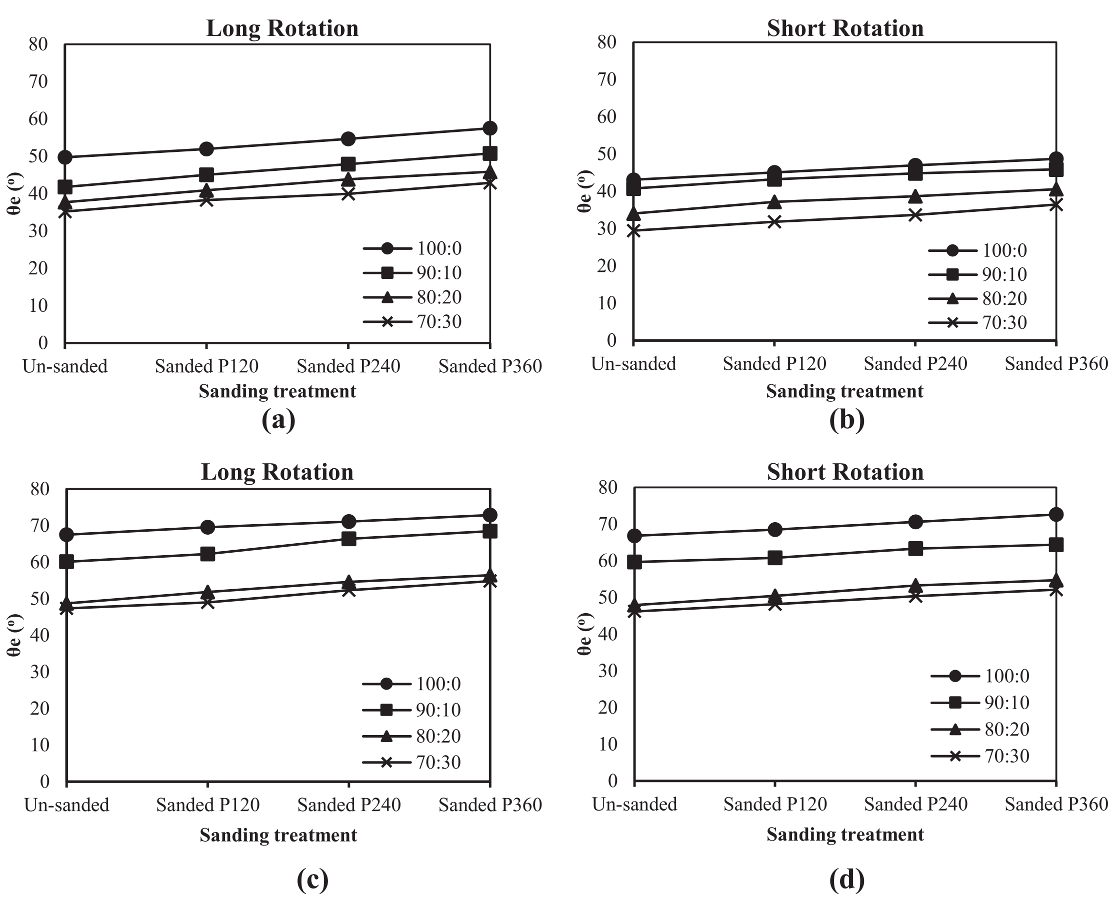

Figure 2. Equilibrium contact angle for pure acrylic paint on long rotation teak wood surface (a), pure acrylic paint on short rotation teak wood surface (b), acrylic copolymer paint on long rotation teak wood surface (c), acrylic copolymer paint on short rotation teak wood surface (d).

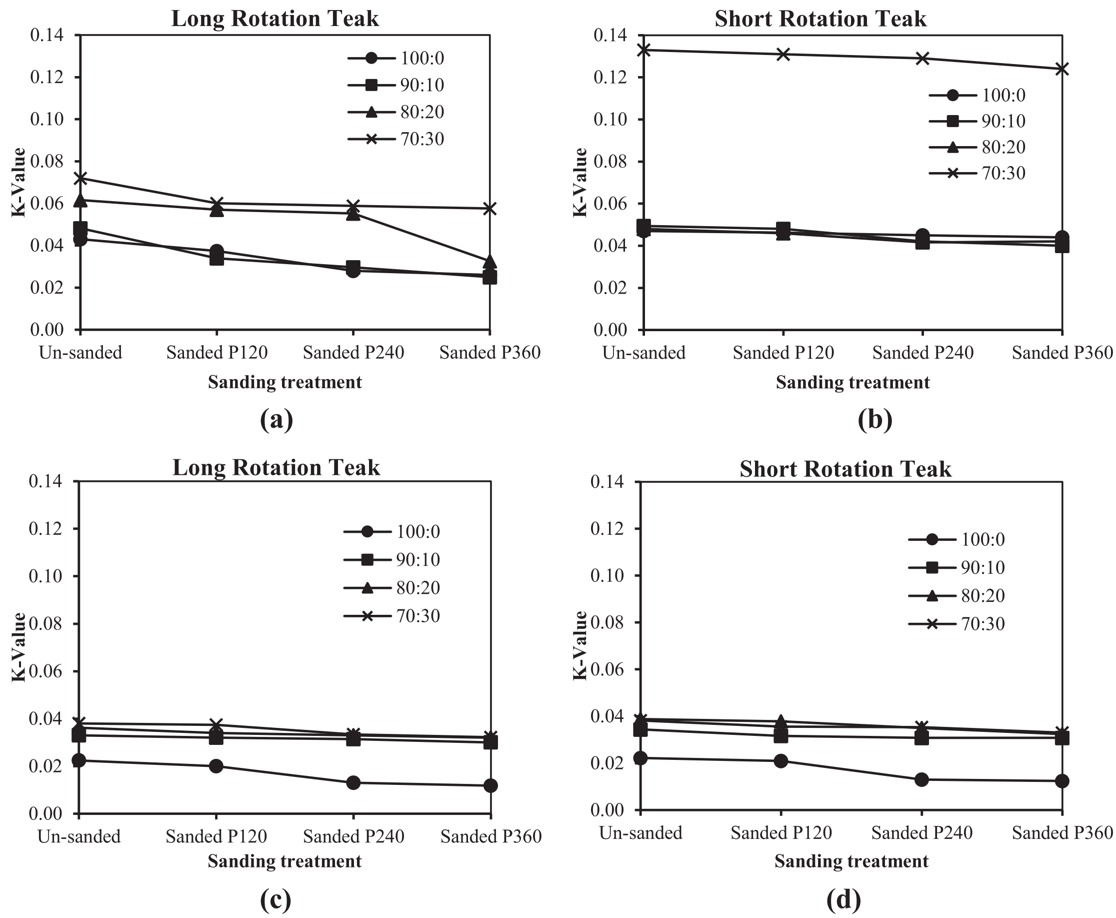

Figure 3. Constant contact angle change rate (*K*-value) for pure acrylic paint on long rotation teak wood surface (a), pure acrylic paint on short rotation teak wood surface (b), acrylic copolymer paint on long rotation teak wood surface (c), acrylic copolymer paint on short rotation teak wood surface (d).

Paint type and its emulsion

The characteristics of emulsion paints for both paints type are presented in Table 3. The results show that the addition of water to the emulsion paint reduced the value of density and solid content. The behaviors of viscosity and surface tension with the emulsion of paint type were presented in Figure 4. The surface tension of emulsion paint increased as the percentage of water in the emulsion increase. The surface tension values 100:0, 90:10, 80:20, and 70:30 emulsion of pure acrylic were 56.85, 57.28, 59.21, 65.08 mJ/m^2, respectively. While, the surface tension values for 100:0, 90:10, 80:20, and 70:30 emulsion of acrylic copolymer were 15.57, 19.50, 27.77, 65.08 mJ/m^2, respectively. The increase in surface tension after addition of water could be caused by the greater proportion of polar groups (e.g. O–H groups) in the emulsion lead to stronger attractive forces between the acrylic polymer and water. The strong attractive forces could cause a high surface tension and the emulsion tended to form discreet droplets on a surface of wood. The viscosity values for 100:0, 90:10, 80:20, and 70:30 emulsion of pure acrylic were 12.0, 6.7, 2.7, and 1.0 poise, respectively. While, the viscosity values for 100:0, 90:10, 80:20, and 70:30 emulsion of acrylic copolymer were 60.0, 19.8, 4.8, and 3.3 poise, respectively. The decrease in viscosity could relate to the decrease in density and solid content in the emulsion. Pure acrylic paint due to its lower solid content had a lower viscosity and higher surface tension value than the acrylic copolymer.

Table 3. The results on measurement of density and solid content of paint emulsions.

Paint	Percentage of water addition (%)	Density (g/cm^3)	Solid content (%)
Pure acrylic	0	1.05	42.80
	10	1.05	38.98
	20	1.04	33.46
	30	1.04	29.02
Copolymer acrylic	0	1.39	56.50
	10	1.33	55.71
	20	1.29	44.27
	30	1.24	41.63

Table 4. Analysis of variance for wettability.

Source	DF	Sum of squares	Mean squares	*F*	Pr > *F*
Paint type	1	0.099	0.099	291.428	<0.0001
Paint emulsion	3	0.005	0.002	5.229	0.005
Sanding	3	0.018	0.006	17.496	<0.0001
Wood	1	0.000	0.000	0.069	0.794
Paint type * Paint emulsion	3	0.020	0.007	19.434	<0.0001
Paint type * Sanding	3	0.001	0.000	0.860	0.472
Paint emulsion * Sanding	9	0.002	0.000	0.692	0.711
Paint type * Paint emulsion *Sanding	9	0.001	0.000	0.432	0.908

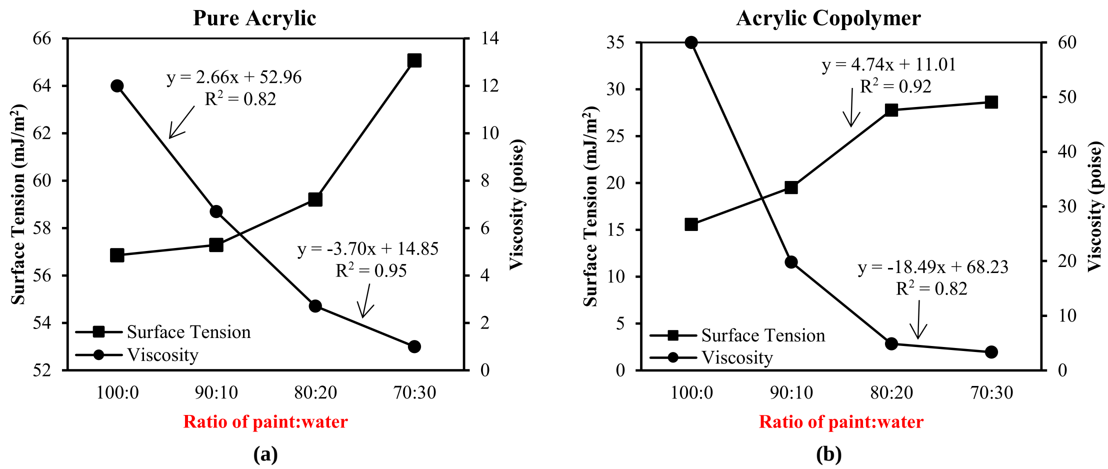

Figure 4. The behaviors of viscosity and surface tension for pure acrylic paint (a), acrylic copolymer paint (b).

The results on analysis of variance in Table 4 show that paint type, paint emulsion, and their interaction had a significant effect on the *K*-value. The *K*-value of pure acrylic paint was significantly different from the *K*-value of the copolymer acrylic paint. The *K*-value of pure acrylic on long and short rotation teak wood was greater than that of acrylic copolymer. This phenomenon could be due to the lower viscosity of the pure acrylic paint. The presence of TiO_2, sodium potassium, aluminum silicate, anhydrous aluminum, and silicate made the acrylic copolymer to be hydrophobic which generates high contact angle (lower *K*-value) on the surface of teak wood. The *K*-value decreased as the emulsion paint more viscous both for pure acrylic and acrylic copolymer. This indicates that emulsion paint with lower viscosity exhibited better wettability than the higher viscosity paint emulsion. This phenomenon is in accordance with the results stated by Gavrilovic-Grmusa *et al.* (2012) that the wettability value decreases with the higher viscosity value of an adhesive. The result on Duncan test for the *K*-value indicates that *K*-value among 100:0, 90:10 and 80:20 emulsion paints were not significantly different, but the values were significantly different from the *K*-value of 70:30 emulsion paint.

Sanding wood surface

Wood surface roughness determined the SFE value which affected the magnitude of the contact angle formed. Increasing in the SFE value resulted in a decrease in the contact angle value and increases the interfacial contact area. The surface sanded with lower grit number had a higher SFE value and generated a higher *K*-value. A higher *K*-value means that the surface is more wetting. Both un-sanded long and short rotation teak woods generated higher *K*-value compared to sanded teak wood. The *K*-value for long and short rotation teak woods sanded by P180 grit was higher compared to sanded by P240 and P360 grit. The results of analysis of variances in Table 4 show that sanding factor had a significant effect on the *K*-value. The result of Duncan test shows that *K*-value was significantly different among the sanded surfaces using different grit number of abrasive papers. The *K*-value of un-sanded wood surface was significantly different from that of the sanded by P360 grit. However, the *K*-values of wood surfaces among the sanded surface using P120, P240, and P360 grit number of abrasive paper were not significantly different.

Long and short rotation teak woods

The *K*-value for long and short rotation teak woods did not show significant different in the ANOVA (Table 4). As shown in Figure 3, both the pure acrylic and acrylic copolymer paint exhibited a greater *K*-value on short rotation teak than on long rotation teak wood surface. The short rotation teak wood was more wetting than long rotation teak wood. This was due to the pore structure for long rotation teak wood vessels were filled with tylosis or other deposits which results in a more even surface compared to short rotation teak wood. According to Unsal *et al.* (2011), the wettability value of wood is influenced by macroscopic characteristics of wood such as density, surface roughness and moisture content. Especially non-polar extractive substances contained in teak cell walls of long rotation can reduce the nature of wettability. Haygreen and Bowyer (1996) stated that extractive substances occupy a number of places in the cell wall that are normally occupied by water so that in the presence of extractive substances block the absorption of water by the cell wall. In addition, the density of long rotation teak wood was 630 kg/m^3 greater than short rotation teak wood of 560 kg/m^3. This higher density could cause the lower absorption of emulsion paint.

Adherence

Average values of Adherence according to paint type, paint emulsion, sanding, and wood species are presented in Table 5. The larger crosscut test values indicated good Adherence between coating layer and wood surface. The results in Table 5 show that high wettability resulted in good adhesion between coating layer and wood surface. Wettability has a significant influence on Adherence (Rathke and Sinn, 2013). Viscosity variations of emulsion affected the Adherence between the coating layer and the wood surface. The lower viscosity of the emulsion produced a high wettability value

Table 5. The test results of adherence of the coating layer.

Sample	Class	Sample	Class	Sample	Class	Sample	Class
JPA1	2B	JRA1	5B	JPA2	3B	JRA2	3B
JPA1P120	1B	JRA1P120	5B	JPA2P120	2B	JRA2P120	3B
JPA1P240	1B	JRA1P240	5B	JPA2P240	1B	JRA2P240	3B
JPA1P360	1B	JRA1P360	5B	JPA2P360	0B	JRA2P360	3B
JPB1	3B	JRB1	5B	JPB2	3B	JRB2	3B
JPB1P120	3B	JRB1P120	5B	JPB2P120	2B	JRB2P120	3B
JPB1P240	2B	JRB1P240	5B	JPB2P240	1B	JRB2P240	2B
JPB1P360	2B	JRB1P360	5B	JPB2P360	0B	JRB2P360	2B
JPC1	4B	JRC1	5B	JPC2	3B	JRC2	4B
JPC1P120	3B	JRC1P120	5B	JPC2P120	3B	JRC2P120	3B
JPC1P240	3B	JRC1P240	5B	JPC2P240	2B	JRC2P240	3B
JPC1P360	3B	JRC1P360	5B	JPC2P360	2B	JRC2P360	3B
JPD1	4B	JRD1	5B	JPD2	3B	JRD2	4B
JPD1P120	3B	JRD1P120	5B	JPD2120	3B	JRD2P120	3B
JPD1P240	3B	JRD1P240	5B	JPD2P240	1B	JRD2P240	3B
JPD1P360	3B	JRD1P360	5B	JPD2P360	1B	JRD2P360	2B

Note: JP, Long rotation teak; JR, Short rotation teak; A, emulsion 100:0; B, emulsion 90:10; C, emulsion 80:20; D, emulsion 70:30; 1, pure acrylic paint; 2, acrylic copolymer paint; P120, sanded with P120 grit; P240, sanded with P240 grit; P360, sanded with P360 grit.

lead to the high value of the Adherence. Considering the comparison on paint type, the pure acrylic retained higher Adherence compared to acrylic copolymer paint in both teak woods. The better wettability of the pure acrylic contributed to the higher Adherence.

In addition, the Adherence of the pure acrylic and acrylic copolymer increased as the roughness of the teak wood surfaces increased. A rough surface was proposed to enhance intrinsic adhesion by providing greater interfacial area and some mechanical interlocking mechanism. By considering that the interfacial or intermolecular attraction was the basis for the paint adhesion, increasing the actual area of contact would increase the total energy of surface interaction. This is in line with research conducted by Vitosyte *et al.* (2012) which stated that paint adhesion and surface roughness have a positive relationship, the lower the surface roughness, the lower will be the Adherence of paint. It was noted in another study, the higher grit number of abrasive paper causes the wood surface roughness to be low and can reduce the wettability and mechanical bond between paint and wood surface (Darmawan *et al.* 2017). According to the wood, the Adherence of short rotation teak wood was slightly higher than that of long rotation teak wood. This was due to short rotation teak wood more wetting than long rotation teak wood.

Conclusion

The results of this study indicate that the roughness of the wood surface and the viscosity of the emulsion paint affect the wettability and Adherence of the coating layer. The higher Ra value of teak wood surface cause the higher SFE value and generates the higher *K*-value. The lower viscosity of the emulsion paint results in a higher *K*-value. The higher *K*-value indicates the better wettability of the pure acrylic and acrylic copolymer on the teak wood surfaces. The Adherence of the pure acrylic and acrylic copolymer layer decrease as the surface become smoother and the emulsion paint become more viscous. The pure acrylic paint has generates better wettability compared to the acrylic copolymer paint. Short rotation teak wood has better wettability and higher Adherence than long rotation teak wood for both types of paint.

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