Towards lighter, safer vehicles: advanced materials research at NewRail

Dr. Joe Carruthers

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NewRail

- NewRail is the railway research centre at Newcastle University in the UK.
- University-based railway research and consultancy in partnership with industry.
- Four groups:
  - Rail vehicles.
  - Rail infrastructure.
  - Rail systems.
  - Rail freight and logistics.
“Advanced materials”? 

- What do I mean by “advanced materials” in the context of the rail industry?

- Any material that isn’t routinely or widely employed for a particular railway application.

- For example:
  - Structural fibre-reinforced polymers.
  - Cellular materials.
  - Structural sandwich materials.
  - Metal-matrix composites.
  - New grades of steel or aluminium.
  - etc.
The benefits of advanced materials

- Well demonstrated by high technology sectors such as aerospace and motorsport.
  - Lightweighting, functional integration, crashworthiness, life cycle savings, etc.

- Relatively little uptake by mainstream land transportation sectors, including rail.

- Since 1994, NewRail has been conducting research into advanced materials and their associated manufacturing processes with a view to their more widespread use in the rail industry.
Today’s presentation

● Lighter rail vehicles:
  – Specifying lightweight materials.
  – Optimising lightweight designs.

● Safe rail vehicles:
  – Energy absorbing composites for crashworthy rail vehicles.
  – Fire-safe polymer composite structures.
Lighter rail vehicles
MODURBAN: “Removing Constraints on the Use of Lightweight Materials”

“... to provide engineers in urban vehicle production with lightweight materials, concepts and designs in order to provide affordable vehicles with reduced weight” (and reduced energy consumption)
Material selection for lightweighting

- The rail vehicle designers within the project team identified the lack of reliable, comparable material property data as one of the current constraints to the use of lightweight materials.

- What they requested was:
  - A large (customisable) database that provides a global population of possible material options.
  - A means of sorting through that database in a systematic and rational manner in order to identify and compare only those materials that fulfil the requirements and constraints of the application considered.

CES Selector / Constructor
The diagonal ‘performance index’ line is positioned to pass through the current grab rail material, stainless steel.

We are interested in the carbon fibre reinforced polymers located here.

Whereas materials that lie above the diagonal line have a better performance than stainless steel as a light, stiff beam.

Each of the 2500+ “bubbles” represents a different material. Therefore, materials that lie below the diagonal line have a worse performance than stainless steel as a light, stiff beam.

All the materials that lie on the diagonal line have an equivalent performance as a light, stiff beam.
A lightweight carbon fibre reinforced polymer grab rail was prototyped in collaboration with Exel Composites UK.

Real (measured) mass saving = 57% (compared to stainless steel).

The prototypes were produced using a continuous manufacturing process known as pullwinding.

In sufficient volumes, the resulting tubes are less costly than the equivalent stainless steel.
For more information on NewRail’s material selection research ...


- Available at [http://eprint.ncl.ac.uk/](http://eprint.ncl.ac.uk/).
Optimising lightweight designs

- Composite / sandwich materials => lots of design variables.
  - Composite: fibre material, matrix material, fibre volume fraction, fibre architecture, number of layers, orientation of layers, etc.
  - Sandwich material: upper facing material & thickness, core material & thickness, lower facing material & thickness, etc.

- Multiple (conflicting) design objectives.
  - e.g. low mass AND low cost.

- Optimisation, to produce the most efficient design according to an application’s priorities, is very challenging.
Ant colony optimisation

- Cheaper
- Lighter

Cost (€/m²)

Mass (kg/m²)

Ant positions
Best solutions
1 ant’s motion
Optimisation results

• A lightweight/high cost solution:
  - Carbon / phenolic
  - Polystyrene
  - Plywood
  - Mass saving = 53%
  - Cost increase = 93%

• An intermediate solution:
  - Steel
  - Polystyrene
  - Carbon / phenolic
  - Mass saving = 40%
  - Cost increase = 13%

• Mass saving = 37%
  - Cost saving = 40%

• Existing design:
  - Plywood
  - Glass wool
  - Mass = 12.7 (kg/m²)
  - Cost = 15 (€/m²)

• A less light/cheaper solution:
  - Steel
  - Polystyrene
  - Glass / phenolic
  - Heavier / cheaper

Existing design

Lightweight / high cost

Heavier / cheaper

Existing design
For more information on NewRail’s optimisation research ...


- Available at http://eprint.ncl.ac.uk/.
Safe rail vehicles
Approaches to cab design ...

Structural metallic framework + composite cladding

Self-supporting sandwich “shell”

Fully structural sandwich cab

Stable energy absorption from affordable glass-reinforced composites (1997)

- The use of “tied-core” sandwich designs that prevent catastrophic, unstable failure.
Fully-structural, crashworthy all-composite rail cab (2004)

- Designed to meet UK Railway Group Standard GM/RT2100 – “Structural Requirements for Railway Vehicles”.

- Energy absorption of 1.5 – 2 MJ.

- Significant parts reduction: from 50-60 parts for a steel cab to around 10-15 parts.
**DE-LIGHT cab (2010)**

- Bombardier’s *SPACIUM* 3.06 Ile-de-France commuter train was selected as the basis of the development.

- Objectives set:
  - 40% lighter.
  - 75% fewer parts.
  - 20% less costly.

- The aim is to meet the primary existing requirements of the *SPACIUM* specification whilst also realising the above improvements.
DE-LIGHT cab innovations

- Three-stage modular construction to facilitate inspection, maintenance, repair and replacement.
- Lightweight buffer-level energy absorbers.
- Lightweight distributed upper energy absorber.
- Significant replacement of steel members with lightweight structural sandwich construction.
Design assembly
Prototyping

See the prototype on the Kemrock stand (hall 26, stand 310)!
Fire-safe polymer composite structures

- The wider exploitation of polymer matrix composites is often limited by their poor fire performance.

- Organic matrix resins soften on heating and ultimately decompose.
  - Loss of structural integrity.
  - Smoke, toxic gases, heat release.

- Problem shared with other transport sectors.
NewRail is co-ordinating a new €7.9M, four year project that aims to provide a stepwise improvement in the fire performance properties of polymer composite materials in the transport sectors.

- Four new concepts for fire-resistant materials.
- Multi-scale, coupled simulation: material model / finite element analysis / computational fluid dynamics.
- Design, prototyping and fire testing of three case study components: rail, aerospace, maritime.

14.30, Friday 24th September, Professor Geoff Gibson, “Fire behaviour of composites”.
Thank you for your attention...

- For more information please contact:
  - Joe Carruthers,
  - joe.carruthers@ncl.ac.uk
  - www.newrail.org