Materials Research Proceedings **5** (2018) 31-36 doi: http://dx.doi.org/10.21741/9781945291814-6

Fire Properties of Upholstery and Fire Resistance of the Complete Passenger Seat

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Keywords: Furniture Calorimeter, Cone Calorimeter, Fire Properties, Smoke Density, EN 45545, Fire Safety in Rolling Stock, Fire Hazard, Fire Tests of Seats, Fire Test of Materials, Heat Release Rate

Abstract. The article discusses laboratory tests of fire properties of complete railway seats and upholstery systems used for their construction. The results obtained with the use of furniture and cone calorimeter were especially analyzed to determine the interrelations between them. It has been shown that the criteria for classification of upholstery systems and passenger seats need to be verified. High impact of proper selection of materials on the initiation and development of a possible fire was emphasized.

Introduction

Passenger seats in rolling stock constitute a significant part of the fire load density of vehicles. These elements are directly exposed to potential sources of ignition, such as acts of vandalism - arson, fire, heating system failures, as well as short circuits in electrical installations. Considering the history of fires in the rolling stock, which were the consequence of the ignition of the railway chair, it can be clearly stated that they pose a high risk to life and health of people. Humans are exposed to particular hazards in the direct area of an exposure to a thermal radiation and fumes containing toxic fire gases. The scale of danger increases many times if a fire occurs in the tunnel [1, 2]. That is why for many years now wagon seats and their component materials have been subjected to classification tests. Appropriate selection of rail seat components contributes significantly to the reduction of the fire risk level of the entire vehicle.

Requirements in the field of fire resistance

Selective selection of non-metal materials, as well as their location in the vehicle and production technology is a very important issue in designing rail vehicles. The above also applies to the component materials of the passenger seat.

The fire resistance characteristics of the tested materials under conditions simulating a flared fire make it possible to identify the hazards associated with them and take appropriate preventive measures. Investigations of flammable and smoke properties enable the elimination or modification already at the design stage of materials whose application may cause an unacceptable risk of events causing human and material losses. The research is aimed at obtaining materials that are difficult to ignite and limit the spread and development of fire. They do not eliminate the risk of danger. However, they allow controlling and minimizing them to a large extent. The requirements of the TSI (technical specifications for interoperability) [3, 4] and harmonized European standards are systematically verified.

The main threats resulting from the fire of a passenger seat include smoke density, gas toxicity and the amount of heat emission due to combustion. The listed hazards are included in the F requirements (furniture) (Table 2 according to EN 45545-2 + A1: 2015-12 [5]) for individual components and the complete seat. Table 1 presents a list of requirements applicable to elements

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being the subject of this article, i.e. upholstery system (R21) and a complete passenger seat (R18). The parameter values vary depending on the hazard category (HL) for the rolling stock resulting from its operating category and the assigned railway infrastructure in which it moves.

Table 1. Statement of the R21 and R18 requirements according to EN 45545:2013+A1:2015 [5]

Requirements	Tests method	Parameter [Unit]	Requirement for:		
			HL1	HL2	HL3
R21 (upholstery on passenger seats and headboards)	ISO 5660-1: 25 [kWm^{-2}]	MARHE [kWm^{-2}]	≤ 75	≤ 50	≤ 50
	EN ISO 5659-2: 25 [kWm^{-2}]	D_s max. [dimensionless]	≤ 300	≤ 300	≤ 200
	EN ISO 5659-2: 25 [kWm^{-2}]	CIT_G [dimensionless]	≤ 1,2	≤ 0,9	≤ 0,75
R18 (complete passenger seat)	ISO/TR 9705-2	MARHE [kW]	≤ 75	≤ 50	≤ 20
	ISO/TR 9705-2	RHR Peak [kW]	≤ 350	≤ 350	≤ 350

Laboratory tests

Tests of complete passenger seats and the upholstery systems used for their construction were carried out on 6 representative samples designated successively as seat 1 to seat 6. The material composition of upholstery systems was determined analogously from 1 to 6 and shown below:
1. PUR foam, VIGOR upholstery,
2. NPD-100 foam, INNOVO upholstery fabric,
3. NPD-100 foam, fire kevlar para-aramid barriers, upholstery fabric,
4. NPD-100 foam, kevlar para-aramid fabric, INNOVO upholstery fabric,
5. NPD-100 foam, Kevlar para-aramid fireproof fabric, upholstery fabric,
6. PUR FRC foam, DARA ZWFR107 fireproof nonwoven, Kneitz upholstery fabric.

The scope of testing of upholstery systems included tests in accordance with Table 1. The following parameters were determined:
- Maximum Average Rate of Heat Emission (MARHE) according to ISO 5660-1:2015 [6] determined using a cone calorimeter at a radiation intensity of 25 kW/m^2,
- Maximum Specific Optical Density of smoke (Dsmax) according to EN ISO 5659-2:2013 [7], determined using a one-chamber test,
- Conventional Index of Toxicity (CIT_G) according to EN ISO 5659-2:2013 [7] and EN 45545-2: 2013 + A1:2015 [5] Annex C, determined using the FTIR analyzer connected to the smoke chamber.

A summary of the final results is included in Tab.2. The presented values represent the average of the tests for three samples/objects. In contrast, Fig. 1 shows the heat release rates (HRR) recorded during tests using a cone calorimeter. The graphs for the best (seat 6) and the worst upholstery system (seat 1) are shown. As can be seen, the upholstered systems with the fireproof layer applied have definitely achieved better values for most of the parameters determined. MARHE value in the range (44.2 to 48.27) kW/m^2, while for the systems without a fireblocker: (58.63 to 64.7) kW/m^2. Also, their later ignition and shorter burning time were clearly visible. It was also found that despite the different material composition of the studied systems, Ds max values are at a similar level within the limits of 218-242 and meet the requirements of HL1 and HL2. The toxic properties of combustion products

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are varied, however, all of them are below the acceptable value for the HL3 level, which is definitely lower than 0.75. Nevertheless, none of the upholstered systems tested met the fire requirements for the HL3 threat level.

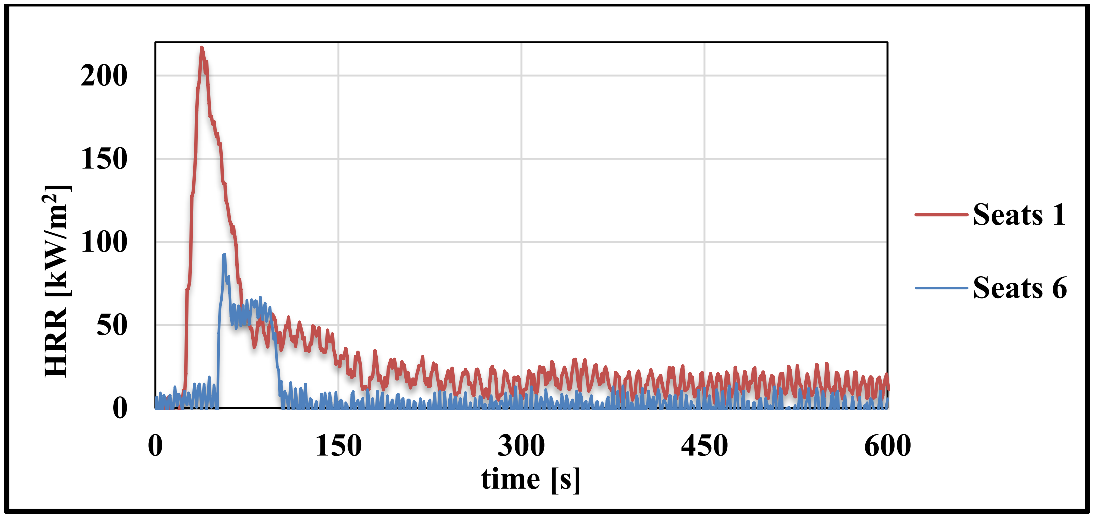

Fig.1. HRR chart during the test on a cone calorimeter

Fig. 2. Seat 1 on the test stand according to EN 45545-2:2013 + A1:2015 [5] and ISO/TR 9705-2:2001 [8] during the test.

Then, complete passenger seats were tested according to EN 45545-2:2013 + A1:2015 [5] Annex B, using a furniture calorimeter according to ISO/TR 9705-2:2001 [8]. This test stand makes it possible to determine parameters that are very important when assessing the level of fire safety. It is used in many research projects and certification tests [9 - 14]. MARHE (Maximum Average Rate of Heat Emission), RHR Peak (Rear Heat Release Peak), as well as TSR (Total Smoke Released) based on SPR (Smoke Production Rate) are the main parameters measured during the test..

During the test, a complete passenger seat placed under the hood with a forced air flow of 0.6m/s shall be treated for 180 seconds with a Belfagor propellant gas burner with a nominal power of 7 kW. Fig. 2 shows one of the tested seats on a furniture calorimeter.

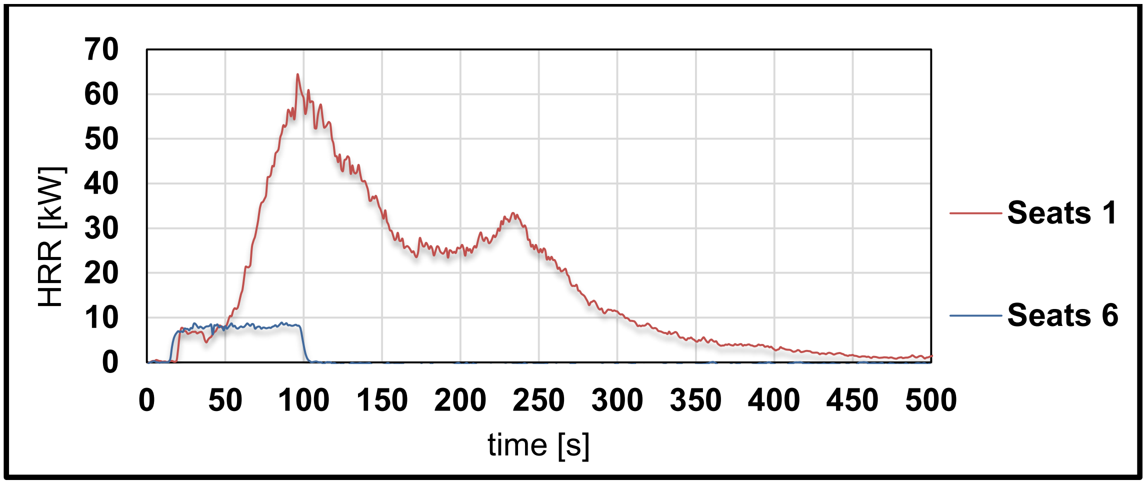

Fig.3. HRR chart during the study on a furniture calorimeter

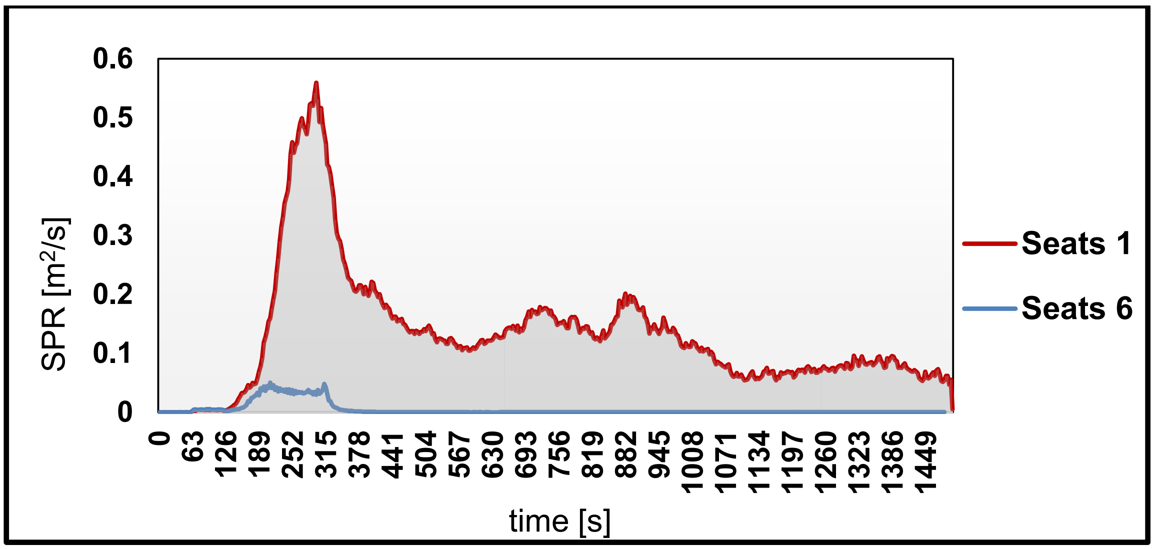

Fig.4. SPR chart during the study on a furniture calorimeter.

Table 2. List of research results obtained on furniture and cone calorimeter.

Parametr	Object					
	Seat 1	Seat 2	Seat 3	Seat 4	Seat 5	Seat 6
	EN 45545-2+A1:2015 Annex B (complete seat)					
RHR Peak [kW]	64.77	28.03	11.71	10.28	10.15	8.74
MARHE [kW]	39.0	14.62	8.83	7.91	8.27	7.67
Total Smoke Released [m^2]	196.0	24.3	8.4	7.9	7.5	6.2
	ISO 5660-1:25 kWm^{-2} (upholstery)					
MARHE [kWm^{-2}]	62.55	58.63	48.27	47.63	46.1	44.2
	EN ISO 5659-2:25 kWm^{-2} (upholstery)					
D_s max.	231.85	242.0	230.9	229.2	227.7	218.7
$CIT_{G(4)}$	0.284	0.09	0.12	0.11	0.08	0.08
$CIT_{G(8)}$	0.348	0.24	0.23	0.21	0.11	0.11

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The obtained results, including the additionally determined TSR values, are also included in Tab.2. The heat HRR waveforms recorded during the tests are shown in Fig.3, and SPR waveforms in Fig.4.

The analysis of the results, also with the fire-retardant layer, shows that they achieved significantly better values of the parameters determined.

At the same time, all the complete seats with a fireproof layer and seat 2 without a fireblocker, met the HL3 requirements and reached the following values: MARHE: (7.67 - 14.62) kW and RHR Peak: (10.15 - 64.77) kW. On the other hand, seat 1, for which an intensive smoking process was observed with a flame of a maximum of 1.9 m in height and whose upholstery system was qualified only for HL1, met the requirements adopted for HL2.

As a part of the further analysis, the relationship between the MARHE values of upholstery systems and complete seats was determined. The graph in Figure 5 shows that this relationship is not linear and can be described by a 4th degree polynomial.

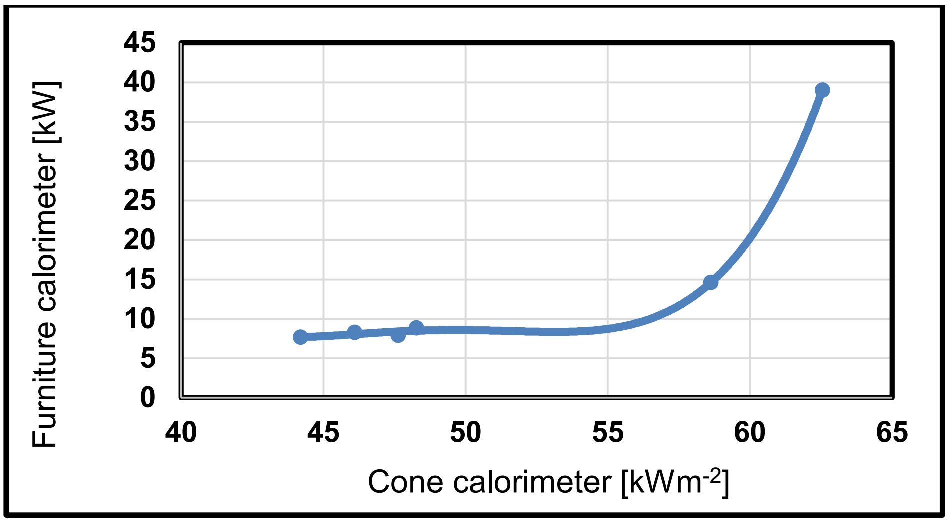

Fig. 5. Dependence between MARHE values of upholstery systems and MARHE of complete seats.

Summary

The tests showed that the seats, not protected by a fireproof fabric during combustion, are characterized by a much higher intensity of heat emission, as well as dense smoke, than the secured seats. The above phenomenon occurred also as part of tests on samples of the upholstery systems. The relationship between MARHE values of upholstery systems and MARHE of complete seats has the character of a 4- degree polynomial curve. In addition, there was no correlation in the classification of seats and their component materials. The above should be taken into account when verifying requirements as part of the ongoing revision process of EN 45545-2 + A1: 2015-12 [5], in which the Railway Research Institute participates. The proper selection of materials has a significant impact on the emergence and development of a possible fire, i.e. on the safety of travelers. Therefore, it is advisable to obtain compatibility of the criterial values of all parameters included in the classification of passenger seats.

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