Transport has always sought lightweight solutions, from the time when man was the motive power to the present day when the mode of transport may be by land, sea or air.

Plastics and composites have been used to reduce the weight of vehicles since they were first discovered or invented, contributing to corrosion resistance, increased service life and reduced maintenance requirements. Designing complex integral components with composites has also led to further weight savings through fewer parts and less joining. These materials and their processing have developed separately in the various transport sectors.

**Fit for purpose**

Materials and process selection in the automotive sector is dominated by cost and functional attributes. Other key drivers are styling, flexibility, parts consolidation, reduced tooling costs and achieving a Class A finish. This has encouraged the development of polymeric materials most suited to mass production – up to and over 50,000 units per year – from injection moulding of reinforced thermoplastics to long fibre composites and sheet moulding compounds.

Meanwhile, lightweight and high stiffness at low volume are the requirements of the aerospace sector and have necessitated advances in aluminium lithium alloys, structural composites of epoxy resin and high strength carbon fibre systems, often with a complex continuous fibre architecture for the airframe.

**All round savings**

The marine industry requires large, low cost, low volume and corrosion-resistant structures. The reduction in weight has been achieved by using enhanced composites that give increased performance by extending range and speed. This has led to the production of glass fibre and liquid resin systems. The use of carbon composites is restricted by price, but with the ability to tailor laminate designs for optimum performance, these materials are increasingly used on vessels at the high end of the market and are common in highly loaded components such as masts.

Lightweighting for locomotives improves efficiency and is necessary for the high speed trains being developed where the weight per axle is reduced from 22 to 17t. With the introduction of composites into train exteriors and interiors, flame, smoke and toxicity are of concern. Over the last three decades, additives such as alumina trihydrate (ATH) and fire-resistant thermoset resin formulations – mainly phenolics – have been produced to meet safety...
Standards. Special fibre architectures and inorganic resins are being designed to improve fire resistance, but phenolic resin remains the favoured material.

Fuel consumption is a significant environmental consideration. Road vehicles will consume less fuel through greater engine efficiency, less drag and friction, but weight reduction is still one of the most effective tools to improve efficiency. A 10% decrease in vehicle weight is estimated to reduce fuel consumption on average by seven per cent. Many vehicle components are therefore made from lightweight plastic or composite materials. Applications include polyester dough moulding compounds for headlamp housings, acrylic and polycarbonate for lenses, and composite plastic and foams for bumpers, interior panels and sound deadening.

Despite the use of lighter materials, vehicle weight continues to increase due to the incorporation of safety features and higher specifications. A further 30% weight reduction may be possible, mainly by using lighter materials, with greater use of integral parts and adhesives. Although such developments are offset by the rise in cost. The McLaren SLR makes full use of carbon-fibre composites in its doors, bonnet and the complete body-in-white, using largely automated preform processes, but currently this can only be justified for the high performance market.

The biggest gains are expected from more fuel efficient aircraft. Every tonne of weight saved achieves a 1.45% reduction in fuel costs. Carbon-fibre reinforced composites are now widely used for secondary civil wing structures such as leading and trailing edges, flaps, spoilers, fairings, access panels and engine nacelles. Airbus led the move into primary structure of large civil aircraft – the Airbus A380 consists of 17% composites by weight – and is now
introducing materials to further lower the weight and cost by up to a quarter compared to 1990. The A400M, for example, and the future A350 will have completely composite wings. The Boeing 787 ‘Dreamliner’, with a complete composite wing and fuselage, is predicted to give a 25-30% weight saving over the 747-400 and will be the first super-efficient commercial jet to have the majority of its primary structure made from carbon reinforced epoxy composite – 50% of the aircraft’s structural weight compared to five per cent for the 747-400.

However, with this increase in the use of composites in aircrafts, the vulnerability to lightning strikes grows. Protection methods tend to add bulk and so a light-weight sprayed metal composite panel, developed by Bentley Motor Cars, UK, is one possible solution. This product has a finish that is 80% lighter than a conventional automotive steel panel and eliminates ‘print through’ – the appearance of reinforcement fibres in the surface of a moulded part.

Big investments

Carbon composites are well suited to the unmanned aerial vehicle (UAV) and lightweight jet markets, which require high strength-to-weight materials to give optimum payload capacity and, in the case of UAVs, limited radar signature and signal transparency. BAE Systems in London, UK, is involved in the manufacture of wholly composite UAVs. It announced in December 2006 that it is to be the lead partner in a joint £124 million UAV Technology Demonstrator Programme (Taranis) with the Ministry of Defence to develop a world-class UAV that will have a mainly composite airframe. Other partners are internationally known Rolls-Royce, Smiths Aerospace and QinetiQ.

The DTI-funded Foresight Vehicle research project, Affordable Lightweight Body Structures, also successfully addressed print through using a SPRINT resin film infusion process (which consists of a layer of woven carbon fabric either side of a precast, pre-catalysed resin film), and a discontinuous fibre preforming process. Materials costs were significantly less than a comparable prepreg and demonstrated the potential of the technology to produce up to 20,000 parts per annum. Further development has led to directed fibre placement producing stronger parts.

Cross purposes

There is some overlap of materials between transport sectors as cost is driven down and manufacturing becomes more automated. This is expected to continue with demand for greater performance. Virtually all bicycle manufacturers have incorporated carbon-fibre composite into their designs and bicycle frames are wholly or in part made from this material.

Non-destructive testing techniques are developing in parallel to composites’ use in structural applications. This is driven by the need for data on the quality and fatigue behaviour of a component, especially due to the demand for thicker sections such as aircraft wing boxes, gear rib and underwater pressure vessels.

Centralised knowledge

The aircraft industry in North America has set up the Advanced General Aviation Transport Experiments (AGATE) Consortium to produce materials information that is available to numerous end-users, and to ultimately generate standards, similar to those for metals, that are based on industry rather than company specifications. This involves both the materials supplier and processor.

The AGATE methodology recognises the process dependence of composites. The databases, managed by the National Institute for Aviation Research (NIAR), attract users from outside the aerospace industry and allow smaller companies to enter the aerospace composites supply chain. The report on the UK DTI-sponsored technology mission in advanced aerospace composites, which was released last year, suggested that the National Composites Network (NCN) could play a similar role for UK and European manufacturers (see Materials World, August 2006, p5).

Recently, the DTI Materials Innovation and Growth Team also recommended that national databases are set up for materials properties and whole life data. A Materials Property Validation Centre was proposed, which will be managed by the newly formed Materials UK (see Materials World, November 2006, pp22-23).

In the future, as part of Materials KTN, the NCN is expected to play a key role for the UK composites industry over all sectors, in understanding the existing capabilities, identifying best practice in design and manufacture, and the most promising emerging technologies for providing the required performance with improved economically viable manufacture.
The education and training needs of the current and future workforce also need to be addressed for the sustainability of the growing composites industry. Although the requirements for each sector have led, and continue to lead, the development of different materials and processes, there is some common ground in modelling and simulation requirements, joining technologies and repair issues.

Joining forces
Instead of central industrial research, the trend is for collaboration with industrial and academic partners and a sharing of resources. UK universities are well placed to identify possible synergies between the different transport sectors and form the hub of the composites network. The University of Nottingham is associated with automotive composite research and consequently can identify cross-sector synergies with the aerospace sector, with which it is becoming increasingly involved. The Advanced Composites Manufacturing Centre (ACMC) at The University of Plymouth is well known for ‘hands-on’ facilities and its long-standing links with the marine industry, but on manufacturing development, it has expertise across all sectors. The Advanced Composites Manufacturing Centre is a partner in the EU Framework 6-funded Advanced Low Cost Aircraft Structures (ALCAS) project based in Galway, Ireland, to develop the next generation of low-cost, lightweight aircraft wing structures from advanced composite materials, led by Airbus UK and Dassault Aviation.

Another ALCAS partner, the Innovative Manufacturing Research Centre (IMRC) at Cranfield University specialises in continuous fibre thermoset composites from manufacture to property characterisation. It is currently investigating different manufacturing techniques, such as braiding, stitching, automated tape laying, Z pinning, and cure monitoring, and control technologies in the automotive, motorsport and aerospace sectors. While the Aerospace Engineering Department at The University of Bristol researches aerospace composites, especially fatigue properties, and works with all the major UK aerospace companies.

Global research
Imperial College London and Queen Mary’s College London cover many aspects of composites research including ceramic, metal polymer matrices, with Queen Mary’s specialising in materials properties and Imperial, the engineering aspects. The University of Manchester does not list composites as one of their research areas but its School of Mechanical, Aerospace and Civil Engineering (MACE) has been awarded a grant to establish and lead a transatlantic partnership in aerospace composites, the Manchester Seattle Composite Partnership, and is currently investigating the liquid resin ‘Quickstep’ manufacturing process for affordable ‘out-of-auto-clave’ composites.

Woven reinforcement can give control over fibre orientation, fibre architecture and increased productivity, and is an emerging trend in advanced composite reinforcement for applications in the aerospace and defence industries. Three dimensional woven reinforcement, through control of fibres in the Z direction, offers improved interlaminar performance and high fibre volume net shape preforms that require less debulking in the tool. Two of the leading UK universities in textile technology research are The University of Ulster – 3D weaving design and applications – and The University of Nottingham – modelling and simulation of fibre reinforcements for composites.

Predictive modelling provides an understanding as to how composites behave in different conditions and enables materials with enhanced performance to be produced for particular industrial applications. The University of Nottingham has crafted a software programme, TexGen, that models the geometry of textiles and has recently been awarded an EPSRC Platform Grant for Processing and Performance of Textile Composites. Currently the Universities of Nottingham and Ulster are collaborating on a DTI-funded project with The University of Bristol and industrial partners to investigate and model the properties of 3D woven carbon-fibre composite parts.

The DTI Technology Programme has replaced the industry specific research programmes such as the Commercial Aircraft Research and Development (CARAD) Initiative and Foresight Vehicle. Advanced materials, one of the seven key technology areas of the programme, has funded over a dozen composite-based R&D projects since its inception, including projects on recycling, integration, structural health and cost issues. UK industry would benefit from seminars based on these projects.

Further information
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