Rail Vehicle Peak Heat Release Rate Estimation

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Summary
This paper describes the various methods used to estimate vehicle energy released in the event of a rail vehicle flashover fire. It considers real scale test data and whether it can be applied to other designs. It also considers the calculation methods used in a variety of applications including estimation based on heat content, the Boon-Chiam and Heat Release Rate per Unit Area (HRRPUA or Duggan) methods.
It describes features and gives an overview of each calculation method considered. It discusses the energy required to generate flashover in a rail vehicle.
It discusses limitations to confidence in calculation of peak release rate. It proposes some ideas for future work programmes to mitigate them as far as is possible. This includes the possibility of using a validated CFD analysis method. CFD analysis could also determine a greater understanding of what may happen in a tunnel in the event of a vehicle flashover fire.
It is considered feasible to use the concepts proposed in this paper to develop an outline calculation methodology, but it is noted that because of infrastructure variables, it may not be possible to define a fully standardised process.

Keywords: rail vehicle, heat release rate, fire, EU499 Eureka Project, Transfeu Project, Metro Project, CFD

1. Introduction

Rail vehicle peak heat release in the event of a fire is an important parameter, especially for trains operating in tunnels because a vehicle fire is a credible tunnel fire ignition source and:
- A fire with a high heat release rate may affect occupant survivability because it is a factor in evacuation and rescue capability.
- Tunnel structural and ventilation requirements are defined based on the expected vehicle peak heat release rate and are a major infrastructure cost driver.

RIFA has an objective to support activities aimed at agreeing a robust standardised process of determination of peak heat release. RIFA has specifically tasked Mott MacDonald to prepare a paper which reports:

„Experience regarding development of and results from estimations of rolling stock peak fire size; covering peak values, real fires, open gangway trains, research projects like Transfeu, fire growth rates and methods to establish fire sizes (Duggan and Boon), with the initial focus on Network Rail, London Underground, Crossrail and other London Services".

This report, which is a development of a paper written by the author presented at the Fire Safety of Rolling Stock Conference 2009 [10], is intended to satisfy these objectives. It reviews the alternative ways in which vehicle fire peak heat release is currently estimated, and proposes a development programme for a validated calculation method. The process for determination of peak heat release in the event of a fire on board a train is not standardised. Issues which have prevented the definition and modelling of such a process have included questions about:
- The appropriate ignition source size.
- The rate of fire growth.
- Whether to consider only an internal saloon fire, or to additionally or separately consider an underframe fire.

The issue of how to calculate peak heat release rate has proved controversial in recent years, especially since the widespread adoption of open gangway tr a further variable into the discussions – the potential for a fire to progress through the length of a train which could be over 100 m long. The issue of peak heat release rate is separate to the assessment of potential spread of smoke or toxic gas effluents in the train as a result of an internal fire, which requires a separate analysis.

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2. History of rail vehicle peak fire size estimation

Current European Vehicle Fire Safety Standards, including the recently issued EN45545 [4] do not consider potential peak heat release rates. The US Rail System Fire Standard – NFPA130 [8] does reference vehicle heat release rates, which is consistent with its whole rail system scope (compared to BS 6853 and EN45545 which only address vehicle issues). NFPA130 Annex A 8.5.1.3.2 indicates that computer models are typically used to calculate such data, and indicates that a floor fire barrier (such as specified by BS 6853 section 7) will offer protection to people on board in the event of an underfloor fire. NFPA130 does not define any particular approved process or specify a limit for peak heat release rate. NFPA130 also describes in an informative annex (Annex D – Rail Vehicle Fires) an overview of pertinent issues related to peak heat release rates. The methods used in the rail industry when NFPA130 is not the reference document include:

- Interpolation from Test in projects such as EU499 [4] and Metro [6] – Both carried out in Scandinavia.
- Calculation based on Heat Content (Calorific Value limit or Boon method) [9].
- Time based summation of heat release rate of individual materials or vehicle sub systems (HRRPUA – based on a methodology defined by Mr G. Duggan) [3].

Details of these options are considered below.

2.1. Interpolation from Test

There have been a limited number of tests carried out on full size rail vehicles, and the data for some of these tests has been published as follows.

2.1.1. EU499 Eureka Tests

Results from this series of tests carried out in the 1990's were published in a number of papers by Professor Ingasson of SP (Swedish National Testing Institute), including reference [5].

This work included data from one off tests of a variety of road and rail vehicles, including one said to be 'similar to a 1990's German High Speed Inter City (ICE)' train and an obsolete Metro Train, likely to have been built to the fire safety standards in place in the 1960's.

The result for the *'ICE'* Vehicle was 13.7 MW. This carriage had a „theoretical" heat load of 77000 MJ. The result for the obsolete Metro Vehicle was 35 MW. This carriage had a „theoretical" heat load of only 43000 MJ.

2.1.2. Metro Project

The Metro Project was reported in 2012. This also tested an obsolete Swedish Metro car, the SL X1 train (Fig. 1). Prof. Ingasson was also involved in these experiments.

Fig. 1. The SL X1 Car

Two series of tests were carried out:

- The first test used the vehicle as delivered without any design modifications.
- The second test used the same vehicle type with a modern „C20" interior fitted inside the original wall panels. The „C20" was built for the Stockholm Metro system between 1997 and 2004 (and therefore of a similar age as the LUL Jubilee Line trains. It is not known whether the C20 units met the same very high fire safety standards as the LUL units).

The fire performance specified for the SLX1 and C20 is not known. The ignition sources used were cases said to be representative of passenger luggage defined using a separate work package. The maximum rate of heat release measured in both tests was 77 MW (For the unmodified car, this was reached after 12.7 minutes, and for the car where the new interior was fitted over the existing panelling, this occurred after 117.9 minutes – nearly two hours!). The tests also reported:

- The amount of ventilation available significantly changes the rate of heat release. Increased ventilation levels generally increased the peak heat release rate.
- *„…a local flashover occurred…thus the parts distant from the initial fire need much more time to reach local flashover.*" With all doors open (i.e. with no ventilation restrictions), *'the spread from left corner to right corner took about 17 minutes in real scale.'*
- *„…the seats alone did not contain sufficient fuel for the fire to spread within the train, ...there needed to be luggage in between the seats and enough combustible linings* (wall/ ceiling panels)*"*.
- *„…the combustible linings were found to strongly influence the fire development, even if these are only a small proportion of the fire load in the train carriage."*

- The presence of both luggage and petrol were necessary for flashover to generate the necessary conditions. „*…the laboratory tests showed that in the cases where the initial fire did not exceed a range of 400–600 kW, no flashover was observed. If the initial fire grew up to 700–900 kW, a flashover was observed.*"

It is noted that the materials of the train walls were considered to have made a significant effect on the results obtained. It is expected that standards such as BS 6853 and EN45545 prevent the use of materials as used in the X1 carriages, so it is considered that for modern trains built to the highest fire safety standards such as those currently specified by LUL and TfL:

- The recommendations made as part of the Metro project are extremely conservative.
- It is likely that fire growth rate and peak heat release rate will be expected to vary with materials used and train design. The limits of 8.8 MW peak heat release rate currently specified for LUL Metro type trains may be appropriate for vehicles manufactured to equivalent standards.

Experimental data typically requires verification to confirm consistency of results between specimens, and likely range of variation. It is for this reason that the standard flame spread test (BS 476-7) requires testing of six samples before a formal classification can be reported. These tests necessarily are single samples, which are very useful information, but with a high level of uncertainty, with a wide number of variables.

2.2. Calculation Based on Heat Content

This method calculates the theoretical heat release rate based on the heat content of the actual design.

2.2.1. Estimation of Heat Content

British Rail in their Fire Safety Code of Practice CP-DDE-101 used a limiting value of 1100 MJ/m^2 of the floor area of the saloon areas of mainline and suburban rolling stock built in the 1980's and the early 1990's. Some TfL Docklands trains had an absolute limit for the saloon, floor and underfloor areas of their rolling stock.

Non UK train administrations also follow this type of limitation, for instance requiring a maximum of 28000 MJ per carriage for Metro stock, which is consistent with an expected value of approximately 500 MJ/m^2 which may be typical of a modern Underground train carriage.

Assuming all the heat content in one carriage is consumed in an hour, the 28 000 MJ value indicates an equivalent to a rate of heat release of 7.7 MW, which is in an equivalent range to the current London Underground limit of 8.8 MW as determined using the Duggan method. It is noted that the tests reported by Prof. Ingasson did not conclude the measured peak fire load was proportional to the original vehicle heat content. In EU499, the opposite conclusion was found – the lower heat value vehicle resulted in the higher peak heat release value, probably because of different material performance.

There is no certainty that heat will be released during a fire at a rate proportional to the duration time. The tests conducted as part of the Metro project had widely differing times to peak heat release. There is only limited data available from small scale tests to investigate this issue because they generally are specified to last for only 30/40 minutes. Data from these tests does indicate significant differences in performance between different materials, so it is reasonable to believe that it is unlikely that the heat content of the design will not be released at a rate proportional to elapsed time. There are also a number of other issues which make this method an unreliable one:

- It is unlikely that all of the theoretical heat value of all the interior materials will be totally consumed during a fire. Materials used to satisfy modern rail vehicle Fire Safety specifications such as BS 6853 and EN45545 are required to have stringent Fire Propagation properties (such as Flame spread and Heat Release Rate), which may limit the extent of their involvement in any fire. Some components may shield and protect others from the ignition source.
- In the event of a flashover fire, the real scale testing has reported that a fire would be expected to start in one zone of a carriage, and progressively spread to other areas as the original peak reduces, making it unlikely that a full carriage would be the appropriate zone size.

For these reasons, it is concluded that this type of analysis is subject to a high level of uncertainty, and data from such tests cannot be used with confidence.

2.2.2. „Boon" Method

Boon [8] carried out a comprehensive analysis of peak fire size predictions for Singapore Metro as part of his PhD dissertation at Christchurch University. He also used an estimate based on the heat content of rolling stock. He concluded: „*A peak HRR value of 5 MW has been proposed for a metro train fire at the station trackway and a peak HRR value of 10 MW has been proposed for a metro train fire in the tunnel.*"

It is uncertain why the limit is proposed to be changed between the two operational situations. The proposed requirement for a Metro fire in the tunnel is higher than proposed for the station, and therefore contradicts Ingasson et al in the Metro project. The proposed values of 5 MW and 10 MW are both in the same range as the current LUL limits of 8.8 MW.

Boon discusses options on how best to manage the issue that it is unlikely that the whole train will reach flash over simultaneously. CCL Singapore were said to have used a delay of 20 or 30 minutes between open carriages on some contracts. For the contract being considered by Boon, a 10 minutes delay between carriages was specified. Boon proposes a rolling spread of 10% per car length travel per minute, equivalent to a 10 minute delay factor between cars, which is more conservative compared to the Metro project proposal, where a delay of 17 minutes side to side was reported.

Boon's proposal appears to have some merit, but as written introduces another possible inconsistency. It would allow long carriages to be treated more leniently than short carriages (10% of 10 m is 1 m, while 10% of 20 m is 2 m). For any future standard, it is recommended that this value is specified in terms of rate of spread (i.e. x metres spread per minute).

Boon also notes that the fire development rate will vary with installation, depending upon issues such as quantity of burning materials, geometry of train and tunnel, and extent of ventilation. This conclusion suggests the rate of fire development varies with each incident, indicating that a standard calculation method may give misleading results.

The issue related to quantity of burning material may be significant for modern designs where there are frequent large vestibules without seats or other equipment. These areas may act as a „Fire Break" which will significantly reduce the rate of fire spread, making the standardisation of a rate of fire development more difficult to define. Boon's calculation method also takes account of a contribution of underframe equipment, which is not considered in other methods.

2.3. Heat Release Rate per Unit Area (The Duggan Method)

The Duggan method [8] of estimating peak heat output is currently the norm for LUL and TfL projects, as well as a number of other projects around the world. Standard Fire Engineering principles have identified that the area of peak heat release in a flashover fire occurs at the ceiling level, and the standardised level of heat release here is 50 kW/m^2. For walls and floor areas, the respective levels of heat release are 35 kW/m^2, and 25 kW/m^2.

An estimate of heat release rate per unit area for a material or composite can be determined via the Cone Calorimeter Test Method – ISO 5660-2, carried out at the same standardised radiation levels. This test value is converted from the 100 mm × 100 mm test piece area to an equivalent value for the area of that material/ composite used in a particular design, assuming the rate of heat release will be proportional for large areas as for small areas.

To determine the HRRPUA peak heat release rate estimate for a complete car, the values for each individual material/ composite multiplied up to represent the whole vehicle area are summed. This is described in more detail in reference [3]. This method has the benefit that the output from materials which have a peak release rate near the test start time may be balanced with materials which peak later in the test, with a resultant predicted value lower than if all materials are assumed to peak simultaneously at the calculated end time.

The ISO5660-2 output includes transient spikes resulting from testing issues which would not be expected to have a major macro effect on perceived heat emission, and which would not be considered to affect the safety issues for which the peak value is calculated. The protocol described by Mr Duggan includes a „smoothing" process to eliminate these spikes. It has been noted that there is some variability in the „smoothing" method used by different practitioners of the HRRPUA. Various HRRPUA reports have used a smoothing average over a range 20–60 seconds, and it is noted that the greater the smoothing interval, the lower the predicted peak value. This means that for the same data smoothed using a 20 second average, the predicted peak value would be higher than if the smoothing were done using a 60 seconds average.

Mr Duggan's paper has described guidelines on how smoothing should be carried out, but it is recommended that these are made more explicit in a future standard to avoid any concern that the smoothing time has been adjusted to achieve specified limits. This calculation method results in predicted peak values of less than 8.8 MW for modern Metro type trains operating on LUL and TfL networks. Rolling stock used on other mainline networks typically has a predicted peak value of 15 MW, which is actually consistent with the other methods described in this report.

2.4. Calculation of Heat Release Rate Using computational analysis

NFPA 130 indicates that computational analysis may be carried out to determine heat release rates. There are a number of computer based analysis methods which can be used to predict the rate of fire growth, and as a result, to predict the peak heat release rate following a specified ignition event.

Older methods such as C-FAST may be used to give a macro view of the likelihood of flashover, and resultant peak heat emission value. This is a 1 zone or a 2 zone analysis method, which uses standard physical constants and fire performance to estimate fire growth rate. Such tools allow ready generation of guidelines for rate of fire growth.

There are more complex computational fluid based analysis (CFD) tools available. The most common software is NIST FDS (which is free to all users). Many other tools are available such as SMARTFIRE from Greenwich University and Jasmine from BRE. These all claim particular benefit, maybe for a specific application. The CFD process analyses a detailed 3D mesh pattern of the structure to determine the rate of a variety of fire growth properties. The mesh typically has a cell size of 5 cm. All cells in the mesh are treated as solid materials with fixed properties, and a separate calculation to determine flame spread, heat release rate and smoke production is carried out for every interface at frequent intervals (0.2–0.5 seconds) for the required time period. This process typically uses a cell count of 200 000. This process therefore involves a significant number of calculations, and requires a large amount of computer power and takes a considerable time.

CFD is routinely used in the UK to aid building designs, but at present, its use to evaluate the rate of fire growth on rail vehicles is limited, and consequently, the extent of validation data available is also limited. One input is the results from ISO5660 tests, as for the HRRPUA method. Other inputs are assumptions on combustible fraction of the materials used, smoke production rates during test, how to set up the boundary conditions for assessment, the numerical set up and the physical modelling parameters. CFD is therefore considered uncertain by some authorities.

However, as described above, the validation for other estimation purposes is not available in any significant depth, and there are many potential variables in the set up and calculation methods which are often accepted as the best available estimate for the process used, so it is not considered certain that CFD will be any less reliable than traditional methods. It is also noted that CFD does have some advantages of its own – repeat runs with different set ups and scenarios can readily be carried out if required, enabling a sensitivity analysis to be readily prepared, unlike for other processes.

3. Discussion

3.1. Required Ignition Source to Generate Flashover

All of the estimation methods reviewed assume that there has been a sufficient ignition source to generate a flashover. The Metro R&D project team reported that the size of ignition source required to generate a flashover fire is over 700 kW. Duggan references a heat source of 1.5 MW in the assessment of the HRRPUA method. Various large scale tests on modern rolling stock designs have also indicated that large ignition sources are required to generate a flashover.

It is therefore reasonable to conclude that for a modern rolling stock design, an ignition source of the order of 1 MW is required to generate a flashover fire. Assessment of public data suggests that the overwhelming majority of fires within train interiors have a power which is consistent with the limits defined in EN45545-1 source 5 up to 150 kW, which is much less than the size required for flashover.

This disparity may contribute to the reason why flashover fires on board trains are very rare, and caused by a variety of unpredictable events. They require a different operational management to the more common, but still rare small arson or technical fires.

3.2. Calculated Peak Heat Release Rates at Flashover

The analysis techniques described in this paper indicate typical peak fire sizes as follows:

Method	Predicted Peak Fire Size – MW	Vehicle Description
Eureka Test	35*	1960's? Metro
	13.7	1990's DB ICE
Metro	77 – after 12.7 minutes*	1960's? Metro
	77 – after 117 minutes*	1960's? Metro overlaid with 1990's Stockholm C20 Interior
	60	Proposed if fast growth model used
	20	Proposed if medium growth model used
Calorific Value/ 60 minutes burn time	7.7	Metro Car – 28000 MJ
	16.94	Intercity car – pro rata based on 1100 MJ/m^2 compared with 500 MJ/m^2
Boon	5	Metro – Station
	10	Metro – Tunnel
		Proposal to include a staged time delay
HRRPUA (Duggan)	8.8	LUL Limit
	15	Inter-City coaches

The values marked * as determined for actual tests of Metro vehicles used very old rolling stock (~ 50 years old). They would not have been built to performance levels which even approach current standards, so it is highly unlikely results would be representative of current designs. For this reason, that data has not been considered in the following analysis. Using the data for the other estimates, values are consistent within a wide range – for Metro vehicles, the LUL defined value of 8.8 MW (as determined by the HRRPUA – Duggan methodology) is consistent with the Calorific value estimate (7.7 MW) and within the boundaries of Boon-Chiam (5 MW or 10 MW, depending upon ventilation levels). For Mainline coaches outside the TfL control, the value of 15 MW used in some UK and overseas operations is also consistent with the Eureka test results, the Calorific value estimate and the Duggan method estimate.

3.3. Limitations to Confidence in Peak Heat Release Rate Calculation

A number of factors have been identified which could cause variability in the value determined for peak heat release rate as follows:

- Should a full car length (or in the case of an open gangway train, a full train length) be considered to the same time base? It has been noted that because of the heat input of ~1 MW needed to flashover railcars, it is unlikely that full car lengths would simultaneously experience these levels and flashover simultaneously. Fire development is likely to be a progressive event.
- Vehicle designs typically include multiple large vestibules around doorway areas where there is very limited combustible material and the fire development process is not obvious.
- It is therefore considered reasonable to include a time delay between different vehicle / train sections, especially taking into account modern commuter train design where there are often a series of wide, relatively empty vestibules between limited seating areas.
- Is it reasonable to expect all materials are totally burned by the fire, releasing their total calorific potential? It is expected that some materials will be protected from any heating event. For instance the seats may shield the floor, and bulkhead panels near doors may protect adjacent surfaces. Some methods analysed take account of this, by for instance assuming only 75 or 80% efficiency.
- Formal account is not taken in the peak heat release calculations for minor materials. In the referenced paper, Duggan uses a notional 3 MW addition to the calculated peak for this purpose, but it is not known how this was calculated, so it requires some quanitative assessment and validation.
- Should the ignition source be included in the final estimated value? Duggan includes a value for the ignition source – in the situation referenced; this is a severe luggage stack fire continuous heat output of 1.5 MW, but other processes do not include any such allowance.
- Should any allowance be made for other train borne heat load, such as luggage etc. It does not appear that Duggan took any account of such imported risk, but it may be considered he has already included for it in the 3 MW addition for minor items referenced above.
- What level of ventilation should be used in any analysis? Results from the Metro tests indicate that the level of ventilation has a significant effect.
- If a HRRPUA process is formally adopted, a protocol is required for smoothing to ensure reported values are not too optimistic or conservative compared to expectations.

If a standardised specification is eventually raised to determine a notional value for peak heat release rate from rail cars, these issues all require to be standardised.

3.4. Proposals for Future Work

It is suggested that the following are each addressed as part of any future development of this work stream:

- Consider whether to include a factor to standardise assessment of smaller standard length carriage sections, based on them reaching their notional peak heat release value at different times. FD analysis may help to validate the proposal by Boon that, it is suggested that the delay could be ~10 minutes per carriage section.
- It is not considered reasonable to assume the whole calorific value is released during a fire. Boon-Chiam addressed this by adding an „efficiency" factor into that calculation. The Duggan HRRPUA methodology does not formally take this into account. It is therefore considered that further research is carried out to estimate the likely effects of such issues and to confirm Boons estimate or propose an alternative.
- Include a validated estimate for minor materials. If data can be determined, use some data from a modern train design to verify the 3 MW proposed by Duggan.
- A value should be added to the calculation to take account of the contribution of the ignition source. A value also has to be added to take account of the possible contribution of the imported train borne luggage. These should be considered together to avoid double counting, because the luggage is often considered to be the ignition source
- Consider testing whole cars or sub sections to define an approved CFD analysis process. The cost of testing whole cars is very high. A possible alternative is to test a car section built to replicate design standards using the ISO9705 hood currently specified in EN45545 as part of the seat test method.

It is noted that for many of the above issues, they are likely to be design or operation specific. Examples include:

- Modern infrastructure built to latest design requirements (such as those defined in the TSI

standards) may have different performance capabilities than older installations.
- An airport train is likely to require a higher input for luggage than an inner city metro train.

The HRRPUA method only calculates a theoretical heat release rate for train interiors, and does not take any account of underframe fires. Since modern Fire Safety requirements specifications for rolling stock generally includes requirements for floor fire barriers, this may be considered reasonable. For tunnel and station ventilation purposes, it is recommended that if the HRRPUA calculation method is used, a supplementary assessment of risk from potential underframe fires is also undertaken. The results from the above research will allow a standardised process for estimation of peak heat release for design purposes.

3.5. Tunnel – Vehicle Interaction

In the event of a vehicle flash-over fire, the rate of radiation from the vehicle will be affected by the vehicle design (e.g. variation in ventilation levels, including any automatic HVAC reaction in the event of a fire which may change the rate of reaction, variation in the insulation in the vehicle design which will modify the rate of radiation out from the vehicle) and the tunnel design (i.e. a large tunnel volume will perform differently to a tight tunnel volume).

These impacts may have an effect on the infrastructure reaction, so need to be considered in any future assessments. For these reasons, it is suggested that a further work package considers how vehicle / infrastructure variation affects resultant impact.

4. Conclusions

A review has been carried out of data available concerning train vehicle peak heat release in the event of a fire on board rolling stock. It is noted that any fires on board trains are very infrequent. Fire instance, UK data indicates it is more likely that trains will become involved in collisions than a significant fire which causes injury to anyone.

The values currently in use in the UK, based on HRRPUA, based on the Duggan methodology, are consistent with other data. I.e. The limits of 8.8 MW for Metro cars and 15 MW for Intercity cars appears to be comparable to other reported estimation methods. This may mean all methods are very conservative for current rolling stock.

The HRRPUA process seems more pragmatic than some, with some real time basis from material heat release rate data. Some areas which require further research and assessment have been identified, and with the resultant modification, HRRPUA may be considered a suitable pragmatic ongoing method. Some initial analysis has been carried out, and recommendations have been made on how to develop a future standard practice for this property. The principal issues are:
- Consider using a time delay factor based on the low likelihood of simultaneous flashover over the whole vehicle (or train) length.
- Agree a standard methodology for treatment of minor materials and luggage.
- Agree a standard methodology for time based smoothing of results.

However, a large number of infrastructure based issues have been identified which prevent a standardised assessment of the heat impact on tunnel infrastructure even if vehicle output is more accurately controlled. This may mean that a different assessment is required for each application, and no standardised limits can be used in such calculations.

Following suitable development and validation, the CFD methods described will take real time account of the issues which have been identified as uncertain in the HRRPUA method. They will allow multiple runs to assess variables in design and their effects, so is considered the best method currently available, provided suitable validation is carried out. It is recommended that CFD research is carried out to identify or produce the necessary validation with a view to it being adopted in the longer term as the calculation method of choice.

5. Next Steps

It is proposed that further research is carried out to identify a standardised working protocol for the HRRPUA assessment method. This could allow preparation of a formal specification for determination of vehicle peak heat release using the validated HRRPUA method. A number of infrastructure based variables have been identified, and their effect on the heat impact on the infrastructure from a vehicle fire requires further investigation. In the longer term, work is required to fully validate the CFD methodology and to define a working protocol for assessment of peak heat release in future. An action plan should be considered to this is achieved as soon as possible.

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Szacowanie największej prędkości wydzielania ciepła przez pojazd kolejowy

Streszczenie
Artykuł opisuje różne metody stosowane do szacowania energii pojazdu wydzielanej w przypadku gwałtownego rozgorzenia (*flashover*) w pojeździe kolejowym.
Autor przytacza dane z badań w skali rzeczywistej i rozważa, czy mogą być one wykorzystane do innych celów. Podaje również metody obliczania używane w różnych aplikacjach, takich jak: szacunki na podstawie zawartości ciepła, metoda Boon-Chiam'a i obliczanie gęstości mocy pożaru Duggana (HRRPUA). Artykuł zawiera przegląd i opis cech charakterystycznych wymienionych metod obliczania. Charakteryzuje ilość energii potrzebnej do stworzenia rozgorzenia w pojeździe kolejowym oraz ograniczenia dotyczące pewności obliczania największego wydzielanego ciepła. W artykule zaproponowano koncepcje przyszłych programów prac w celu umożliwienia korzystania z uznanej metody analizy CFD (obliczeniowej mechaniki płynów). Analiza ta, umożliwia zrozumienie, co może się zdarzyć w tunelu podczas rozgorzenia w pojeździe kolejowym. Koncepcje zaproponowane w artykule mogą być wykorzystane do opracowania metody obliczeń, jednak ze względu na zmienne parametry infrastruktury, może nie będzie możliwe zdefiniowanie procedury w pełni znormalizowanej.`

Słowa kluczowe: pojazd kolejowy, prędkość wydzielania ciepła, pożar, projekt EU499 Eureka, Transfeu Projekt, Metro Projekt, CFD

Оценка самой большой скорости выделение тепла единицей подвижного состава

Резюме
В статье описаны разные методы оценки энергии единицы подвижного состава выделаемой в случае резкого распространения пожара (*flashover*) в единице подвижного состава.
Автор приводит данные из тестов в реальной шкали и обсуждает, могут ли они быть использованы для других целей. Приводит также методы вычислений использованные в разных аппликациях, таких как оценки на основании содержание тепла, методов Бун-Хиана и удельная мощность пожара Дуггана (HRRPUA). В статье содержается просмотр и характеристику каждого метода вычислений. Обсуждено количество энергии нужной для получения резкого распространения пожара в единице подвижного состава. Затем описаны ограничения уверенности вычисления самого большего выделения тепла. Предлагается некоторые идеи будущих программ работ их минимизации, что предпологает возможность использования признанного метода анализа вычислительнной гидродинамики CFD. Этот анализ позволяет понять то, что может произойти в случае выступления резкого распространения пожара в единице подвижного состава в туннеле. Предлагаемые в статье концепции могут быть реально использованы для разработки методики вычислений. Однако из-за изменчивых инфраструктуры, определние вполне нормализированной процедуры может показаться невозможным.

Ключевые слова: единица подвижного состава, скорости выделения тепла, пожар, проект EU499 Eureka, проект Transfeu, проект Metro, CFD