



Bus Fire Safety

Feu – Fibres naturelles

ECOFRAM-2018

PolyFlame est une newsletter à destination des chercheurs et des industriels du domaine du «comportement au feu des matériaux organiques». Cette newsletter périodique est publiée via la Société Chimique de France (SCF).

A travers cette newsletter, vous découvrirez les nouveautés et les dernières avancées

dans le domaine du comportement au feu en matière de recherche et développement, la synthèse et la production de nouveaux systèmes de retardateurs de flamme, les besoins industriels. Pour faire avancer la connaissance et l'expertise, une partie de cette newsletter est consacrée à l'écoute des chercheurs et des industriels reconnus dans ce domaine.

Bonne Lecture,

*Bus Fire Safety Research for Reducing the Risk of Fires**

Björn Sundström and Fredrik Rosen

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Bus transportation is regarded as one of the safest modes of public transportation and millions of passengers ride safely every day to and from work, school and for pleasure. However, a fire resulting from a collision or failure of a component puts lives at risk and will impact on operational costs as well as on customer confidence.

Aircraft, trains and passenger ships all have well established standards, regulations and certification processes to ensure the maintenance of high levels of safety as new materials and constructions are introduced. Buses on the other hand, mostly rely on the efforts of the OEMs, operators and suppliers of fire systems to ensure safety in an environment of few strict regulations.

Bus fire safety encompasses many aspects of design, operation, maintenance, evacuation and even first responders. All have a critical role in establishing effective standards and best practices. Buses pose many unique challenges in regards to fire risks. The varying modes of operation (city, highway, long distance), unique vehicle types (School, Transit and Coach) and design changes to meet new emissions standards, provide the context for fire safety. Every area of fire hazard, whether it is an engine compartment, a battery compartment, a wheel well or even a luggage compartment, poses unique challenges of geometry, airflow, clutter, flame spread.

The engine compartment includes challenges for detection and suppression of fires. Ventilation, through fans and openings is necessary for cooling but will also increase fire

intensity and fire spread. The particularity of a windy and often dusty environment in the engine compartment influences the possibility for fire detection and fire suppression.



Figure 1: Bus fires are a common issue worldwide. (Photo: The Greater Stockholm Fire Brigade – Niklas Nordenskär)

SP Fire Research at the forefront of bus fire safety

SP Fire Research is one of the largest fire research facilities in the world and has been active in promoting bus fire safety for more than a decade. As part of this work, SP has supported the development of standards and test methods specific to vehicle hazards. The aim of such test methods is to establish performance based standards for the objective

evaluation of safety performance of products and solutions. Products are tested for performance against realistic fire scenarios and environmental aspects specific to the hazard.

New international standard/certification for bus engine fire suppression

SP Fire Research has established a certification process (SPCR183) and a test method (SP Method 4912) for testing fire suppression systems against known fire threats and environmental conditions specific to bus engine environments. A major part of the test method is since November 2015 adopted in UN ECE Regulation 107. The regulation states that installation and testing of fire suppression systems will be mandatory in engine compartments of all single-deck, double-deck, rigid or articulated vehicle of category M2 or M3 and specifically vehicles having a capacity exceeding 22 passengers, "Class III" vehicles. This will be following the transitional provisions meaning June 2018 for new types of vehicles and June 2019 for all existing types. This is indeed a major step towards increased fire safety in buses.

The SP P-mark system includes testing of the suppression systems but the incorporated components are also tested for mechanical and thermal stress resistance, corrosion resistance and ingress protection rating of electrical equipment. In addition, a risk assessment has to be made prior to installation of the system by an experienced professional. Further on, an annual follow-up inspection of the manufacturers' production facility and quality control plan ensures compliance to the requirements of the certification rules.

Successful systems are then given a certificate including the right to "P" mark components, see Figure 2. More information can be obtained from www.sp.se/safebus/certified.



Figure 2: The P-mark is a voluntary certification/quality mark for verifying and securing a high level of quality for fire suppression systems in engine compartments of buses and coaches.

Adoption of the standard is becoming more common around the globe, e.g. US Transit operators are among the first to actively include the "P" mark in their procurement specifications.

Preventive fire safety

Bus fires often relates to component failures. Due to this, SP is developing a new certification system: SPCR 190 - Certification rules for vehicle manufacturers, operators and authorized service centers (workshops) with regard to fire safety. The P-certification will enable the manufacturer/body builder/operator/authorized service center (workshop) to certify their fire risk mitigation process.

The P-certification aims at ensuring that personnel, strategies and techniques involved in fire safety mitigation of new and existing vehicles are kept at the highest performance level. It also implies that new information is incorporated and updated into best practice working procedures helping the customer to operate at the front line of fire safety.

There are three different labelling systems: $P_{\text{vehicle manufacturer}}$, P_{operator} , P_{workshop}

The certification is composed of the following elements:

1. Risk assessment
2. Quality procedures and configuration management (document control)
3. Safety certification training program
4. Reporting of thermal events (fire events) – database
5. Initial assessment of the manufacturers FPC, Factory Production Control.
6. Annual audits of the FPC.

Three of these elements are explained in more detail below.

Risk assessment:

The manufacturers, operators and authorized service centers (workshops) must do regular fire risk assessment which is a systematic study to identify hazards and make recommendations for their elimination or control during all phases of the life cycle of the product. The risk assessment includes predictive failure modes for high risk components which can facilitate the rapid identification of pending failures to hoses and lines carrying flammable fluids or components that have greatly exceeded their operational parameters.

Consequently the input from the fire risk assessment can be used for future design improvements, enhancements to maintenance documents, operation manuals and practices, replacement cycles of critical components etc.



Figure 3: Work on fire risk assessment. (Photo: Fredrik Rosen)

Safety certification training program in vehicle fire risk assessment

Mandatory education and training of design engineers, production quality control inspectors, and maintenance personnel is the basis of the certification. This includes training in vehicle fire risk assessment as well as study of hazards specific to different types of vehicles and fuels.

Reporting of thermal events (fire events) – database

The manufacturers, operators and authorized service centers (workshops) must have procedures for linking information, data and experience from actual thermal incidents in the field to the design engineers, production quality control inspectors and SP. The data will be confidentially stored in SP's database and available for the P-certificate holder.

Future goals

Fire safety in buses has been the focus of significant research in recent years but much improvement still remains to be addressed, in particular related to fire prevention and safe egress. SP has identified particular areas for necessary fire safety research, listed below. Some research has already been funded and is in progress; for others we are actively searching for funding opportunities.

Wheel well fires (containment, preventing fire through window)

The exposed environment and the risk of deep seated fires make wheel well fires particularly difficult to detect and suppress. Tests have shown that it can take less than 5 minutes before toxic fumes and smoke enter the passenger compartment. Tire pressure/temperature monitoring systems represent one method for early detection; other methods need to be explored. Previous testing of some coatings in the wheel well area has been shown to provide a significant increase in

the evacuation time before toxic fumes enter the passenger compartment. Continuous work in this area could provide a low cost solution.

Bulkheads/fire partitions (smoke tightness)

The bulkheads between high risk areas such as the engine compartment and the passenger compartment can allow spread of toxic fumes and flames into the passenger compartment. New materials and increased complexity of systems connecting the engine compartment to the driver area might increase fire hazards. This area should be investigated further.

Detection systems

SP is currently working on a project funded by the Strategic Vehicle Research and Innovation Foundation in Sweden, an independent funding agency. The project has several co-financing partners, including vehicle manufacturers, insurance companies, end users, a transport agency and several suppliers of fire detection systems for vehicles. An important part of the project is to develop a new test method and propose a standard for fire detection and fire alarm systems in heavy vehicles.

Use of flammable material in high risk areas

Lighter, less costly materials might be flammable and produce toxic gases. There are very few standards and regulations regarding the flammability and toxic fume production of such materials. Since these materials are needed further research is necessary to establish adequate performance requirements for the use of them in high risk areas in buses and coaches.

Fires induced by electrical faults

Electrical fires are not something new but with increasing use of hybrids and electrical vehicles, the number of electrically induced fires will increase. Electrical arcing and short circuits do not always trip protective devices such as fuses and some cables carry very high currents capable of producing enough heat not only to ignite nearby combustible materials, but also to cause breaches in hydraulic lines and metal covers.

The adoption of best practices for routing, securing and protection can greatly reduce the risks. Early detection methods such as current monitoring or better circuit protection should be explored.

Alternative Fuels

All over the world, new alternative fuels are emerging to replace fossil fuels. Hybrids, natural gas, all electric and even hydrogen buses, are currently being used. The overall benefit is great but with new fuels and new technical solutions, the fire hazards also change. In addition, first responders face new risks. New fuels e.g. ethanol, require new extinguishment strategies. Figure 4 shows the scenario after an ethanol fire has been extinguished using an alcohol resistant foam.



Figure 4: Alternative fuel fires like ethanol can be challenging to extinguish. (Photo: The Greater Stockholm Fire Brigade – Niklas Nordenskär)

Some countries have been using alternative fuels for more than 20 years, others are just beginning. A major challenge to the introduction of alternative fuels is the perception of an increased fire risk. Dissemination of present knowledge and development of new data is key to the wide-scale introduction of alternative fuels.

Post-crash initiated fires

Two high-profile cases of fatal post-crash initiated fires have occurred recently. The first one occurred in May 2014 in California, USA where a FedEx truck collided with a bus that was transporting high school students causing the death of 10 people. The second occurred in October 2015 in Puisseguin, France where a bus crashed into a truck, causing the burning of two vehicles and the death of 43 people. The sudden impact of the fuel tanks might create an increased pressure risking mist of diesel oil spraying from the tank. When coming into contact with hot surfaces like an exhaust a fire may start. Little is known about post crash fires and more research is needed.

Interior materials

SP is doing work on interior materials. As part of the research full-scale fire tests of coaches have been conducted. The full-scale tests clearly demonstrate that once flames reach the passenger space, flashover will occur quickly. This is clearly

insufficient and stricter performance requirements are needed.

Durability of components due to long term heat exposure

The subcontractors of engine compartment components specify the ambient operational and maximum temperatures for the environment in which the component is going to be placed. The maximum temperature is the peak temperature under short periods of time but a frequent misconception is that the component can be placed in a maximum temperature environment for a constant period of time. A lot of the hosing material is petroleum based and longtime use in a warm environment will make the petroleum to evaporate. The consequence of this might be that these hoses become stiff and brittle. This in turn might create rupture and leakage potentially spraying flammable fluids on hot surfaces.

Future developments

Establishing standards and best practices will ultimately lead to legislation that is based on sound scientific knowledge and best practices. It is believed that this development will continue.

If you have any questions or would like to share some of your experience or best practices you are welcome to contact SP Fire Research.

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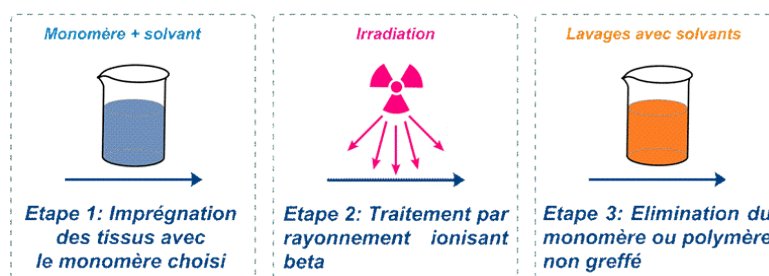
**Cet article a été publié pour la première fois dans la newsletter n°54 de "Brandposten". Nous remercions Björn Sundström et Fredrik Rosen de nous avoir autorisé à le publier.*

Ignifugation de fibres naturelles par greffage de retardateurs de flamme sous rayonnement ionisant

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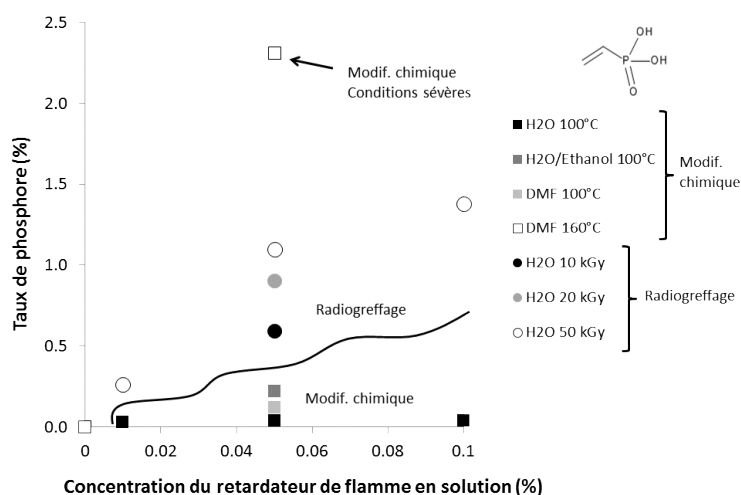
Différents travaux menés par le C2MA de l'Ecole des Mines d'Alès (projet FUI BIONICOMP porté par la société Ionisos, projet FERIA sur fonds propres, thèse de Raymond Hajj en cotutelle avec l'Université Libanaise) visent à conférer aux fibres naturelles de nouvelles fonctionnalités, notamment des propriétés ignifuges, pour des applications textiles et composites en utilisant la technologie de radio-greffage (bombardement électronique). Le procédé consiste à immerger un tissu dans une solution contenant des molécules retardatrices de flamme porteuses d'insaturations. Après imprégnation et séchage à température ambiante, le tissu est irradié sous faisceau d'électrons accélérés puis lavé pour éliminer l'excès de molécules n'ayant pas réagi.



Etapes du procédé d'ignifugation par radiogreffage

L'intérêt du procédé est de permettre un contrôle fin du greffage au travers de différents paramètres opératoires : choix et concentration du retardateur de flamme en solution, choix du solvant, dose d'irradiation. Le radiogreffage de retardateurs de flamme de différentes natures a été étudié et comparé à d'autres voies de modification. Les molécules phosphorées se sont avérées particulièrement efficaces. Il a été montré que la phosphorylation de la cellulose par voie chimique ne permettait d'atteindre des taux de phosphore significatifs qu'à des

températures élevées dans des solvants organiques. Le greffage de molécules phosphorées sur la lignine peut être réalisé dans des conditions plus douces, mais le faible taux de lignine dans les fibres de lin (< 3%) limite cette voie de fonctionnalisation. Au contraire, des molécules promotrices de char, éventuellement en solution aqueuse, peuvent être facilement radiogreffées permettant de développer des tissus de lin auto-extinguibles.

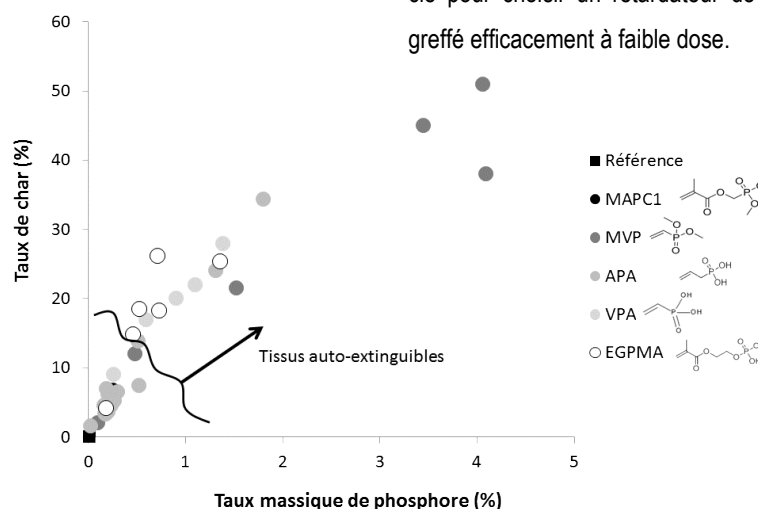


Taux de phosphore obtenu après radiogreffage ou greffage par voie chimique d'acide vinylphosphonique sur tissu de lin

Un taux de phosphore de l'ordre de 0.5-1% en poids suffit à conférer au tissu des propriétés d'auto-extinguibilité, quel que soit le retardateur de flamme considéré. Les meilleurs résultats ont été obtenus en greffant des molécules porteuses de groupements phosphates ou phosphonates, permettant d'atteindre des taux de phosphore jusqu'à 3-4% en poids, même à des doses faibles (10-20 kGy) n'altérant pas les propriétés mécaniques des fibres (la cellulose étant sensible

aux rayonnements ionisants). Un tel taux est rendu possible par la pénétration lors de l'imprégnation des molécules à cœur des fibres élémentaires poreuses puis par leur greffage ou éventuellement leur homopolymérisation sous rayonnement.

Dans ce cas, les polymères formés restent piégés dans la structure ligno-cellulosique et ne sont pas éliminés par le lavage ultérieur. La réactivité de la double liaison C=C est la clé pour choisir un retardateur de flamme susceptible d'être greffé efficacement à faible dose.



Influence du taux de phosphore sur le taux de char mesuré lors de l'essai d'auto-extinguibilité pour différents retardateurs de flamme phosphorés

Les travaux à venir concernent la caractérisation fine du greffage, le radiogreffage de nouvelles molécules ignifuges et l'utilisation de tissus ainsi fonctionnalisés comme renforts de composite pour réduire l'incorporation de retardateurs de flamme dans la matrice polymère. En parallèle d'autres

fonctionnalités sont envisagées telles que l'hydrophobisation/oléophobisation. La souplesse du procédé permet en effet de greffer en une seule étape plusieurs molécules d'intérêt, éventuellement de manière régiosélective (greffage cœur-peau).

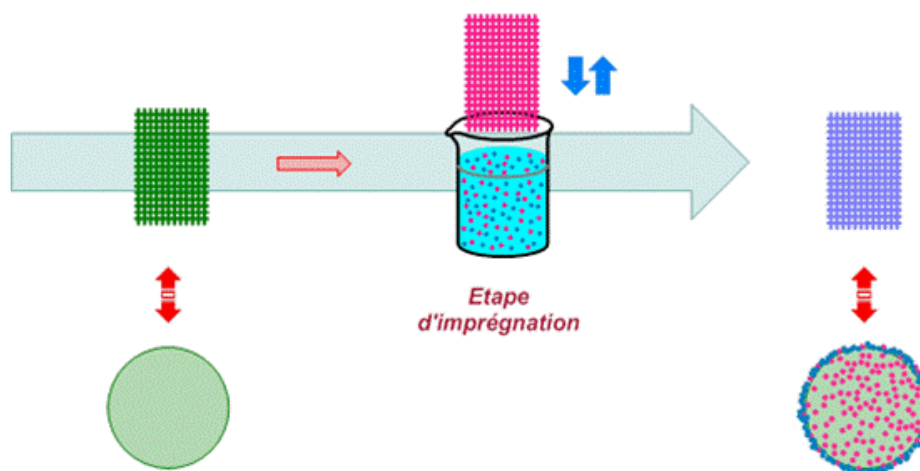


Schéma représentant l'étape d'imprégnation de deux molécules d'intérêt avec localisation différenciée dans la section des fibres élémentaires

Références

Sonnier et al., European Polymer Journal 68, 2015, 313-325

Teixeira et al., Radiation Physics and Chemistry, <http://dx.doi.org/10.1016/j.radphyschem.2017.10.013>

Hajj et al., Polymer Degradation and Stability, in press



THE SECOND INTERNATIONAL CONFERENCE ON
ECO-FRIENDLY FLAME RETARDANT ADDITIVES AND
MATERIALS (ECOFRAM)

CALL FOR PAPERS

<https://ecofram2018.com/>



TEMPLE NEUF / METZ

Metz, 28-29th March 2018, France

LMOPS and French Chemical Society are pleased to announce that the Second International Conference on ECO-friendly Flame Retardant Additives and Materials (ECOFRAM) will take place in Metz in CentraleSupélec School, France on the 28th & 29th March 2018

Over the two days, the conference will be devoted to the state of the art as well as the latest development of basic and applied research concerning the development of eco-friendly flame retardant additives and materials

KEY TOPICS INCLUDE:

- New and Sustainable flame retardant additives
- Bio-based FR additives and polymers
- Life cycle analysis of flame retardant products (ageing, recycling)
- Environmental aspects, fire toxicity and smoke
- Fire retardancy of fibers, textiles and composites
- Industrial applications and markets for Eco-FR products
- Regulation, standardization and fire testing

INVITED SPEAKERS

- Dr. Jenny Alongi: University of Milan, Italy
- Dr. Sabyasachi Gaan : EMPA- Materials Science and Technology, Switzerland
- Prof. Jean-Luc Gardette: Institut de Chimie de Clermont Ferrand, France
- Dr. Anna Stec : UCLan, Preston, England

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Abstract deadline (poster and oral presentation): 15th december 2017

	Student delegate	Full delegate	Exhibition
Early (before 15 january 2018)	190 €	300 €	700 €
Late	250 €	380 €	

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