METAL CORROSION IN WATERBORNE PRESERVATIVE-TREATED WOOD

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ABSTRACT

The rigidity and firmness of wooden construction and furniture those are joined by metal screws depend on corrosion rate of these metals. This paper examines the weight-loss percentage of metal screws used in wood samples that have been treated with water-borne preservative (i.e. 3% borax boric acid and 3% diffusol CB) and concurrently investigates the effect of brake fluid on preventing metal corrosion. Wood samples tested included three acacia and one eucalypts wood species which were grouped into sapwood and heartwood containing samples. Wood samples fastened with metal screws were freely suspended in glass jars that contained 25 ml of sulphuric acid (H_2SO_4) to keep the humidity rate above 90%. After 12 months, the metal screws lost their weight due to the corrosion brought about by the related factors either in separate individual or in combination, which comprised brake and fluid-dipping, wood species, wood portion (sapwood and heartwood), kinds of preservatives used. Corrosion rates of metal screws fastened in eucalypts wood sample as indicated by the screw-weight loss (i.e. 5.8%) was more severe than that fastened in acacia wood. Furthermore, corrosion rate of metal screws as fixed firmly in sapwood sample proceeded faster than that in heartwood. This might be caused by the higher moisture content in sapwood. On the other hand, corrosion rate of the screws as fastened in waterborne-preservative-treated wood samples was greater than that in non-preserved wood due to electrokinetic characteristics and ionic potential exhibited by the preservative thereby intensifying the screw-corrosion process. Meanwhile, less severe corrosion was observed and recorded on the screws pre-dipped in brake fluid compared to those on the non-dipped screws.

Keywords: corrosion, wood species, preservation, brake-fluid dipping

I. INTRODUCTION

In timber construction and wooden furniture manufacturing, metal materials, such as screws and nails, are frequently used as joint components. The use of metal components often creates problems due to the corrosion, as the corroded metals become lost in strength and easily break when used in joinery. Metal corrosion is an electrochemical process that occurs when metal is exposed to moist and acid condition. The rigidity and firmness of wooden construction and furniture that are joined by metal screws depend on the corrosion process of the metal material in the wood itself (Baker, 1987; Aytekin, 2008).

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Factors that may enhance metal corrosion in wood include wood species, presence of external corrosive contaminants, and preservative treatment of wood (Baker, 1987: 1992). Wood species may bring about metal corrosion rates as chemical content in wood creates acidity and humid environment for metal screws. Most wood species are slightly acidic, with a pH of 4 to 6, while some other wood species contain greater organic acid which causes the lowering of pH.

One of the external contaminants that may induce corrosion rate is water condensation that happens when timber construction is used in humid conditions. For example, excessive steam condensed in the wooden roof that covers steam chamber. The condensed steam will release heat, which further warms up the moist air inside the structure of wooden materials together also with their metal joineries thereby catalysing the metal-corrosion rate (Baker, 1987).

In general, the effect of preservative treated wood in corrosion rates varies accordingly. Wood that has been treated with oil-based preservatives suffers less corrosion than that with water-borne preservatives (Baker, 1992). Heavy-oil-based wood preservatives do not only preserve the wood but also coat the surface of the metal fasteners, which consequently reduce the corrosion rates. On the other hand, water-borne preservatives which mainly contain metal elements, particularly copper enhance the electrochemical process of metal corrosion because copper ions that penetrate the wood cells and then become saturated inside inflict differential potential of electronegative ion inside the fasteners (Baker, 1987).

The relationship between metal corrosion rate and the use of preservative wood has been studied by several researchers. Baechler (1934) studied the corrosion of wire nails in wood treated with zinc-chloride and exposed to moderately humid conditions in Madison. He stated that the corrosion of wire nails in zinc-chloride treated wood was significant, and some efforts to protect the wood, such as painting and sodium chlorate addition were ineffective to reduce the corrosion rates.

Extensive study was carried out in 1973 to obtain some information on the corrosion rates of various metals and metal coatings in wood treated with water-borne preservatives. In preliminary research, Kadir and Barly (1974) noted that metal corrosion in wood treated with water-based preservative was tolerable. However, such experiments were carried out with limited number of samples of softwood species, i.e. tusam (*Pinus merkusii* Jungh et de Vr.). Meanwhile, the information on metal corrosion of hardwood species especially fast growing species had not been identified.

Traditionally, brake fluid was used by carpenter to slow down corrosion rate. Brake fluid is a typical hydraulic fluid used in hydraulic brake system in motorcycles and automobiles. Brake fluids refer to hygroscopic glycol-ether-based solutions that are able to absorb moisture and therefore reduce the corrosion rate. The use of brake fluid for metal screw before being used for wood joinery has not been studied extensively. As the relevance, this paper examines corrosion rates of metal screws that were used in wood samples treated with the so-called borax boric acid and diffusol copper boron (CB). Wood species studied included three acacia wood species and one eucalypts species classified as fast growing species. The samples were grouped into sapwood and heartwood-containing samples. To look into the effectiveness of brake fluid in preventing metal corrosion, some screws were dipped into the brake fluid prior to the test.

II. MATERIALS AND METHODS

The hardwood species studied included acacia 01 (*Acacia crassicarpa* A.Cunn.), acacia 02 (*Acacia auriculiformis* A.Cunn.), acacia 03 (*Acacia aulacocarpa* A.Cunn.) and pellita 04 (*Eucalyptus pellita* F.Muell.) that were taken from plantation forest in Riau, Indonesia. The wood samples were cut and divided into sapwood and heartwood containing samples to the size measuring 50 mm x 25 mm x 15 mm. Air dried wood samples were selected accordingly so that the grain direction was tangentially angled to the 50-mm face. For the experiment with water-borne preservative, ten blocks were treated using 3% borax boric acid and 3% of diffusol CB each. Air dried wood samples were initially pre-vacuumed for 30 minutes and then compressed for 30 minutes.

Prior to the insertion into the treated and untreated wood samples, stainless steel screws of 5/8 inch NASA, made in China were cleaned and allowed to dry before being weighed. Each screw was then fastened into a separate piece of wood to prevent cross contamination between metal screws. To see the effect of brake liquid in preventing metal corrosion, steel screws were pre-dipped into Preston Dot-3 brake fluid.

To keep the humidity above 90%, the samples with the metal screws inside were then tested according to those explained by G. Schikorr (Broese van Groenou *et al.,* 1951) then modified by Kadir and Barly (1974). Wooden samples were freely hanged with nylon string in the glass jars that contained 25 ml of 2N-sulphuric acid (H_2SO_4) solutions and further left for 12 months (Figure 1).

After 12 months, metal screws were then removed in such a way to minimize damage to the metal screws, and then soaked into HCl solution to clean them up from the excess of corrosion. Before weighing, the screws were cleaned using ethanol and acetone. The metal corrosion rates were examined based on the percentage of weight loss in metal screw during the corrosion test.

Factorial analysis of variance was tested using a statistical software SPSS version 17.0, based on four factors: brake fluid (B), wood portion (P), wood species (S) and preservative treatment (T). Interaction effect between factors have also been analysed to see the combination effect of the predictor values on response variables.

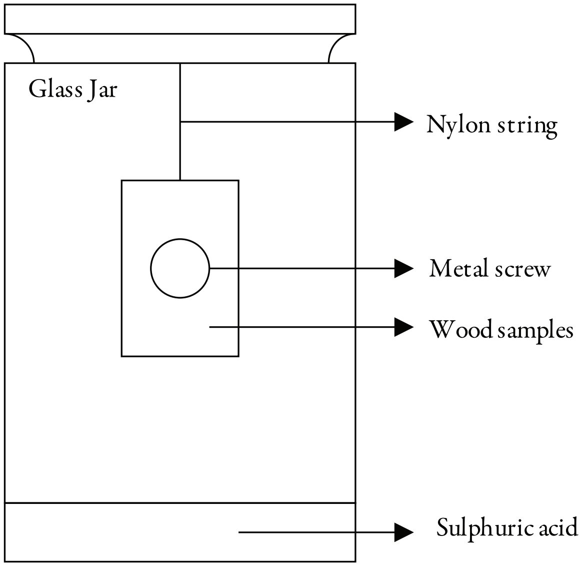

Figure 1. Glass jar containing screwed wood samples

III. RESULTS AND DISCUSSIONS

The percentages of weight loss in metal screw during the test were shown in Figures 2 and 3. Figure 2 shows the percentage of weight loss of metal screws that were not treated with brake fluid, while Figure 3 presents the corresponding value for metal screw dipped in brake fluid before the corrosion test.

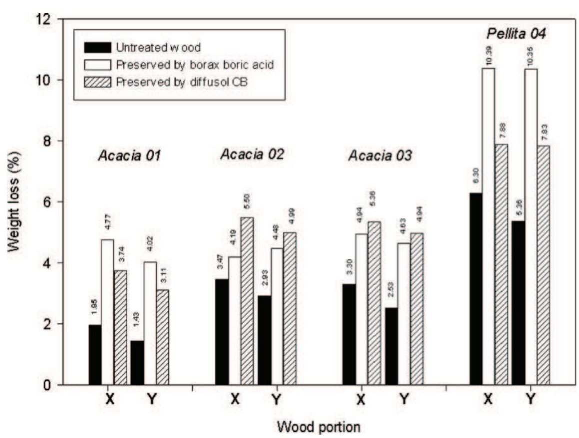

Figure 2. Weight loss (%) of non-dipped metal screw after corrosion test
Remarks: X = sapwood, Y = heartwood

It turns out that percentage of weight loss varies with wood species, different wood portions and kinds of preservatives (Figure 2). The highest percentage of weight loss occurred to metal screws that had been fastened in pellita 04 wood samples, which recorded a weight loss of 10.4%. Meanwhile, the metal fastened in acacia wood samples (01, 02 and 03) lost only 1.6 to 5.5% of their weight. This implies that the corrosion rate is greater in pellita wood than that in acacia wood samples. The higher corrosion rate in eucalypts (pellita 04) wood was presumably caused by more acidic condition in pellita wood samples. Krisdianto *et al.* (2006) reported that the percentages of hemicellulose and lignin in pellita wood are slightly higher than that in acacia wood sample; as a result, the more acetyl groups in pellita wood created lower pH condition than those in acacia wood samples.

Figure 2 also shows that the percentage of weight loss of metal screws that were turned inwards the heartwood is less than those in sapwood samples. In other words, metal screws fastened in sapwood suffered corrosion more severely than those in heartwood. Compared to heartwood, sapwood contains more alive wood cells (e.g. parenchyma cells) that function as water and nutrient transport, food reserves, and other physiological activities (Butterfield, 1993), thereby providing more moisture content inside which further creates more humid condition and hence enhances corrosion rate.

The use of water-borne preservatives being borax boric acid and diffusol CB on wood samples significantly increases the percentage of weight loss of the screw. Analysis of variance (Table 1) shows that the weight-loss percentage of metal screws fastened in preserved wood samples is higher than that in unpreserved wood samples. In the preserved wood samples, the deposit of copper ions as by-product of salt preservative increased electrical conductance of screws, thereby significantly intensifying their corrosion rate.

Humidity in wood samples as mentioned before leads to higher corrosion rates of the screws. For a single screw in moist wood samples, corrosion can be explained in terms of crevice corrosion (Baker, 1987). When screwed in the moist wood samples, the head of the screw becomes cathode, while the shank (tapering end) on the crevice wood serves as the anode. During the test, hydroxides of iron precipitated around the anode and left an excess of hydrogen ions in the water phase and decreased the pH nearby. The formation of hydroxyl ions in the cathode caused alkaline condition. Metal ions and acidic condition formed in the anode together with alkaline conditions formed in the cathode in a single screw generate differential electrokinetic potential, thereby arousing chemical reactions that led to higher metal corrosion rates (Baker, 1987).

Table 1. Analysis of variance on the weight loss of metal screws fastened in the preserved wood

Source	Degrees of freedom	Mean square	F calculation	Significance
Brakefluid (B)	1	336.469	270.478	0.000*
Wood portion (P)	1	10.214	8.210	0.005*
Wood species (S)	3	48.462	38.957	0.000*
Treatment (T)	2	65.047	52.289	0.000*
Interactions :				
B x P	1	0.002	0.002	0.968
B x S	3	114.579	92.107	0.000*
P x S	3	0.310	0.250	0.862
B x P x S	3	0.505	0.406	0.749
B x T	2	19.282	15.500	0.000*
P x T	2	0.415	0.333	0.717
B x P x T	2	0.660	0.531	0.589
S x T	6	3.521	2.831	0.012*
B x S x T	6	6.762	5.436	0.000*
P x S x T	6	0.441	0.355	0.907
B x P x S x T	6	0.165	0.132	0.992
Error	192	1.244		
Total	240			

Remarks * = significance at 5% level

Weight losses of metal screw that have been dipped into the brake fluid are shown in Figure 3.

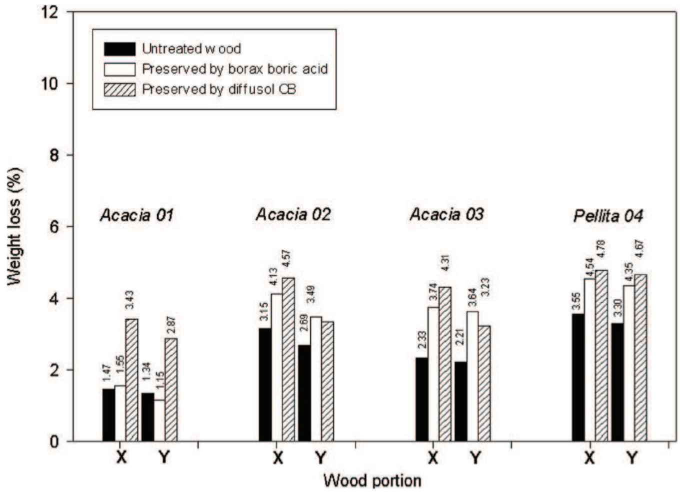

Figure 3. Weight loss (%) of metal screws pre-dipped in brake fluid
Remarks: X = sapwood, Y = heartwood

In general, the percentage of weight loss occurred in metal screws which were pre-dipped into the brake fluid (Figure 3) was 24 – 43% less than that of the non-dipped screws (Figure 2). The percentage of weight loss of pre-dipped metal screws in average is 1.9% for acacia-01, 3.6% for acacia-02, 3.2% for acacia-03 and 4.2% in pellita-04. Based on the wood treatment, the weight loss is 2.5% in untreated wood, 3.3% in borax boric-acid-treated wood and 3.9% in diffusol-CB-treated wood (Figure 3). Meanwhile, the corresponding weight loss for the non-dipped metal screws were consecutively 3.4%, 5.9%, and 5.4% in untreated wood, borax boric-acid and diffusol CB wood treated samples (Figure 2). Analysis of variance in Table 1 shows significant differences at 5% level in the weight losses of the metal screw, between the non-dipping and the brake-fluid dipped screws.

Weight-loss patterns of pre-dipped metal screw (Figure 3) were similar to those of non-dipped metal screw weight loss (Figure 2). In general, the corrosion rates of metal screw fastened in pellita 04 wood were 34 – 46% higher than those in acacia wood samples. Further, the corrosion rates of metal screws in sapwood were 12 – 28% higher in average than those in heartwood. Still related, the corrosion rates of metal screws fastened in preservative treated wood samples were higher than those non-preserved wood samples (Figures 2 and 3).

Analysis of variance (Table 1) also shows the significant difference at 5% level in the weight loss of metal screws that occurred due to non-dipped and brake-fluid-dipped screws (B); different wood portions, i.e. sapwood and heartwood (P); different wood species, i.e. acacia 01-02-03 and pellita 04 (S); and different kinds of preservatives, i.e.

untreated, borax boric-acid and diffusol CB (T). Less severe corrosion occurred in metal screws pre-dipped in brake fluid. The brake fluid which is inherently glycol ether based oil, protected metal screws from corrosion by blocking moisture from wood samples to contact the screw surface. However, excessive brake fluid created oil marks in the area surrounding the metal screw (Figure 4).

Analysis of variance on the weight loss of metal screws (Table 1) also reveals that significant effect at 5% level was inflicted not only by individual factors, i.e. brake-fluid treatment (B), wood species (S), wood portion (P) and kinds of preservatives as used (T), but also by interaction between two as well as three of those four factors (B, S, P, and T), i.e. B x S, B x T, S x T, and P x S x T. Those significant interaction effects implied that the effect of each of those four factors separately might behave differently from those in combination; and these occurring phenomena are essential and should be taken into thorough consideration.

A B

Figure 4. Non-break-fluid-dipped metal screw (A) and oil marks of break-fluid-dipped metal screw in the surrounding area (B)

IV. CONCLUSION

Metal screws that were inserted into eucalypts (pellita 04) wood samples suffered more severe metal corrosion than those into acacias wood samples. Weight loss of metal screws in pellita wood samples reached 5.8%, while the corresponding loss for the screw in acacia wood samples (01, 02 and 03) were only 1.4 to 3.5%.

The weight loss of metal screws that were pre-dipped in brake fluid was 43 – 24% less than those not pre-dipped. This means that less severe metal corrosion occurred in metal screws pre-dipped in brake fluid.

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