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Influence of composition of anti-graffiti coating system used in rolling stock on fire end structure properties

Wpływ składu systemu powłokowego antygraffiti na właściwości ogniowe i strukturalne

Abstract

The paper discusses fire parameters of individual layers of anti-graffiti coating systems proposed for use in rail transport. Modifications and their effect on flammable properties of these coatings have been described. Performed tests included, first of all, parameters such as lateral spread of flame over the surface and heat emission, whose fulfillment proved the most difficult in the previous studies. For this purpose, polyester putties were tested on an epoxy primer. Then, fire parameters for different anti-graffiti systems containing a swelling layer as an additional protective layer were determined.

Keywords: fire tests of railway materials, critical heat flux at extinguishment, lateral spread of flame on products, cone calorimeter, maximum average rate of heat emission, fire safety

Streszczenie

W artykule omówiono parametry ogniowe poszczególnych warstw systemu malarskiego antygraffiti proponowanego do zastosowania w transporcie szynowym. Opisano modyfikacje systemu i ich wpływ na właściwości palne tej powłoki. Przeprowadzone badania obejmowały przede wszystkim takie parametry, jak rozprzestrzenianie płomieni na powierzchni i emisję ciepła, których spełnienie w poprzednich badaniach okazało się najtrudniejsze. W tym celu przeprowadzono testy szpachli poliestrowej na podkładzie epoksydowym. Następnie określono parametry ogniowe dla różnych systemów antygraffiti zawierających warstwę pęczniejącą jako dodatkową warstwę ochronną.

Słowa kluczowe: badania ogniowe materiałów kolejowych, krytyczny strumień ciepła podczas gaszenia, boczne rozprzestrzenianie się płomienia po powierzchni, kalorymetr stożkowy, maksymalna średnia szybkość emisji ciepła, bezpieczeństwo przeciwpożarowe

1. Introduction

An important effect of the existing fire (posing a deadly threat to passengers and impeding evacuation) is the spread of flames on the surface as a result of combustion of materials used in railway vehicles. European Standard EN 45545-2 [1] introduced the need to meet new requirements in terms of fire properties for paint systems too. This requirement proved difficult to reconcile with physical and mechanical requirements of coatings in the functional scope, i.e. allowing ease of application and maintaining protective and decorative properties as long as possible. The above has become a challenge for the paint industry, trying to develop new or modify existing products. The works were started by testing the impact of different variants of the anti-graffiti coating on properties of the entire paint system. However, the values of the specified CFE and MARHE parameters were significantly different from the admissible criteria. However, due to the fact that the coating had a negligible thickness in relation to the thickness of the entire system subjected to combustion as part of laboratory tests, no significant influence of the applied anti-graffiti layer on the test results was demonstrated [2]. Therefore, in the next stage of the work, the effect of the thickness of the putty layer on the properties of the entire system was determined, and then an additional protective layer was introduced into the system.

2. Laboratory tests of fire properties

To assess fire resistance, fire parameters were selected that characterize the material's resistance to external fire sources, i.e.:

1. CFE – critical heat flux, kW/m^2 (the lower its value, the greater the fire hazard) according to ISO 5658-2 [3] (Figs. 1 and 2),
2. MARHE – maximum average rate of heat release kW/m^2 – (the higher its value, the greater the fire hazard), according to ISO 5660-1 [4] (Fig. 3).

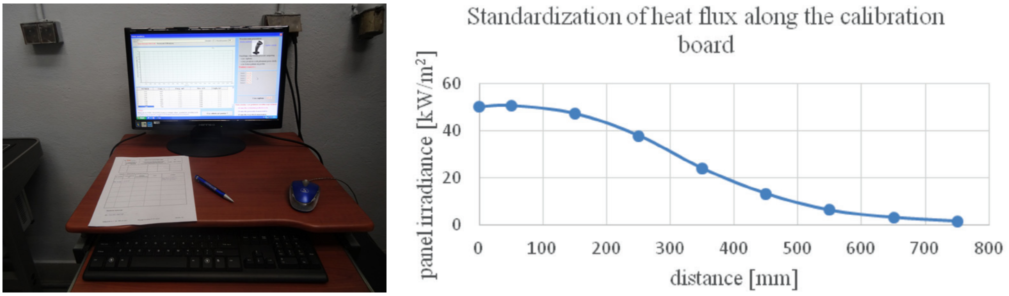

Fig. 1. Standardization of flux along the calibration board

All the tested coatings were applied to 1 mm thick S355 steel plates. Paint systems for rolling stock must also fulfill mechanical and qualitative properties to protective and decorative properties maintenance longer on the vehicle. These requirements include adhesion, resistance to weather conditions (humidity, UV, corrosion) as well as hardness and specialized properties such as anti-graffiti. Coating systems intended for rolling stock ,in addition to the above-mentioned requirements as well as ease of application and operation, must also have adequate fire performance [5, 6].

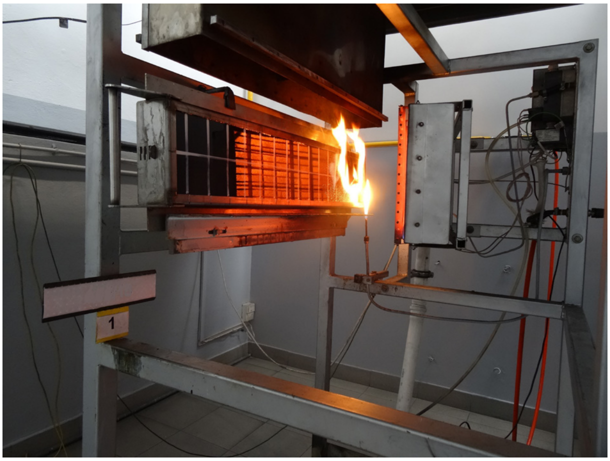

Fig. 2. The sample during test in Railway Institute according to ISO 5658-2

Fig. 3. The sample during test in Railway Institute according to ISO 5660-2

The quality of the putty affects the parameters of the entire system, and especially its flexibility, resistance to extrusion, scratching and impact, as well as the flammable and smoke properties. As a preliminary study aimed at directing further modification work, the impact of the thickness of the putty on its fire properties in terms of flame propagation was determined. LongLife polyester putties with a thickness of 1000 μm, 2000 μm and 3000 μm were prepared on an 80 μm thick epoxy primer SPR91001.

In the next stage of the work, an intumescent layer was introduced into the system in order to limit the impact of the ignition source operation on the lower layers, especially on the putty. The first CFE tests were carried out for the system with anti-graffiti XPC 60036 in two variants, i.e. using a 200 μm intumescent paint placed as the third or as the fourth layer. In both cases, a putty thickness of 2000 μm was assumed.

Then, further research was undertaken to determine the required thickness of the intumescent layer, placed as the third layer in the system, to meet the requirements for CFE. The tests were carried out for the thickness of 200 μm, 400 μm and 600 μm. As a protective layer against graffiti, BO-100AGR varnish with the best physical and chemical properties was used in all samples.

3. Results and discussion

A microstructure analysis was conducted for anti-graffiti coating systems using a JEOL JSM-7100F scanning electron microscope with field emission and a Hirox KH-8700 light microscope.

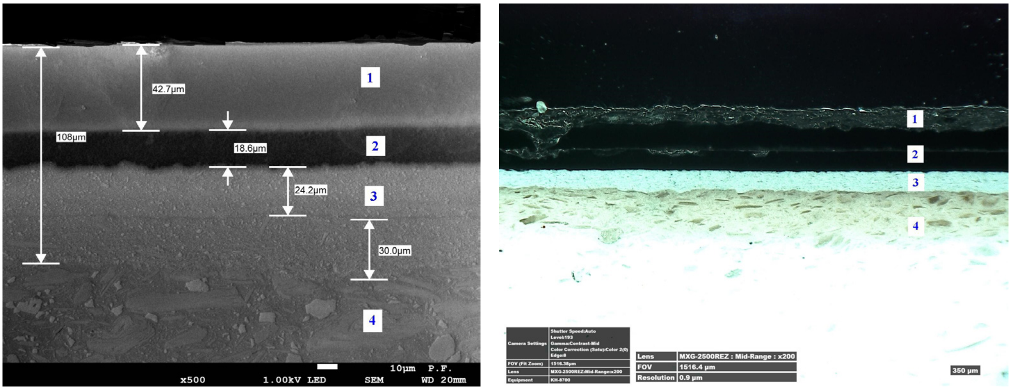

Fig. 4. SEM (left) and LM (right) micrographs of the polished cross-section through an anti-graffiti O-100AGR coating system on S355 carbon steel substrate: 1 – anti-graffiti layer, 2 – base layer, 3 – undercoat layer, 4 – putty

The thickness of the obtained coating systems was from approx. 2350 to approx. 2450 μm. There are clear boundaries between the individual layers (Fig. 4). Fig. 4 shows a clear boundary between the varnish layers and the putty. Also, the varnish layers are free of pores and microcracks.

A putty is the thickest layer in the coating systems applied to the external walls of rail vehicles. The above results from the desire to hide all inequalities and obtain the maximum flatness of the painted surface of the wagon body shells. The research began with the first two parameters, whose fulfillment in the previous studies proved the most difficult.The obtained impact of the polyester putty on an epoxy primer is presented in Table 1.

Table 1. The results of fire tests for sample of polyester putty

No of sample	Coating system layer	Layer thickness, [μm]	CFE, [kW/m²]	MARHE, [kW/m²]
A8/16	SPR91001	80	8.9	126.6
	LongLife	1000		
A9/16	SPR91001	80	8.6	158.6
	LongLife	2000		
A10/16	SPR91001	80	8.2	161.1
	LongLife	3000		
Requirement according to EN45545-2			> 20	< 90

The carried out tests confirmed the high impact of putty on the negative results of entire paint systems. At the same time, it was found that the effect of the layer thickness on the determined parameters from 2000 μm is reduced.

The obtained results of the paint system with a swelling layer are presented in Table 2 and Table 3.

Table 2. CFE test results for system sample with XPC 60036 and intumescent layer

No of sample	Coating system layer	Layer thickness, [μm]	CFE, [kW/m²]
A180/16	SPR91001	80	15.1
	LongLife	2000	
	Intumescent layer	200	
	XPP40003	60	
	XPB710	40	
	XPC60036	60	
A180.1/16	SPR91001	80	13.9
	LongLife	2000	
	XPP40003	60	
	Intumescent layer	200	
	XPB710	40	
	XPC60036	60	
Requirement according to EN45545-2			> 20

As can be seen in Table 2, more favorable values were obtained for the first variant, i.e. at the intumescent layer placed lower.

Table 3. CFE test results for system sample with BO-100AGR and intumescent layer

No of sample	Coating system layer	Layer thickness, [μm]	CFE, [kW/m²]
A209/17	SPR91001	80	16.3
	LongLife	2000	
	Intumescent layer	200	
	XPP40003	60	
	XPB710	40	
	BO-100AGR	60	
A210/17	SPR91001	80	17.5
	LongLife	2000	
	XPP40003	60	
	Intumescent layer	400	
	XPB710	40	
	BO-100AGR	60	
A211/17	SPR91001	80	20.3
	LongLife	2000	
	XPP40003	60	
	Intumescent layer	600	
	XPB710	40	
	BO-100AGR	60	
Requirement according to EN45545-2			> 20

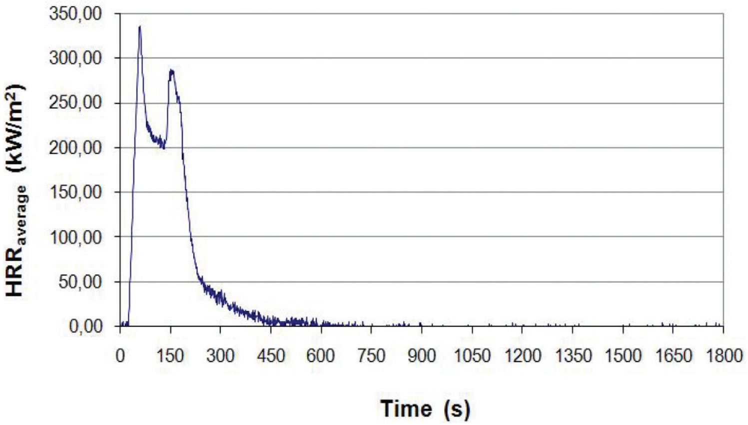

Fig. 5. HRR$_{average}$ heat releasing curve for anti-graffiti BO-100AGR

As a result, the thickness of the swelling layer of 600 μm allowed for obtaining a borderline, positive CFE value. Figure 5 shows an example of $HRR_{average}$ heat releasing curve for tested sample. You can see that bigger thickness of intumescent layer delays ignition and causes less heat emission.

4. Summary

The laboratory tests carried out allow us to state that the introduction of the swellable paint test as the 3rd layer of the coating into the paint system is the right direction of modification in order to protect the system against fire spread.

References

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