FIRE-RESISTANT COMPOSITE MATERIALS

HIGH-PERFORMANCE COMPOSITE MATERIALS, CONSISTING OF REINFORCED CARBON OR GLASS FIBRES IN A POLYMER RESIN MATRIX, ARE AN ESTABLISHED TECHNOLOGY FOR PRODUCING LIGHTWEIGHT STRUCTURES. HOWEVER, CURRENT FIBRE-REINFORCED POLYMER (FRP) COMPOSITES ARE TYPICALLY COMPROMISED TO VARYING DEGREES WITH RESPECT TO THEIR FIRE PERFORMANCE. THE AIM OF THE FOUR-YEAR EUROPEAN PROJECT FIRE-RESIST* IS TO DEVELOP STRUCTURAL COMPOSITE MATERIALS THAT EITHER ARE THEMSELVES FIRE-RESISTANT, OR PROVIDE THE MAXIMUM PROTECTION WITH A MINIMUM WEIGHT PENALTY.

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FIRE-RESIST partners

NewRail Centre for Railway Research of Newcastle University (coordinator)
EADS Deutschland GmbH – Innovation Works
Bombardier Transportation (UK) Ltd
Flensburger Schiffbau-Gesellschaft mbH & Co. KG
Germanischer Lloyd AG
Cytec Industrial Materials (Derby) Ltd
Amorim Cork Composites SA
TransFurans Chemicals BVBA
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APC Composite AB
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PROPLAST – Conzorzio per la Promozione della Cultura Plastica
Fundación Gaiker
Institut National des Sciences Appliquées de Lyon
SP Sveriges Tekniska Forskningsinstitut AB
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Steinbeis Advanced Risk Technologies GmbH

"Although the benefits of using polymer composites in rail and other transport mode structural applications are well known – lightweight, corrosion resistant, ease of fabrication of complex shapes – the main obstacle to their wider adoption is uncertainty over their fire performance," says Dr George Kotsikos, from FIRE-RESIST coordinator NewRail of Newcastle University (U.K.). "If it can be demonstrated to industry that passenger safety would not be compromised, then a wider acceptance of the materials in primary structural designs would be acceptable."

Those composites that currently perform better in fire tend to be poorer in other respects such as weight, surface finish, or processability. Yet for trains, planes, and boats, weight savings in particular translate into lower operational costs and reduced energy consumption. Bringing together the aerospace, maritime, and rail industries, FIRE-RESIST, which runs from February 2011 up to January 2015, is working to develop new material concepts together with advanced simulation methodologies to help to reduce the requirement for costly fire testing. "Rather than tackling these issues in an isolated, fragmented fashion, there is clear merit in a coordinated approach so that experiences, facilities, and solutions can be shared across the transport sectors," points out Dr Kotsikos.

The project consortium, led by NewRail, consists of 18 partners from nine countries, including leading organisations from the three industries involved (see box). The rationale was to bring together vehicle/vessel manufacturers from the three aforementioned industries, together with industry certification bodies, suppliers of fire-resistant composite materials, producers of composite mouldings, developers of new composite materials and processes, plus specialists in fire testing, in fire simulation, and in managing the risk of new product development and introduction.

Funding has been provided to the sum of €7.8 million, with support provided by the European Commission under its 7th Framework Programme.

FIRE, HEAT & FLAME SPREAD

The less than satisfactory fire performance of polymer composites is due to their organic matrix resins, which first soften on heating, causing a loss of mechanical properties and then, at higher temperatures, decompose. Decomposition results in the production of smoke and toxic or flammable decomposition products. The latter are not only hazardous in terms of lack of visibility and toxicity; they can also burn, releasing heat, which can lead to flame spread and exacerbate the fire. Furthermore, loaded composite structures often collapse in a fire within a period of minutes, depending on the magnitude of the load and heat flux. "Comparisons in fire performance of composite structures are usually made with steel structures," expands Dr Kotsikos. "Although steel does not burn, it is a good conductor of heat and therefore spreads fire to adjacent compartments. Composites, on the other hand, do not conduct heat, which limits the spread of fire, but lose their strength at relatively low temperatures. There is no reason, though, that composite materials cannot be used in structural applications with the incorporation of suitable fire protection systems, in a similar way to the approach followed for aluminium alloys."

The work of FIRE-RESIST is being carried out in the U.K. and several other European Union countries. It entails fundamental research activities in understanding the fire behaviour of the materials being developed; fundamental research on polymer chemistry to elaborate novel, fire-resistant resins; laboratory work to characterise the properties of said materials at high temperature; fire tests on samples of them; and predictive model development (based on the understanding of the fundamental properties of the new materials) to provide designers with tools to engineer the best fire protection regime with minimum weight penalty. The investigation into new formulations of materials is centred around the following three technologies, aspects of some of which are patent pending:

- **Multi-layer metallic laminates**

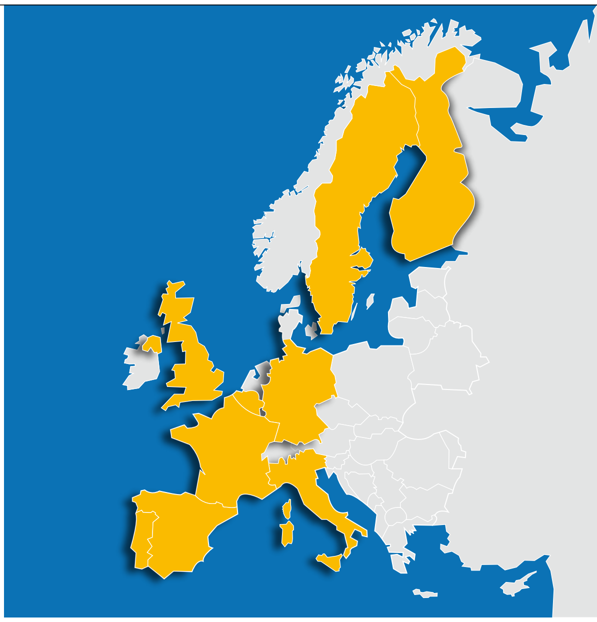
These are a novel advancement of a semi-structural material that is bonded onto to a composite or a metallic structural substrate. The laminate contributes to the structural strength of the substrate, but in the case of fire, it degrades in a manner that offers maximum protection to the underlying structure.

- **New chemical compositions of fire-resistant polymer resins**

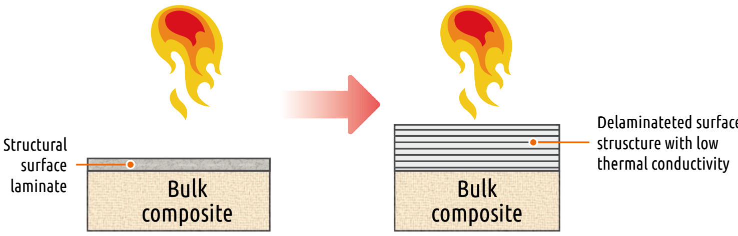
These will be used for the fabrication of composite components and structures, without any compromise in mechanical strength.

- **Commingling technology**

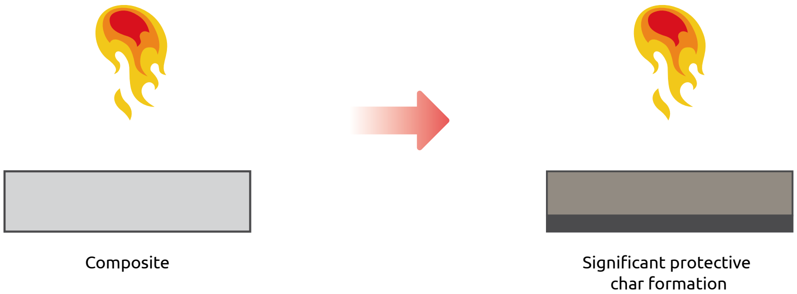
Commingling refers to fibre reinforcement mats made up of a mixture of glass (or carbon) fibres and polymeric fibres (usually thermoplastic fibres) mingled together. The mat is then placed in a mould and pressure and heat are applied. The polymer fibres melt with the heat and the melt flows around the glass (or carbon) fibre, achieving a very good 'fibre wet out' and eventually forming the matrix of the composite. New formulations of fire-resistant fibre systems are being developed to incorporate novel composite applications.



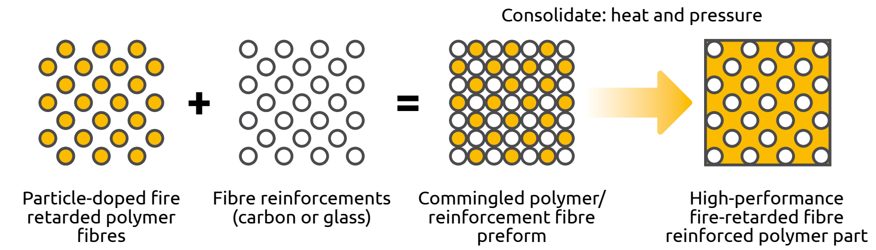
The European scope of FIRE-RESIST



New material developments 1: structural surface laminates



New material developments 2: high char-forming composites



New material developments 3: particle-doped commingled composites

Now that the project has reached midterm, "some new materials have been elaborated and are currently being tested under the 'materials characterisation' phase," reports Dr Kotsikos.
In the 4th and final year, the most promising material developments from the first three years will be applied to relevant transport sector case study components, of which at least one will be designed and prototyped for the rail, aerospace, and marine sectors, respectively. These components also will be subjected to a full-scale fire test to validate the performance of the FIRE-RESIST materials.

INTERDEPENDENCY & COMMUNICATION

While work on the above three technologies is being carried out simultaneously at various research centres around Europe, the latter are interdependent since the partners make use of each other's facilities to undertake specific research tasks. "A project such as FIRE-RESIST is one example of the merits of international collaborative research," points out Dr Kotsikos, "because the complexity of the technologies involved makes such work very difficult to be undertaken by a single entity." Furthermore, given the complexity and size of the initiative as a whole, good communication is instrumental is achieving successful outcomes, as its coordinator confirms: "There are weekly, or in some instances daily, e-mail communications between consortium members focusing on specific tasks. In addition, regular monthly web meetings take place, where partners discuss results and problems within their work package. Also, twice a year physical meetings of the whole consortium take place where progress is presented, and various issues discussed."

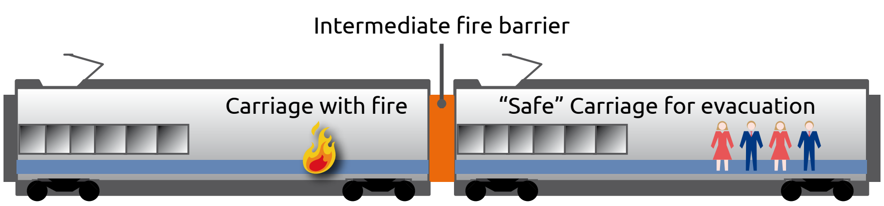
WEIGHING UP THE FACTORS

Over the past 30 years, trains have generally gotten heavier. This weight gain is due to factors such as crashworthiness (e.g. crumple zones), performance (e.g. tilting mechanisms), and passenger comfort, convenience, and accessibility (e.g. power points, air conditioning, and disabled toilets). Yet there are strong commercial and environmental justifications for seeking to reduce the mass. Compared to their weightier counterparts, lighter rolling stock would consume less energy/fuel in operation, produce lower overall CO_2 emissions, cause less damage to the tracks, and prove cheaper for operators to run.

When seeking to build a lighter train, optimising their specifications or their design, e.g. multifunctional components, joints and fixtures, or wireless versus cabled technologies, are two valid and proven approaches; the third is to optimise the material selection. In the rail industry, FRP composite materials are a well-established enabling technology for lightweighting; indeed, in trains they are nothing new – in the U.K., rolling stock with FRP doors was running from as early as the 1950s. Today these composites are routinely employed for semi-structural and decorative train applications such as fairings, interior panels, and seat shells. But, apart from a few, one-off prototypes, fully structural composites have yet to significantly penetrate the rail market, largely due to their relationship with fire.

By working towards improving the fire performance of FRPs without compromising the structural (or wider) performance of the composite, FIRE-RESIST will make a valuable contribution towards saving and protecting resources – environmental, financial, and labour – that are certain to become increasingly valuable in this generation, and the next ■

Lesley Brown



*more details can be found at www.fire-resist.eu; the project can also be followed on Twitter, Facebook, and has a LinkedIn group

Acknowledgements
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