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ADHESIVE WETTABILITY OF FOUR MALAYSIAN WOOD SPECIES

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ABSTRACT

*Adhesive wettability of four Malaysian wood species namely Tualang (*Koompassia excelsa*), Kapur (*Dryobalanops aromatica*), Merbau (*Instia palembanica*) and Meranti (*Shorea spp.*) were determined using contact angle measurement. Two resin systems; polyvinyl acetate (PVAc) and phenol resorcinol formaldehyde (PRF) were evaluated. The wetting angles with water were also determined for the four wood species for comparison purposes. As liquid wetting of wood surfaces is a function of time, this study attempts to quantify the adhesive penetration and spreading during wetting process though dynamic contact angle measurement. Generally, it was learned from this study that PRF exhibits better wettability than PVAc and should form more intimate contact with the wood surface regardless of the four species evaluated. The effect of species on wettability is closely related to the anatomical structure of the species. Merbau and Tualang exhibited greater wettability than Kapur and Meranti with low contact angle values.*

Keywords: wettability, adhesive, wood, penetration, spreading

INTRODUCTION

The growing demand for timber has forced the wood-based industry to search for alternatives to cater for the shortage and depleting supply of quality timber. This includes the introduction of new species as well as utilization of lesser-known and fast growing species. The utilization of such material is known to be associated with processing of small diameter logs producing small size timber.

In order to enhance the utilization of such materials, gluing or lamination techniques was used to obtain larger size of timber. However, gluing of small pieces of defects-free wooden strips currently make use of single species only. In view of the problems that may accompany with the introduction of mix species gluing, a method must be sought to predict gluability of these wood species without the involvement of actual gluing procedure.

Moisture content of timber at the time of gluing and the grain pattern of laminations are known to affect the gluing performance of timbers (1). According to Kollman *et al.* (3) the moisture content must be confined to certain limits for various types of adhesives in order to avoid unnecessary failures. The variations in size and distribution pattern of structural tissues are considered to be the main cause of variation in wood or penetration patterns, even within a species (2). A common cause of wood product failure comes from poor wetting of glue on the wood surface (5). Hence, it is important to achieve basic understanding of wettability or the rate of adhesive wetting on the wood surfaces.

Wettability of a wood surface refers to the rate or how a liquid can wet and spread on it. The wetting and spreading of the liquid involve the principles of surface tension and thermodynamics. According to Minford (4), wetting can be quantified by the equilibrium contact angle formed by the intersection of the solid, liquid and gas phases. When good wetting occurs, the contact angle becomes very small. The liquid spreads or flows spontaneously across the surface. This fundamental behavior of adhesive-wood relationship is not fully exploited especially for Malaysian wood species.

This study was carried out to investigate the adhesive wettability of four Malaysian wood species namely Meranti, Merbau, Kapur and Tualang. They were selected for this study mainly based on their own merits. Meranti was chosen because it was abundance and it is widely used in many applications of wood products. Kapur, with tyloses in its pores, Merbau and Tualang both having moderate to large pores were selected in order to make comparison and obtain better understanding of the effect of intricate nature of these wood materials that may influence the wetting behavior. In practical aspects, this information could be used in the future to predict and enhance the adhesion properties of wood, which would benefit the development of new efficient gluing technology.

MATERIALS AND METHODS

The study was conducted with samples that are prepared from four Malaysian wood species namely Meranti (*Shorea spp.*), Merbau (*Instia palembanica*), Kapur (*Dryobalanops aromatica*) and Tualang (*Koompassia excelsa*). All samples were observed to be flatsawn and hence, all the contact angle measurement was done on the tangential surfaces of the wood samples. All samples of size approximately 75 *mm* X 100 *mm* were free from physical or mechanical damage as well as from fungal and insect attack. Samples from each species were randomly assigned for water wettability and adhesive wettability determination.

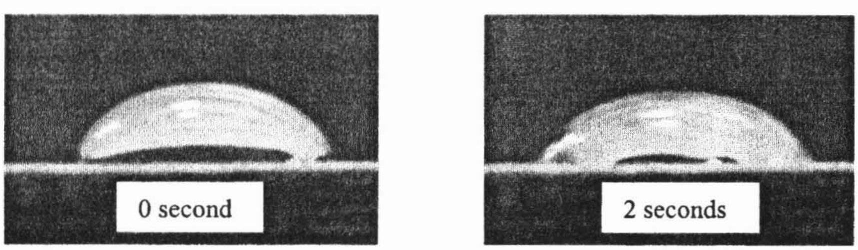
Once the contact angle experiment was about to begin, the surfaces of the samples were smoothed using sandpaper with 180 grids. Two types of adhesive commonly used in the wood industry were evaluated in the wetting experiments. They are polyvinyl acetate (PVAc) and phenol resorcinol formaldehyde (PRF). Both the PVAc and PRF adhesives were purchased from a local glue supplier.

For all wetting measurements, a drop of water or adhesive was placed on the wood surfaces using 0.005 *ml* micro syringe. A digital CCD video camera was used to capture the water or adhesive sessile drop image. The drop shape change process was recorded on videotape. The recording was stopped after the drop shape stabilized (equilibrium contact angle was obtained). The contact angles of water or adhesive drop were averaged from the contact angles of both ends of the drop. The contact angle was measured using UTHSA Image Tools version 2.02 software developed at the University of Texas. Eight data points were taken for each recorded drop to obtain a curve of contact angle versus time. Four to five replicates were averaged for each sample.

RESULTS AND DISCUSSION

Figure 1 shows the representative images of the water drops. It can be seen from the figure that the length of contact between the sessile drop and the solid surfaces increases as time elapses, and this increase is due to liquid spreading. It is also seen from figure 1 that the drop volume decreases as a function of time. The volume decreases is due primarily to liquid penetration into the porous structure of the wood surface. Therefore, these phenomena confirm the fact that the contact angle change as a function of time is caused by both liquid spreading and penetration into the wood substrate.

Figures 2 and 3 shows the plotted experimental data of the contact angle decrease as a function of time for the different wood species with two adhesive systems and water at different time intervals. Table 1 summarizes the water contact angle results for Meranti, Kapur, Merbau and Tualang at different time intervals. The instantaneous and equilibrium contact angles for the four wood species is given in Table 2. Based on these results, the water and adhesive wettability as a function of time for different species is discussed in the following sections.



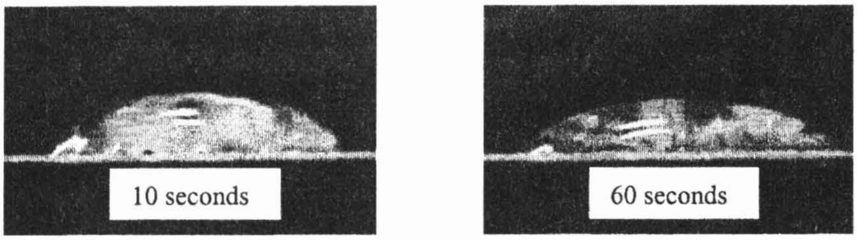


Figure 1. Images of sessile drop of water on Kapur at different time intervals.

Water contact angle between species

From table 1, the mean water contact angle for Meranti at 0 second was found to be the largest with a value of 104.0 degrees. Kapur, Merbau and Tualang followed this subsequently with 97.5, 59.7 and 53.0 degrees respectively. As can be clearly seen in Figure 2, the penetration and spreading of water into the wood surfaces was fast during the first 10 seconds and decrease more gradually until it stabilized at approximately 120 seconds.

From this experiment, Merbau and Tualang exhibited greater wettability than Kapur and Meranti with low contact angle values. Kapur demonstrated less wettability than Merbau and Tualang, but greater than Meranti. The lower contact angles for Merbau and Tualang were expected given the fact that both wood species have large pores to alleviate spreading and penetration of liquid water. For Kapur and Meranti, the explaination for lower wettability could be due to the species characteristics that contain resins and tyloses on its pores that aggravate spreading and penetration.

Table 1. Mean water contact angles (degree) for Meranti, Kapur, Merbau and Tualang at different time intervals.

Time	Mean contact angles (deggee)			
(s)	***Meranti***	Kapur	***Merbau***	***Tualang***
0	104.0 (2.4)	97.5 (2.4)	60.0 (1.9)	53.0 (1.1)
2	91.8 (1.8)	69.8 (2.5)	44.4 (1.6)	42.8 (0.8)
10	84.8 (2.3)	59.6 (2.6)	34.0 (1.6)	36.8 (1.0)
20	81.1 (1.9)	55.0 (3.0)	27.3 (1.3)	34.4 (0.7)
30	78.9 (1.9)	49.8 (2.2)	24.7 (1.2)	31.0 (0.7)
60	75.2 (1.5)	49.6 (2.5)	19.7 (1.2)	29.5 (0.6)
120	72.1 (1.8)	49.6 (2.2)	15.1 (1.0)	26.5 (0.6)
180	69.7 (1.6)	44.9 (2.2)	-	24.0 (0.8)

* Values in parenthesis are standard deviations.

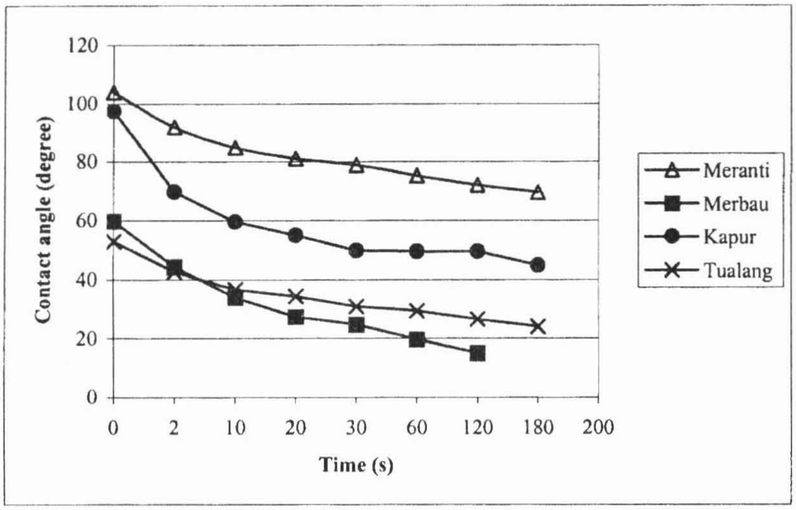
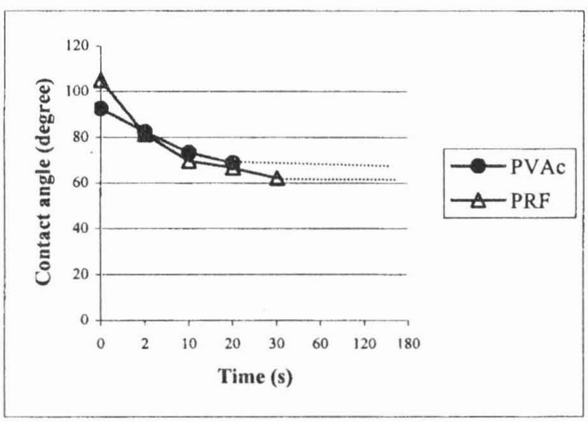


Figure 2. Water contact angle vs. time for Meranti, Kapur, Merbau and Tualang.

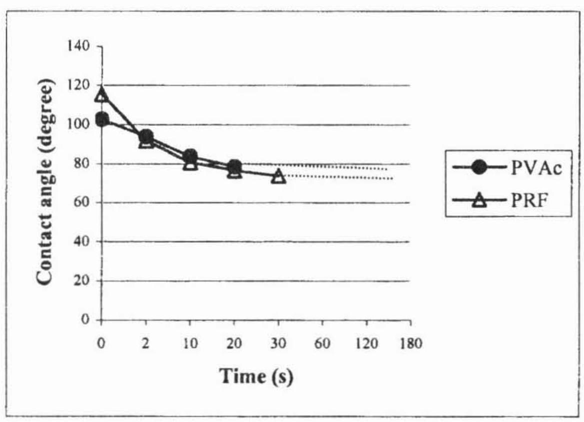
Adhesive contact angle for individual species

From figure 3, it reveals that PRF contact angles for all wood species evaluated at 0 second were higher than PVAc. However, the decrease in contact angle for PRF adhesive was more drastic compared to PVAc during the first 2 seconds and it attains equilibrium faster than PVAc adhesive. The decrease for both adhesives were later found to be more gradually until it reached equilibrium.

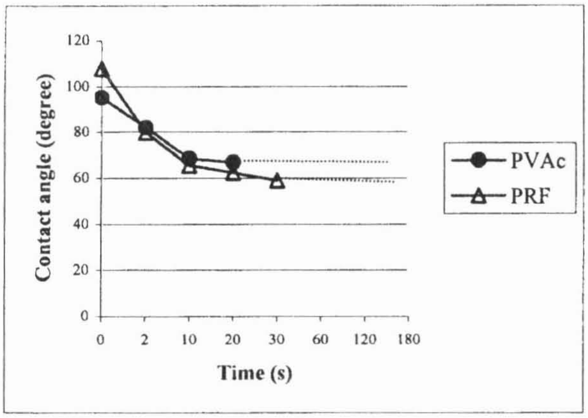
From this experiment, it could be said that PVAc had greater instantaneous wettability than PRF. The rate of spreading and penetration of PVAC however, was slightly slower than PRF. PRF adhesive apparently had lower instantaneous wettability than PVAc, but spreads and penetrates faster than PVAc. This trend was practically true for all wood species evaluated. This results nevertheless, does not suggest that PVAc or PRF is better than one another or would produced stronger glue-bond properties. On the contrary, in gluing many other factors are to be considered to obtain good glue-bonding strength, which includes pressing pressure, pressing time, temperatures, as well as the wood characteristics itself.



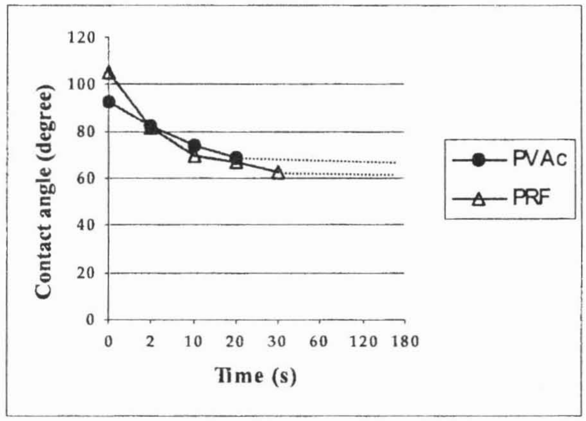
Meranti wood



Kapur wood



Merbau wood



Tualang wood

Figure 3. Contact angle changes as a function of time for Meranti, Kapur, Merbau and Tualang wood surfaces with PVAc and PRF adhesives.

Relationship between instantaneous and equilibrium contact angles

The instantaneous and equilibrium contact angles of PRF and PVAc adhesives on Meranti, Kapur, Merbau and Tualang is tabulated in table 2. The percentage of decrease from instantaneous to equilibrium contact angles for all wood species tested was also given in the table.

From table 2, it is observed that PVAc had smaller percent decrease in contact angle from instantaneous to equilibrium for all wood species (16.7% - 30.4% vs. 35.9% - 45.5%). This trend is another indication that PVAc exhibits poorer spreading and penetration behaviors than PRF adhesives. Therefore, it can be held that PRF exhibits better wettability than PVAc and should form more intimate contact with the wood surface regardless of the four species evaluated. However, it should be noted that this result could not be practically applicable to all other wood species. This is because different woods have different characteristics and hence, it affects the wettability of wood.

Table 2. Instantaneous and equilibrium contact angles for Meranti, Kapur, Merbau and Tualang with PVAc and
PRF adhesives.

Wood Species	Adhesives	Contact angles (degree)		Percentage decrease
		θ_i	θ_e	
Meranti	PVAc	104.5	87.0	16.7
	PRF	119.6	65.2	45.5
Kapur	PVAc	102.6	78.6	23.4
	PRF	115.4	74.0	35.9
Merbau	PVAc	95.3	66.9	30.4
	PRF	107.9	59.0	45.3
Tualang	PVAc	92.5	69.0	25.4
	PRF	105.0	62.2	40.8

θ_i : instantaneous contact angle
θ_e : equilibrium contact angle

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