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THE COMPARISON OF THE COATING SYSTEMS ACCORDING TO THE BASIS CRITERIA

Leon Oblak, Borut Kričej, Igor Lipušček
University of Ljubljana, Biotechnical Faculty,
Department of Wood Science and Technology, Slovenia

ABSTRACT

The quality of the surface system depends on the suitable choice of the groundwork and the coating system or lining. What needs to be considered is that the properties of the surface system are not a sum or an average of the groundwork and the coating system or lining. The surface system needs to be thoroughly analysed if its physical, mechanical and chemical properties are to be established. Assessment and evaluation of surface systems is a demanding task in itself, but it can be performed successfully by means of suitable methods for determining the surface systems properties. One of such methods, enabling us to choose from among many options the one which best fits the set aims or demands is the method of the multi-criteria decision-making.

KEY WORDS: coating system properties, basis criteria, polyurethane coating systems, selection, comparison

INTRODUCTION

The surface of timber industry products usually consists of the base (wood and wood based panels) and the coating system (one or more layers of the same or different coating) or the base and the panel (synthetic resin foil or synthetic resin laminate), which altogether form the surface system.

We expect the surface system to have suitable aesthetic properties and certain resistance properties according to the purpose of use. What is important is the time preservation of these properties, which thereby ensures the expected durability of the surface system. High compatibility of the base with the coating system and the panel is crucial in this and vice versa. The quality and the value of the product are a great deal dependent on the quality and durability of the surface system.

The physical, mechanical and chemical properties of the base, the coating system and the panel are determined by classical methods, but we are unfamiliar with the properties of the individual coating systems, which can be produced. A different authors (Jaić et al. 1996, Logar 2005, Pavlič et al. 2003) have given a lot of thought with this problem.

This way we often find products made of quality base with a quality coating system or a quality panel, which on the other hand does not fulfil the expected properties. The properties of a surface system are not a sum or an average of the properties of its structural parts, but rather the characteristics of a new compound made up of the enumerated parts according to some technological process. Therefore, the data about the properties of the structural parts only allows us to infer and expect the produced surface system to have similar properties as the base parts, which is not always necessarily true. The number of the available structural parts, the possible combinations among the parts of the surface system, the technological procedures and possible deviations in one technological procedure alone can quite realistically increase the level of insecurity of the expected quality of the produced surface system.

Every product is designed and made for a known purpose of use and for a predictable burdening. This is where some generally established expectations and demands on behalf of the quality of the surface system of a product derive from. Generally speaking, we can talk about mechanical-physical and resistance properties of a certain product's surface system, which the product is supposed to have for it to serve its purpose for the anticipated period of time and to fulfil the users' expectations (Pavlič et al. 2003).

With products intended for use in the interior, all being exposed to more or less predictable burdening, especially the following mechanical-physical and durability properties are important (Pavlič et al. 2004):

- elasticity of the coating system and the panel;
- adherence of the coating system and the panel to the base;
- resistance of the surface system to scratching;
- resistance of the surface system to blows;
- resistance of the surface system to heat;
- resistance of the surface system to liquids (water, alcohol, acetone, oil, etc.) and
- impact of time to the changes of these properties (aging).

Being familiar with the enumerated properties for a certain surface system enables us to evaluate the quality of this surface system and offers the groundwork for comparison with other systems.

MATERIAL AND METHODS

Materials

Our base was a wood chip panel veneered with beech plywood, our alternatives being polyurethane (PU) coating systems, which we marked with the numbers from 1 to 6.

Methods for Determining Surface Coating Systems Properties

Six coating systems were taken for evaluation and choice with the multi-criteria decision-making model and they were measured and evaluated for the following:

- adhesion to the base;
- resistance of the coating system to scratching – the hardness of the system;
- resistance of the coating system to blows;
- resistance of the coating system to heat and
- resistance of the coating system to liquids (water, alcohol, acetone and oil).

Measuring Adhesion With the Pull-Off Method (SIST EN ISO 4624)

Stamps (the stamp being 1 cm^2 big) glued onto the surface of the surface system are pulled off on the pull-off machine and we measure the pressure (in MPa) needed for separating the coating system and the panel from the base. In case of stratification of the base or the coating system i.e. panel (the cohesive hardness of the base, the coating system or the panel), the adhesion of the coating system or the panel to the base is bigger than these values and therefore unknown. This method for measuring adhesion is quite simplified. More precision methods are described in literature (Liptakova and Kudela 2002, Xie and Hawthorne 2003, Podgorski et al. 2004, Podgornik 2004).

Measuring the Hardness with the Test of Scratching (SIST EN ISO 1528)

The surface of the surface system is loaded in lines with the nib of a half-round shape 1 mm in diameter with a constant pressure to the nib (from 1 N to 20 N) for at least 60 mm in length and the speed from 30 mm/s to 40 mm/s. The result of such burdening is a plastic deformation in the shape of a seen trace (print of the nib) or a scratch (unbalancing the coating system or the panel). The measure for the hardness or resistance of the coating system to scratching is the width of the print measured in tenths of a millimetre at the chosen pressure to the nib or the amount of pressure to the nib, by which the nib scratches the coating system or the panel.

Evaluating Resistance to Blows (SIST ISO 4211-4)

Onto a steel ball 14 mm in diameter, lying on the surface of the surface system, we freely drop a weight of 500 g with standardised heights (10 mm, 25mm, 50 mm, 100 mm, 200 mm and 400 mm). We observe the spot of such a drop on the surface system and according to the shape of the resulting deformation we estimate its resistance to blows with the mark from 1 to 5, mark 5 meaning no changes appearing in the point of impact and the surface system being resistant to blows, and mark 1 meaning a hole in the point of impact and a number of cracks and/or peal-offs of the coating system or the panel on the inside or the outside of the hole, which is a sign that the surface system is completely useless and non-resistant to blows.

Evaluating Resistance to Dry Heat (SIST EN 12722)

A standardised body is heated to a chosen temperature and placed for a period of 20 minutes onto the surface of the surface system. After the unburdening, we observe the consequences of the heat effect and evaluate resistance of the surface system to dry heat with the marks from 1 to 5. The resistance mark 5 means no changes in the exposed place therefore the surface system being resistant to heat, and resistance mark 1 means a bigger damage with visible changes in colour and structure of the coating system, the panel or the surface system is seen in the point of impact due to heat, meaning the surface system is non-resistant to the chosen temperature.

Evaluating Resistance to Cold Liquids (SIST EN 12720)

We burden the surface of the surface system with the standardised and agreed cold liquids ($T = 23\ ^{\circ}C \pm 3\ ^{\circ}C$) and the standardised agents (tampons, covering goblets) for a certain period of time (water – 24h, alcohol – 1h, acetone – 2 min and oil 24h) and then the unburdened surface is evaluated in the point of burdening according to the standardised protocol. Resistance of the surface system to cold liquids is later numerically evaluated with the marks from 1 to 5. The resistance mark 5 means that the burdened place showed no changes on the surface and that the surface system is resistant to the performed burdening, and the resistance mark 1 means bigger damage in the burdened place (an altered structure of the coating system or the panel, or that both of these are degraded all the way to the base, the filtering paper is contaminated or glued onto the surface of the tested object), which is a sign that the surface system or the panel is not resistant to cold liquids.

Multi-criteria decision-making method

Decision-making is a process where we need to choose from more than one alternative (possibility, variant, option) the one that best suits the set goals or demands. If we want our decision to be optimal, we need to consider a wide range of factors influencing the quality of our decision. In such cases, the decision-maker can help himself with various methods and computer programmes for decision-making support (Biloslavo 1999).

One of these methods successfully being used in practice for solving demanding decision-making problems is the method of the multi-criteria decision-making. The essential element of this method is to break the decision-making problem into smaller sub-problems, which are later dealt with individually. These options are then separated into individual parameters and are evaluated separately. By combining these evaluation marks, we get the final mark, which is the basis for choosing the best option (Kropivšek and Oblak 1997).

First, we need to define the problem and then determine and produce a list of criteria we consider to be relevant. These criteria need to be structured for the purposes of the model, i.e. they need to be hierarchically arranged where mutual dependency and contextual links need to be considered. Thus, we get a tree of criteria. Each criterion in this tree is given a measuring scale i.e. an estimated value it can take in evaluation (Rajkovič and Bohanec 1995).

With the help of decision-making support software (in this case we used the programme DEXi), we define the utility functions. On the basis of these functions, the computer determines the best from among all the options, which are previously described with values of the basic criteria.

RESULTS AND DISCUSSION

Options of the multi-criteria decision-making model

Six options i.e. six surface systems with the same base and six different polyurethane coating systems were chosen for estimation and evaluation. Thus, our options were in fact the coating systems PU1, PU2, PU3, PU4, PU5 and PU6.

Criteria for the Decision-Making

The first step in the decision-making process was determining the criteria later serving as the basis for evaluation of options - coating systems. These criteria were divided into two structural groups and we got the following tree of criteria:

I. Mechanical – physical resistance properties

⇒ adhesion to the surface
⇒ hardness – resistance to scratching
⇒ resistance to blows
⇒ resistance to heat

II. Resistance to liquids

⇒ water
⇒ alcohol
⇒ acetone
⇒ oil

Estimated Values

Within individual criteria, coating systems can take many different values, which define their properties i.e. are the reflection of the properties of the structural parts (the base, the coating system, the panel) and their mutual harmony. For the product – the coating system to serve its purpose it has to have certain properties for it to withstand all the anticipated burdening in practice without having any inadmissibly lower aesthetic (shine, colour) and functional properties (resistance to liquids, scratching, blows, heat, etc.) therein. In short, the values we use to measure the coating system properties need to reach and exceed certain criteria of acceptability i.e. minimal demands, the latter being the starting point for a complete evaluation of a certain coating system.

The acceptability criteria are being developed for decades on the basis of domestic and foreign laboratory research and empirical confirmations and are about to be supplemented and changed with new findings. In our evaluation and application of the decision-making model, we used all the acceptability criteria recognised domestically and abroad alike.

Estimated Values for Adhesion

Adhesion of the coating system to the base needs to exceed 2.5 MPa. Comparative measurements and research have shown that with the measured value for adhesion being approximately 2 MPa or less, coating systems start peeling off at the minimal exterior or interior burdening – they start separating from the base, and they also peel off the base in a relatively short period of time with no exterior or interior burdening on the basis of the negative effect of time to the size of the internal tensions in the coating system. On the basis of these findings we empirically developed the following estimated values:

- unacceptable adhesion to the base (less than 2.5 MPa)
- acceptable adhesion to the base (from 2.5 MPa to 3 MPa)
- good adhesion to the base (more than 3 MPa to 5 MPa)
- excellent adhesion to the base (more than 5 MPa)

Estimated Values for Hardness – Resistance to Scratching

What is acceptable hardness i.e. resistance to scratching of the surface system is the one where a standardised nib with the pressure of 5 N does not scratch the surface and its trace is not wider than 0.5 mm. Realistic are the following estimated values:

- unacceptable resistance to scratching (traces at the pressure of up to 5 N)
- acceptable resistance to scratching (no traces at the pressure of up to 5 N)
- good resistance to scratching (no traces at the pressure from 5 N to 7 N)
- excellent resistance to scratching (no traces at the pressure bigger than 7 N)

Estimated Values for Resistance to Blows

In evaluating resistance of surface systems to blows, a reasonable height of a weight's free fall is 10 mm with the combination of base + coating system and 25 mm with the combination of base + panel. Besides the mark 5 for resistance of the surface system to blows, the mark 4 is acceptable as well (the point of impact only showing a slight deformation in the form of a hole, where the coating system and the panel show no signs of cracking). The estimated values in this case are:

- unacceptable resistance to blows (mark 1,2 or 3)
- acceptable resistance to blows (mark 4)
- excellent resistance to blows (mark 5)

Estimated Values for Resistance to Dry Heat

In evaluating resistance to dry heat, the standardised body is most often heated to the temperature of 70 °C, 85 °C or 110 °C. In our case we evaluated resistance to heat at the temperature of 85 °C. Besides the mark 5 for resistance of the surface system to heat, the mark 4 is acceptable as well (a slight change in shine or colour, visible only with the reflection of the light or hardly seen slight damages in a few isolated places). In this case, we can present the following estimated values:

- unacceptable resistance to dry heat (mark 1, 2 or 3)
- acceptable resistance to dry heat (mark 4)
- excellent resistance to dry heat (mark 5)

Estimated Values for Resistance to Cold Liquids

When discussing resistance to cold liquids, besides the mark 5, what is acceptable is also the mark 4, meaning slight changes of shine or colour visible only in the reflection of the light. For this criterion, we developed linguistic estimated values:

- unacceptable resistance to cold liquids (mark 1, 2 or 3)
- acceptable resistance to cold liquids (mark 4)
- excellent resistance to cold liquids (mark 5)

For the computer support of the decision-making model, we chose the software DEXi. Using this method, the measuring scales i.e. the estimated values of the criteria are expressed with linguistic values and ordered from the bad (unacceptable) towards the good values. The estimated values are presented in Tab. 1.

Tab. 1: Estimated values for criteria in the decision-making model

Criterion	Estimated value
COATING SYSTEM	*bad* / acceptable / good / very good / **excellent**
I. Mechanical-physical resistance properties	*bad* / good / very good / **excellent**
⇒ adhesion to the surface	*unacceptable* / acceptable / good / **excellent**
⇒ resistance to scratching	*unacceptable* / acceptable / good / **excellent**
⇒ resistance to blows	*unacceptable* / acceptable / **excellent**
⇒ resistance to heat	*unacceptable* / acceptable / **excellent**
II. Resistance to liquids	*bad* / good / very good / **excellent**
⇒ resistance to water	*unacceptable* / acceptable / **excellent**
⇒ resistance to alcohol	*unacceptable* / acceptable / **excellent**
⇒ resistance to acetone	*unacceptable* / acceptable / **excellent**
⇒ resistance to oil	*unacceptable* / acceptable / **excellent**

Key: *italic* – worst value,
bold – best value

CONCLUSIONS

With the method of the multi-criteria decision-making and with the help of the computer system DEXi we got a general qualitative mark for the mechanical-physical and resistance properties of the individual coating systems (the base being the same in all cases, therefore we may speak of coating systems and not surface systems). Thus from a multitude of the measured values (with a great number of options this becomes quite complex and unclear) and the coating systems assessments we got one piece of information, which defines an individual coating system as either more or less applicable. In the research, out of six options the highest mark "very good" was given to the coating system PU3. The coating system PU5 got the mark "good", and three coating systems (PU1, PU2, PU4) were given the mark "acceptable". The negative mark "unacceptable" was given to the coating system PU6.

In cases of the same mark being given to two or more options, the decision-making phase on the basis of qualitative mechanical-physical and resistance properties needs to derive from the intended use of the product i.e. the surface system and together with this the expected properties i.e. demands of such a system in use. In such a case, we need to set priority properties of the sought optimal surface system i.e. coating system for the final decision and by the use of deduction choose the best one according to the marks given.

Supposing the surface system will be exposed to alcohol while in use (table panels in certain catering industry places), we will choose the system with the highest mark of resistance to alcohol, this being the prevailing criterion in this case. If the prevailing criterion should be resistance to blows, we will choose the system with the highest mark in this criterion.

In case of more than one priority condition (resistance to scratching, blows and alcohol or resistance to water, heat and scratching), which is typical for everyday situations, we need to consider the fact that some system properties present a qualitatively mutual opposite dependency. In such situations, the final choice as to the optimal coating system or surface system is the result of a compromise of a professional decision.

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Doc. dr. Leon Oblak
University of Ljubljana, Biotechnical Faculty
Departnent of Wood Science and Technology
Rožna dolina, C.VIII/34
1000 Ljubljana
Slovenia
Tel.: + 386 (1) 423 11 61
Fax.: + 386 (1) 423 22 97
E-mail: leon.oblak@bf.uni-lj.si

Borut Kričej
University of Ljubljana, Biotechnical Faculty
Departnent of Wood Science and Technology
Rožna dolina, C.VIII/34
1000 Ljubljana
Slovenia
Tel.: + 386 (1) 423 11 61
Fax.: + 386 (1) 423 22 97
E-mail: borut.kricej@bf.uni-lj.si

Dr. Igor Lipušček
University of Ljubljana, Biotechnical Faculty
Departnent of Wood Science and Technology
Rožna dolina, C.VIII/34
1000 Ljubljana
Slovenia
Tel.: + 386 (1) 423 11 61
Fax.: + 386 (1) 423 22 97
E-mail: igor.lipuscek@bf.uni-lj.si