Development of Requirements for Fire Protection of Rolling Stock in Poland and ITS Comparison with EN 45545

Jolanta Maria RADZISZEWSKA-WOLIŃSKA[1]

Summary
The paper presents the development of works in the field of fire safety rolling stock in Poland and the courses of action taken at this field in Europe. Characterized the scope of the new standard EN 45545, and compared the approach of Part 2 on the requirements for materials and components of the combustion with the current requirements of the Polish PN-K-02511. Also, it demonstrates a much more detailed and complex European approach. It contains a much larger variety of research and the requirements for the individual vehicle components. It also presents the preliminary results of the comparative tests for several materials tested according to PN which has been tested in accordance with ISO 5660-1 which is one of the requirements of EN 45545-2.

Key words: fire protection, rolling stock, fire and smoke properties

1. Introduction

In the mid-twentieth century, the railway has become a mass transport. Its growing popularity resulted in accelerating the development of vehicle design. The aim was to reduce their weight, increase speed, and to increase the comfort of the passengers. Appearance of the vehicles and its aesthetic value have become also an important issue. Thus began the introduction of new, modern materials produced on the basis of synthetic or modified natural polymers. The development of the chemical industry made it possible in wider and wider range. However, it was found that plastics in addition to the many advantages also have disadvantages, including high susceptibility to ignition [3, 15, 16].

[1] Assistant Professor; head of Materials & Structure Laboratory, Instytut Kolejnictwa; e-mail: jradziszewska-wolinska@ikolej.pl.

2. Development requirements for fire protection

The increasing number of fires which were more and more dangerous for passenger of rolling stock initiated at the end of the 70s of the twentieth century research aiming to develop laboratory methods for determining the flammability and smoke properties of materials and the classification requirements for rolling stock.

Developed in Instytut Kolejnictwa (formerly CNTK), Polish Standard PN-K--02500 established in 1984 by PKN (Polish Standardization Committee), was one of the first in Europe, and has initiated actions in fire safety rail vehicles in Poland. Development of Polish standardization is shown on the timeline (Figure 1). Currently:

- PN-K-02511: 2000 [13] specifies requirements for non-metallic materials used in rolling stock, which refers to standards for individual tests,
- PN-K-02506:1998 [10] specifies requirements for electric traction vehicles,
- PN-K-02507: 1997 [11] specifies requirements for combustion-engines power units.

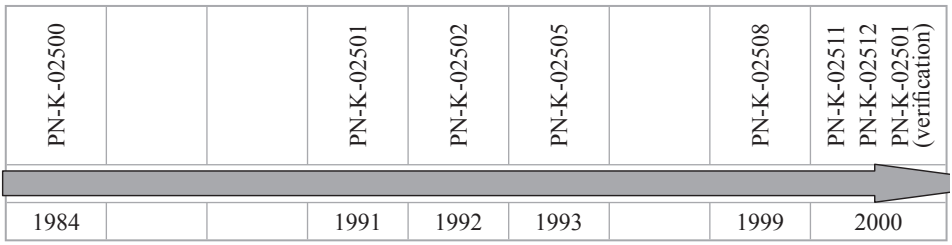

Fig. 1. Development of Polish normalization in the field of fire safety of rolling stock

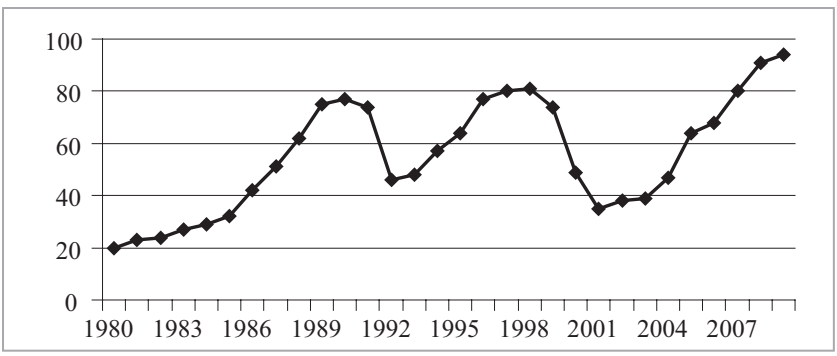

Fig. 2. Number of the materials tested according to Polish Standards which comply with requirements

Subsequently introduced new standards resulted in decrease in the number of materials that meet the requirements. However, as demonstrate in Figure 2 statistics data of IK Laboratory, new requirements became an impulse to modify manufacturing processes, including the use of flame retardants and contribution to the gradual improvement of the properties of the tested products [3, 15, 16]. Also these requirements (as demonstrate in Figure 3) contributed to about 5,5 times decrease of the number of registered cases of fires in passenger rolling stock [18, 19].

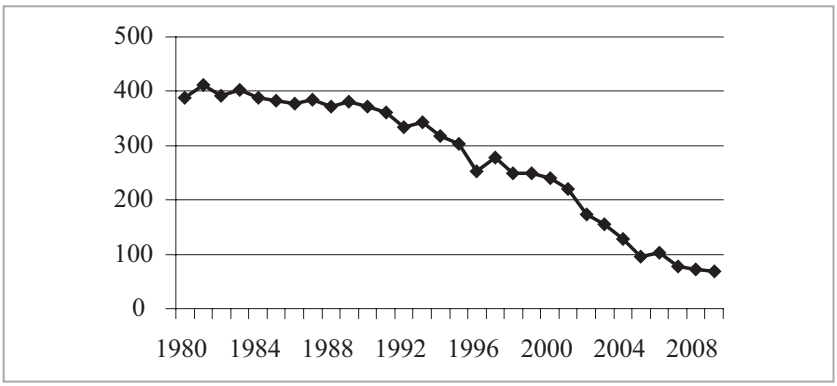

Fig. 3. Number of fire incidents in the Polish rolling stock

Standardization work in the field of fire safety in rolling stock has been also done in other European countries, what resulted in establishing of British Standards BS, French Standards NF, Italian Standards FS, and German Standards DIN.

Also, due to the fact, that the development of the rolling stock in different countries occurred in different directions (both in terms of construction and the materials used) and various ways the rolling stock maintenance rules was developed in particular countries, there were different causes and different growth of fires. There were failures in brake systems, short circuits in electrical installations, arson, and other. This led to the development of different test methods in order to reflect in the laboratory of potential ignition sources. Nevertheless, in most cases, the essential characteristics of the material properties are described by the following parameters:

- smoke properties,
- toxicity of combustion products,
- flame propagation,
- flammability.

Also, in most of the systems of requirements assessment, the various material groups are differentiated according to:

- the dimensions and weight in the vehicle,
- the location and distance from potential sources of ignition,
- The hazard levels depending of type of vehicle and operation category.

The development and implementation of UIC 564-2 [21] were an attempt to standardize testing methods and requirements. However, this document has not been generally accepted and most of the railways continued its own measurement techniques. However, lack of comparative tests often required repeated testing of the same materials for different rail or different industries (buildings, automotive, furniture etc.). This strongly influenced the increased costs and longer time contracts realization, making impossible rapid and flexible choice of materials. Therefore, in 1991 work was undertaken to develop an European standard, which was completed only in March of 2013. Standard EN 45545 [1] presents complex approaches to safety of passenger rolling stock, including passive and active measures aimed at reducing the risk of fire and to minimize the consequences in the event of fire occurrence [18]. It comprises much more comprehensive and detailed range than requirements of PN [13]. Standard EN 45545 [1] consists of seven interrelated parts listed below:

- Part 1 – General
- Part 2 – Requirements for fire behaviour of materials and components
- Part 3 – Fire resistance requirements for fire barriers
- Part 4 – Fire safety requirements for railway rolling stock design
- Part 5 – Fire safety requirements for electrical equipment including that of trolley buses, track guided buses and magnetic levitation vehicles
- Part 6 – Fire control and management systems
- Part 7 – Fire safety requirements for flammable liquid and flammable gas installations.

3. Comparison of PN-K-02511 with EN 45545-2

Part 2 of EN 45545 is the most extensive part and, in comparison to the existing requirements of PN-K-02511 [13], contains in addition to oxygen index, quite different research methods. The objective of European standardization work was to maximize the alignment of test methods and classification rules to the real life. It was a big challenge, and as shown by further work and testing (among other things, the project TRANSFEU [20]), it will require verification.

Comparison of the most important aspects of EN 45545-2 requirements for fire properties of materials and components with the existing requirements of the Polish PN-K-02511 [13] is given below (3.1 i 3.6).

3.1. The materials to be tested

According to PN all kind of materials which the unit mass is more than 25 g or total mass in the vehicle is greater than 1 kg are examined. Whereas, according to EN grouped products are tested if the total combustible mass exceeds:

- 100 g for interior materials,
- 400 g for exterior materials.

However, if the combustible mass of the grouped products exceeds the limits mentioned above, but is less then:

- 500 g for interior materials,
- 2 000 g for exterior materials,

one combustible product of particular group has to be tested according to R24 (only one test).

3.2. The range of requirements

EN 45545-2 adopted the general principle that the requirements depend on the location of materials / products in the vehicle. This allows us to identify the five following groups:

- Internal (IN),
- External (EX),
- Furniture (F),
- Electrical equipment (E),
- Mechanical equipment (M),

whereby subgroups are defined (including 68 items). This approach is much more detailed than this presented in the norme PN-K-02511 [13], which identified only 12 material groups with assigned 6 group of requirements. Whereby, in this EN, elements are classified into various sub-groups assigned to 26 groups of requirements (R1 to R26). These include the need to determine from 1 to 5 parameters, which limits depend from hazard level of vehicle (HL). It means that the same material for the various items of equipment of rolling stock will be subject to various tests and / or should meet different requirements. This is illustrated in Table 1 in which, for example, the requirements for materials intended for various elements of rolling stock equipment (lining the walls, ceilings, tables, seats shell, strips, etc.) are given. As follows from it, determination of the scope of tests necessary to perform and requirements that should be met, given material requires careful analysis of the standards for a specific intended use of the given product. Wherein the standard permits acceptance of the material meeting higher requirements.

Table 1

Requirements for plastic material depending on application in vehicle

Requirements	Hazard level	MARHE	CIT_G	VOF_4	CFE	$D_s(4)$
		kW/m²	–	min	kW/m²	–
Interior vertical surfaces (IN1A) and interior horizontal downward-facing surfaces (IN1B)						
R1	HL1	a –	≤1,2	≤1200	≥20 a	≤ 600
	HL2	≤ 90	≤0,9	≤600	≥20 a	≤ 300
	HL3	≤ 60	≤0,75	≤300	≥20 a	≤ 150
Limited surfaces (IN2) ($S \leq 0{,}2\ m^2$ and $l \leq 1\ m$)						
R2	HL1	a –	≤1,2	≤1200	≥13 a	≤ 600
	HL2	a –	≤0,9	≤600	≥13 a	≤ 300
	HL3	≤ 90	≤0,75	≤300	≥13 a	≤ 150
Strips (IN3A)						
R3	HL1	a –	≤1,2	–	≥13 a	–
	HL2	a –	≤0,9	≤960	≥13 a	≤ 480
	HL3	a –	≤0,75	≤480	≥13 a	≤ 240
Passenger seat shell (F1C, F1D)						
R6	HL1	≤ 90	≤1,2	≤1200	–	≤ 600
	HL2	≤ 90	≤0,9	≤600	–	≤ 300
	HL3	≤ 60	≤0,75	≤300	–	≤ 150

3.3. Preparation of test samples

According to PN and EN, the test sample should be prepared from the final product or as laboratory sample while maintaining the same as for the final product manufacturing, finishing technology and thickness. The series shall be tested for extreme performance products range in thickness or density, e.g.

3.4. The assembled products

According to PN, the sandwich elements which are composite of a few single materials glued together should be tested in the end use condition and at their full thickness.
Whereas, according to EN, materials of final configuration should be tested as set. For example, the following items do not require separate test:

- upholstery fabrics, sandwich, or foam – sample should be prepared for the whole of the upholstery,
- similarly for a flooring the entire floor panel including for example, thermal insulation, and taped floor covering should be tested.

However, with negative results, sometimes be difficult to determine which of the components of the system must be replaced for the better.

3.5. The functional requirements of the material

Standard EN allows the use of materials which do not meet the requirements, if they are the best available in the market and their use is necessary for the sake of other functional properties (e.g. electrical resistance or resistance to high or low temperatures). At the same time, the decision should be preceded by a thorough assessment. PN standard does not contain these provisions. However, the above expert assessment is applied in practice.

3.6. Comparison of the properties of materials

Establishment of EN 45545 [1] started a 36-year-month transition period for the implementation of national versions of the Member States of CEN / CENELEC and the withdrawal of conflicting national standards. This period is also necessary for the full implementation of the new test methods to laboratory practice, confirmed by their accreditation.

This raises the question of whether the materials meeting the current requirements of PN-K-02511: 2000 [13] meet also the requirements of EN 45545-2:2013 [1].

To this end, initial tests were performed. Several materials tested according to PN-K-0251 subjected tests according to ISO 5660-1 [2] in Laboratory of Instytut Kolejnictwa (Fig. 4). The samples came from Laboratory archives and some of its meet the requirements of PN and some are not meeting the requirements. These were materials of the structure and lining the walls and curtains. All these materials subject to the requirements R1 in accordance with EN 45545-2 [1].

Fig. 4. Tests on cone calorimeter according to ISO 5660-1

ISO 5660-1 [2] uses the principle of oxygen calorimetry. It is based on the relationship, which shows that each kilogram of oxygen consumed in the combustion process of the material releases heat in the amount of 13.1 MJ. Carrying out very accurately measurements of oxygen concentration and the mass flow rate of exhaust gas in the exhaust duct, device calculates the intensity of the heat generated [4]. For the purposes of classification according to EN 45545-2 MARHE determine the parameter representing the maximum average rate of heat emission (ARHE) within 20 minutes of the test. ARHE value is calculated by the following formula (using a trapezoidal area assumption):

$$ARHE\left(t_n\right) = \frac{\sum_2^n \left(t_n - t_{n-1}\right) \times \frac{q_n + q_{n-1}}{2}}{t_n - t_{n-1}},$$

where:

t – time, and generally $t_1 = 0$,

q – rate of heat emission, and generally $q_1 = 0$.

The results are plotted in Figure 5. Unfortunately, they do not allow for the conclusion of any relationship between the results of the PN and the value of

MARHE. This suggests that Polish manufactures are facing another challenge for product improvement.

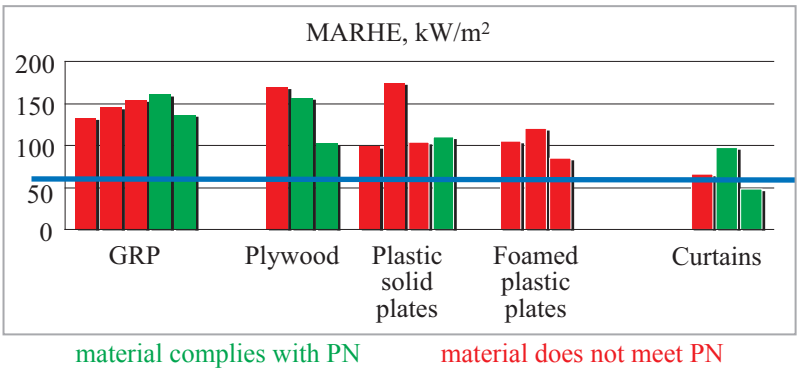

Fig. 5. Results of MARCHE in comparison tests

4. Conclusions

- The Standard EN 45545-2 is much more extensive and more complex than the PN-K-02511.
- Determination of the range of necessary tests and requirements that should be met by given material, requires a careful analysis of the standards for a specific intended use of the product.
- Obtaining of negative test results for sandwich elements can cause difficulties in determining which of the components of the system must be replaced by a better.
- Previous experience in the implementation of the next Polish requirements and preliminary tests carried out according to ISO 5660-1, for materials for Polish rolling stock, lead to the conclusion that manufactures are facing another challenge for product improvement.
- Therefore, the tests for the certification of materials, components and systems should be carried out in accredited laboratories (reliable and independent).
- Fire risk assessment in the rolling stock should be performed by responsible experts with knowledge in the field of physics and chemistry of combustion and the development of a fire in the vehicle.
- Implementation of EN for use in all areas (design, laboratory tests, purchasing procedures, production, maintenance, etc.) will be a challenge, but in the future should facilitate the functioning of the European rail market.

Literature

1. EN 45545:2013 *Railway applications – Fire protection on railway vehicles –Requirements for fire behaviour of materials and components*.
2. ISO 5660-1:2002: *Reaction to fire tests. Heat release rate. Smoke production and mass loss rate – Part 1: Heat release rate (cone calorimeter method).*
3. Janowska G., Przygocki W., Łochowicz A.: *Palność polimerów i materiałów polimerowych*, WNT, Warszawa, 2007.
4. Peacock R.D., Bukowski R.W., Markos S.H.: *Evaluation of Passenger Train Car Materials in the Cone Calorimeter*, Fire and Materials, 1999, vol. 23, s. 53–62.
5. PN-EN ISO 4589-2:2006: *Tworzywa sztuczne. Oznaczanie zapalności metodą wskaźnika tlenowego. Badanie w temperaturze pokojowej.*
6. PN-K-02500:1984: *Tabor kolejowy pasażerski. Wymagania i badania materiałów pod względem ochrony przeciwpożarowej* (norma wycofana w 2000 r. zastąpiona przez [7, 8]).
7. PN-K-02501:2000: *Tabor kolejowy. Właściwości dymowe materiałów. Wymagania i metody badań.*
8. PN-K-02502:1992: *Tabor kolejowy. Podatność na zapalenie siedzeń wagonowych. Wymagania i badania.*
9. PN-K-02505:1993: *Tabor kolejowy. Stężenie tlenku i dwutlenku węgla wydzielanych podczas rozkładu termicznego lub spalania materiałów.*
10. PN-K-02506:1998: *Elektryczne pojazdy trakcyjne. Zabezpieczenie przeciwpożarowe. Wytyczne konstrukcyjne.*
11. PN-K-02507:1997: *Spalinowe pojazdy trakcyjne. Zabezpieczenie przeciwpożarowe.*
12. PN-K-02508:1999: *Tabor kolejowy. Właściwości palne materiałów. Wymagania i metody badań.*
13. PN-K-02511:2000: *Tabor kolejowy. Bezpieczeństwo przeciwpożarowe materiałów. Wymagania.*
14. PN-K-02512:2000: *Tabor kolejowy – Bezpieczeństwo przeciwpożarowe materiałów – Metoda badania wskaźnika rozprzestrzeniania się płomienia.*
15. Radziszewska-Wolińska J., Milczarek D.: *Uniepalnienie materiałów niemetalowych a ich właściwości funkcjonalne*, XIX Konferencja Naukowa „Pojazdy Szynowe", Targanice k. Andrychowa, 15–17.09.2010 r.
16. Radziszewska-Wolińska J., Zienkiewicz-Gałaj B., Milczarek D.: *Plastics development in Rolling Stock,* INMAT, Gdańsk, 11.2006.
17. Radziszewska-Wolińska J. : *Acceptance of application of materials not complying with fire safety requirements,* 5th annual Fire Protection of Rolling Stock Conference, London, 10–11.03.09, EURAIL mag. N°20.

18. Radziszewska-Wolińska J.: *Outlining the progress with regards to fire safety of Polish rolling stock*, 6th annual Fire Protection of Rolling Stock Conference, London, 24–25.03.2010, CD.
19. Radziszewska-Wolińska J.: *Rozwój bezpieczeństwa pożarowego taboru szynowego Polsce i Europie*, „Problemy Kolejnictwa", 2011, vol. 153, s. 83–91.
20. Radziszewska-Wolińska J.: *TRANSFEU – Transport Fire Safety Engineering in the European Union,* II International Conference Transport Problems, Kraków – Katowice, 8–11.06.2010, CD, Transport Problems , Volume 6, Issue 4, Wydawnictwo Politechniki Śląskiej, Gliwice 2011, s. 35–40.
21. UIC Code 564-2, *Regles relatives a la protection et a la lutte contre l'incendie dans les vehicules ferroviaires du service international, transportant des voyageurs, ou vehicules assimiles*, 3 edition of 1.1.1991 and 2 Amendments.

Rozwój wymagań w zakresie ochrony przeciwpożarowej taboru szynowego w Polsce i ich porównanie z EN 45545

Streszczenie
Przedstawiono rozwój prac w zakresie bezpieczeństwa pożarowego taboru szynowego w Polsce oraz kierunki działań w tym obszarze podjęte w Europie. Scharakteryzowano zakres nowej normy EN 45545 oraz porównano podejście jej Części 2, dotyczącej wymagań dla materiałów i elementów w zakresie właściwości palnych, z dotychczasowymi wymaganiami polskimi według PN-K-02511. Wykazano bardziej szczegółowe podejście europejskie. Zawiera ono większe zróżnicowanie zakresu badań i wymagań dla poszczególnych elementów pojazdów. Przedstawiono wyniki wstępnych badań porównawczych dla kilkunastu materiałów przetestowanych według PN, które poddano badaniom według ISO 5660-1, stanowiących jedno z wymagań EN 45545-2.

Słowa kluczowe: ochrona przeciwpożarowa, tabor, właściwości ognia i dymu

Развитие требований к противопожарной защите подвижного состава в Польше и их сопоставление с EN 45545

Резюме
Рассмотрено развитие работ по противопожарной защите подвижного состава в Польше, а также представлены направления действий в этой области, предпринимаемых в Европе. Определён объём нового пакета стандартов EN 45545 и сопоставлен подход, принятый в Части 2, касающейся требований к горючим свойствам материалов и элементов, с существующими до сих пор польскими требованиями согласно стандарту PN-K-02511. Доказано, что европейский подход на много более детальный и сложный. Объём испытаний и требований к отдельным компонентам транспортного средства при этом подходе более разнообразный. Представлены также результаты предварительных сравнительных испытаний для нескольких материалов, испытанных по польскому стандарту PN, а затем подвергнутых испытаниям по стандарту ISO 5660-1, принятым в EN 45545-2 как одно из требований.

Ключевые слова: противопожарная защита, подвижной состав, горючие и дымовые свойства