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FUNCTIONAL FILLERS FOR BLOCKING WOOD STAINS

A combined approach proves highly effective. By Dr. Maria Parry and Klaus Freund, Gebrüder Dorfner.

Most wood tannins are water-soluble and therefore a major cause of discolouration in water-borne white or light-coloured topcoats. Various technologies are employed to suppress them, but each has its drawbacks. This article shows how a combination of different technologies within a product is highly effective at blocking stains

For thousands of years, wood has been one of the most invaluable materials to humans. It is readily available in nature, and occurs in every geographical zone as a renewable, sustainable, instant raw material. Wood has the most balanced set of characteristics of all natural materials. It offers high compressive strength whilst remaining elastic, a low weight-to-strength ratio and high aesthetics, and is easy to process and recycle. Hence, it is a material that is used not only for furniture, paper, and musical instruments but is also ideal for construction purposes. Indeed, islands that are now bare of trees were stripped of their wood for construction purposes in the past.

Wood's performance properties and aesthetics can be protected and enhanced with coatings and finishes. However, certain factors need to be considered when these are being designed. One task which such coatings are often expected to fulfil is the prevention of discolouration caused by wood components. To understand this discolouration phenomenon and explain the correlations, it is necessary to review the composition of wood.

The various species of wood exhibit minor differences in the chemical structure of the three major cell-wall components, namely cellulose, hemicellulose and lignin. By contrast, the secondary metabolites of wood species, known as extractives, are extremely diverse. In temperate zones, the concentration of extractives in wood is commonly no more than five to ten percent. However, for tropical woods, it can be as much as 20 percent. Even though this concentration is low compared with those of the cell-wall polymers, it is sufficient to permit each wood species to be chemically identified. The quantities and composition of extractives depend heavily on factors such as type of wood, habitat (forest type, climate, etc), season and age of the tree. Furthermore, extractives exhibit properties which are characteristic of their function within the wood. For example, they mainly contribute to wood colour, odour and natural durability.

Tannins, one of these components, are phenolic compounds that have a high molecular weight in the range 500 to 3000 and beyond. Chemically, they are glucose esters of gallic or ellagic acid that are hydrolysable. Tannins occur naturally in plant and wood materials, especially in bark, heartwood, roots, branch bases and wound tissue of woods such as oak, redwood, cedar, jarrah, meranti, mahogany, and

RESULTS AT A GLANCE

→ Water-soluble extractives in wood can cause coatings to fail prematurely.

→ To prevent undesirable staining of wood coatings, the extractives need to be inhibited with suitable stain-blocking systems.

→ The functional filler material presented in this paper offers a combination of barrier and adsorption functionality that outperforms a combination of conventional filler materials and additives.

→ Further benefits are simple addition, good compatibility and ease of handling.

merbau. They have been linked to plant defence mechanisms against mammalian herbivores and insects [4].

Most tannins are water-soluble extractives, which is precisely the dominant issue for water-borne white or light-coloured coatings. When a water-borne coating is applied to a wood substrate, the water causes the tannins to be released. During drying and as moisture evaporates, mostly reddish-brown tannins, as well as other water-soluble components in the wood, migrate into the coating where they cause permanent staining. This migration can recur upon each subsequent coating step, whereby the intensity of staining decreases with every applied coat. The effects of delayed tannin migration may appear when a dried, coated wood substrate is exposed to moisture, for instance heavy dew, rain, cleaning water, or condensation. The moisture penetrating into the coating system solubilises the encapsulated tannins and so they leach from within the wood into the coating film, where they cause unsightly stains. However, it is not just the solubility properties of tannin compounds which are responsible for the discolouration and staining of wood. Further aspects such as time, pressure, temperature, humidity and other environmental factors play a role as well.

In softwoods such as pine, larch and Douglas Fir, the wood components are commonly exuded from the knothole area and these woods also have a greater quantity of resin pockets that should be removed prior to coating. In highly porous woods and in most hard and tropical woods, especially oak, merbau and framire, the components are increasingly exuded from the pores, causing permanent staining and extensive discolouration. However, this is only a generalised distinction. There are often exceptions, such as Western Red Cedar, a softwood that gives rise to rather large, reddish discolouration.

Discolouration of white topcoats is a major commercial problem. In order that the various challenges just described may be overcome, water-borne coatings need to be properly equipped to block the

Figure 1: Pine, larch, merbau (from left to right).

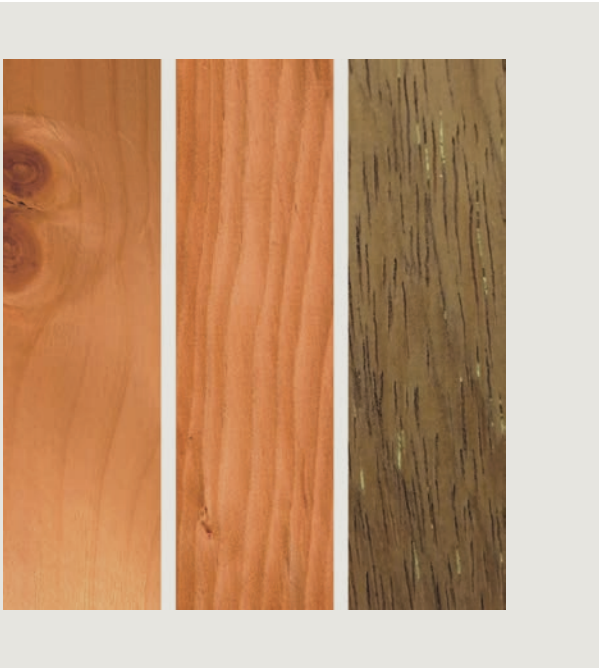


Figure 2: Lock-and-key mechanism of WSP.

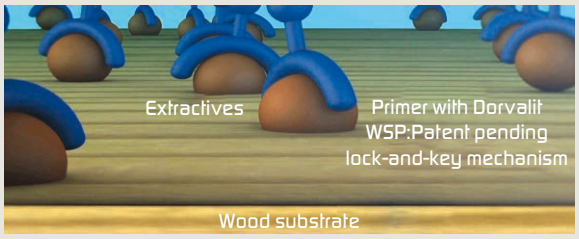
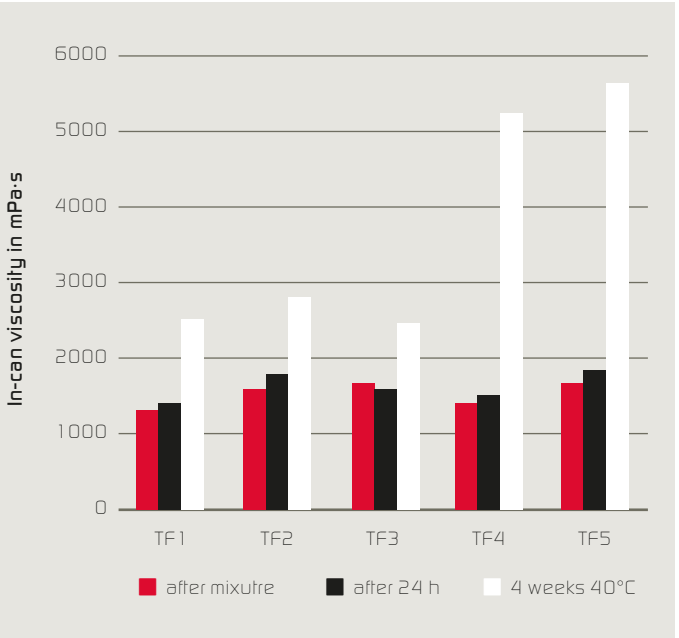


Figure 3: Comparison of in-can viscosity after production, 24 hours, and 4 weeks at 40 °C.



staining components. Several technologies exist, such as those presented below.

Zinc derivatives: Zinc oxide or zinc phosphates are often used for blocking wood extractives. However, these compounds are classified as hazardous to water. Products containing them at loading levels greater than 1 % are therefore subject to mandatory labelling. They are often incompatible with other ingredients in the coating and this can raise the viscosity and shorten the shelf life.

Additives: Liquid additives based on zirconium / aluminium composites react with the migrating wood components to yield complex compounds. A formulation containing these additives may experience incompatibility with other coating ingredients and lead to a viscosity rise during storage.

Cationic binders: By virtue of their chemical properties, cationic binders are highly effective at blocking wood extractives. However, the downside is that they must not be combined with anionic compounds, as that would induce coagulation of the polymers. Consequently, separate production lines and equipment are required for cationic-based formulations. Often, it is not possible to utilise some additive products in the formulations.

Filler materials: Platelet-shaped filler materials are particularly good at supporting the functionality of stain-blocking primers. The fillers lengthen the migration routes while simultaneously forming a barrier layer. This effect can be enhanced by packing the filler materials as densely as possible using appropriate filler combinations of different grain size and shape. However, this protection is only effective for a limited period of time. Furthermore, formulating with these raw filler materials is both complex and challenging. Not only does stain-blocking functionality need to be provided, but it is important not to neglect application properties, processability, and adhesion characteristics as well.

Table 1: Comparison of formulations

Item	Raw Material	TF1	TF2	TF3	TF4	TF5
1	Water	24.9	24.9	24.9	24.9	24.9
Admix items 2-8 separately						
2	PUR thickening agent	0.3	0.3	0.3	0.3	0.3
3	Webbing & dispersion aids	0.4	0.4	0.4	0.4	0.4
4	Anti-foaming agent	0.1	0.1	0.1	0.1	0.1
5	TiO_2	12.5	12.5	12.5	12.5	12.5
6	Calcium carbonate	15	-	-	15	-
7	Kaolin	-	15	-	-	-
8	"Dorvalit WSP"	-	-	15	-	15
Disperse for 15 minutes						
Admix items 9-14 separately						
9	In-can conservative	0.2	0.2	0.2	0.2	0.2
10	Anti-foaming agent	0.2	0.2	0.2	0.2	0.2
11	2-Amini-2-methyl-1-propanol	0.2	0.2	0.2	0.2	0.2
12	HASE thickening agent	1.2	1.2	1.2	1.2	1,2
13	Acrylate dispersion	45.0	45.0	45.0	45.0	45.0
14	Stain blocking additive	-	-	-	2	3
Stir for 10 minutes						
Sum		100	100	100	102	103

Figure 4: Standard formulation on a primed sample of merbau (primer and commercial topcoat with a uniform coating thickness of 200 µm).

TF1 TF4 + 2 % additive TF3

THEORY: REDUCE COMPLEXITY BY COMBINING DIFFERENT MECHANISMS

By combining different active mechanisms within a product, it is possible to reduce the complexity of the formulation and therefore the number of potential sources of defects.

The approach adopted by Dorfner in its wood-stain protection (WSP) technology is to combine the barrier function and dispersing properties of a platelet-shaped filler with an effective, permanent adsorbend layer around the filler. The dispersion of a the solid filler material provides a highly uniform distribution, and also a firm adhesion within the coating film, where the adsorption layer is well distributed and unable to migrate. The barrier function inhibits migration of wood components while the adsorbent layer binds to the substances responsible for staining in the manner of a lock and key (*Figure 1*). Here, the crucial factors are the choice of filler that will carry the adsorbend material (appropriate particle size and aspect ratio) and of suitable treatment media to create the adsorbend layer around the filler material.

TEST CRITERIA AND EXPERIMENTAL PROCEDURE

The product that emerged from initial screening was tested according to the following criteria:

› Incorporation into water-borne coating systems
› Impact on the shelf life of the coating material
› Blocking properties towards the wood components

The incorporation properties were assessed by adding the functional (treated kaolin) filler material to a water-borne wood primer (TF3). For comparison, the same formulation was created first with a conventional calcium carbonate (TF1, *Table 1*) and then with an untreated kaolin (TF2, *Table 1*). The fillers were added in the same order to the slurry, which was then dispersed with an agitator for 15 min at 3000 rpm. The formulations were then examined for any agglomerates or other abnormalities but no abnormalities were found. Repeat examination after finalisation with the remaining ingredients verified these results. Additionally, two formulations with the untreated filler materials were created (TF4 & TF5, *Table 1*) To each of these two formulations, 2 % of a stain-blocking additive was added. The shelf life of the

resulting coatings was then tested by measuring their viscosity immediately after production, after 24 hours, and after 4 weeks at 40 °C (*Figure 3*). The viscosity was determined by means of a Brookfield R/S and a C-50 plate at 10 rpm.

The results show that at 40 °C the viscosity increases over time. The fact that the increase was equal across TF1, TF2 and TF3 indicates that no deterioration in storage stability occurred that could be attributed to the treated filler material. The viscosity values for the formulations containing the stain-blocking additive more than doubled. This was confirmed by the same tests on other binders.

The stain-blocking properties were assessed by applying the coatings to wood substrates, namely merbau, larch and pine (*Figure 1*). For best comparison, the different coatings were applied side by side to a single piece of wood. After drying for a week at 23 °C and 50 % rel. humidity, the specimens were weathered in an accelerated-weathering apparatus for 150 hours. This revealed that the product had highly effective stain-blocking properties, a fact which was confirmed by tests on other additives.

These tests were conducted on commercial stain-blocking primers for industrial wood coatings as well as multiprimers available in hardware stores. WSP was admixed by means of a high-speed mixer to formulations containing these products. All coatings were tested on merbau substrates (*Figure 4*) and showed a significant increase in stain-blocking properties. The addition of other filler materials did not bring about the same level of improvement, and so this effect cannot be attributed to the higher filler content.

A MATCH FOR SOLVENT-BORNE COATINGS

Staining of white and light-coloured coatings is a major commercial issue and has triggered considerable research activity. A major challenge for any stain-blocking wood coatings is how to formulate them without solvents. Solvent-borne coatings have a significant advantage over water-borne systems. However, we have shown that the technology featured in this article and a combined approach can boost the performance of water-borne coatings to match their solvent-borne counterparts.

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"In comparison to competitive technologies we have achieved very good results."

3 questions for Klaus Freund

Can you explain a bit more detailed what kind of adsorbend layer you are using for your fillers? *The adsorbing layer was selected based on four main criteria: good adhesion on the filler chosen as a carrier, blocking effect on staining wood extractives and compatibility to water based lacquers. In addition the final product had to be mandatory labeling free. We are using Kaolin as a carrier to prevent migration of the adsorbent to the boundary layer. The barrier effect has an additional positive impact. The final solution was patented.*

Can you say something about the stain blocking performance on other wood substrates than merbau? *To show the efficiency of Dorvalit WSP we chose Merbau because of high percentage of extractive substances in the wood. Beside Merbau we included several types of wood, like oak, pine and larch in our experimental run. Even in comparison to competitive technologies we have achieved very good results. Staining wood ingredients, in this case tannins have one thing in common: in order to fulfill their function in the plant they need to be water-soluble. Due to the different types of wood, the quantity and solubility of the extractive ingredients vary, and therefore the required input of our new product.*

Figure 4 only shows the comparison of the WSP technology to the calcium carbonate samples. What was the performance in comparison to the samples that used Kaolin fillers? *In a comprehensive test series we proved the basic performance of the minerals related to the stain blocking properties. The stain blocking efficiency of all tested minerals is insufficient related to tannins. This proves the necessity to apply functionality on the carrier material.*