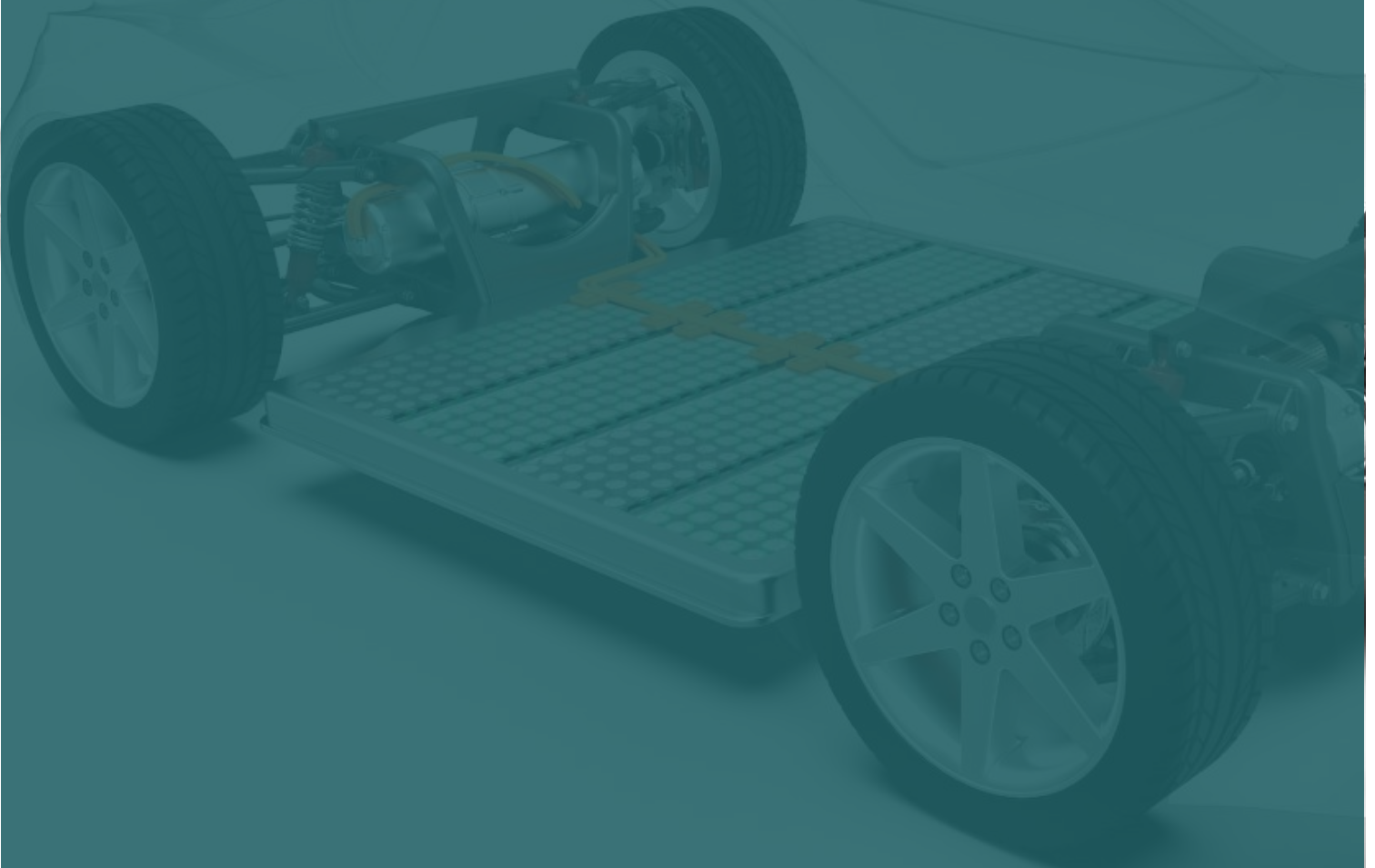




Lightweighting through composite- metal bonding

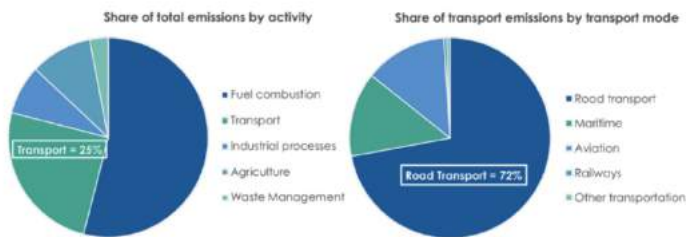


Dr Nick Welton
 Technical Consultant
 Powdertech Surface Science

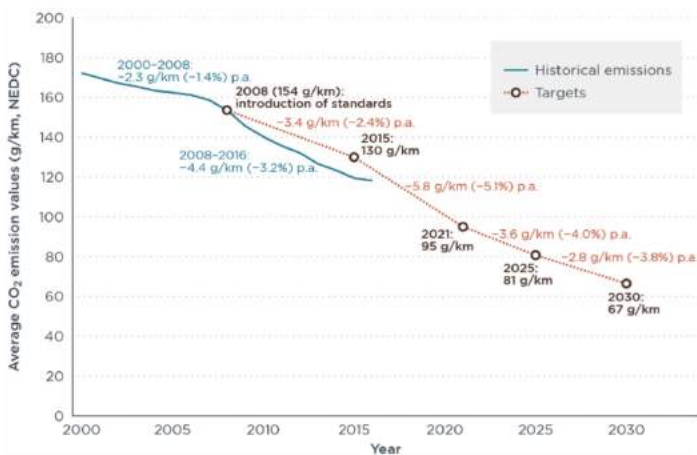
As the spotlight is focussed on the impact CO2 emissions are having on our climate the transport sector in particular has come under intense scrutiny and is being challenged to adhere to the CAFÉ regulations to sustainably reduce emissions from automobiles.

Transport is a pivotal sector for achieving EU wide emission targets as it accounts for 25% of all EU's greenhouse gas emissions with road transport having the largest impact due to the sheer number of vehicles in operation.

Shares of European greenhouse gas emissions (source: EEA)

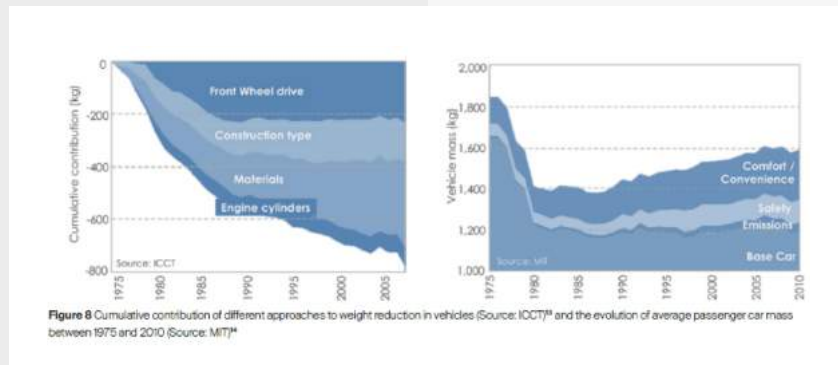


Current Euro 6 targets stipulate CO2 emissions for passenger vehicles at <95g CO2/km by 2021, with the 2025 targets being ~70g/km. Even with the steps many OEMs have taken, they will miss the legislated 2021 targets, and will be liable to face fines of up to €95/g above the target. From the current average emissions of 118.1g/km, the required reductions of 23.1g/km will require OEMs to lose >230kg/ vehicle in the five years



Prioritising lighter weight in vehicle design

Reducing vehicle weight is a critical piece of the puzzle with all manufacturers prioritising this design aspect into future vehicles. Many vehicle OEMs have significantly reduced the weight of their vehicles in recent years, in a bid to achieve the stringent CO₂ targets. Over the past 20 years, the industry has shifted from relying predominantly on steel for chassis structures towards increasing use of aluminium, with OEMs such as Audi unveiling entire aluminium models with their 3rd Generation Audi A8 model. Beyond this, further weight optimisations are being sought through the increased use of lightweight materials with composites such as glass-filled and/or carbon fibre in structural applications alongside conventional materials, such as in the BMW i3/i8 and 2017 Audi A8 models (multi-material BIW – aluminium, hs steel, magnesium and CFRP).



However, consumer demand for SUVs, more integrated functionality, autonomous vehicles coupled with more stringent safety requirements is countering the incremental weight savings that can be achieved and forcing designers to seek more radical solutions.

Thus the industry focus is also on eliminating emissions during the use-phase of a vehicle by replacing the ICE powertrain with EV propulsion systems. A long term strategy of hybrid ICE/EV powertrain being succeeded by plug-in battery powered EV and eventually yielding to fuel cell EV vehicles is anticipated.



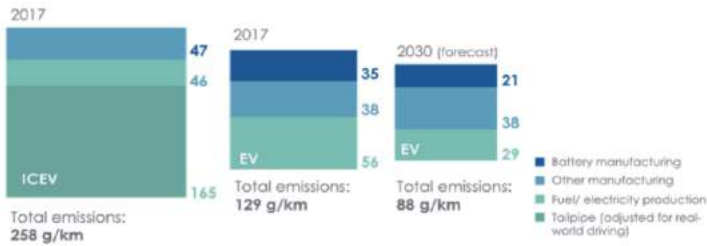
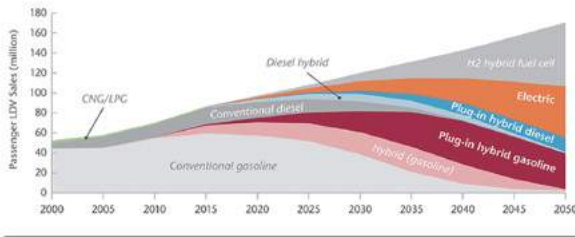


Figure 14 Average lifecycle (150,000 km) emissions of electric cars in Europe in 2017 and 2030 (Source: ICCT)²²

Ref: Alliance Report – see end of article, ref 1.

EV's do not eliminate greenhouse gas emissions completely when a life cycle analysis of the vehicle is considered including the manufacturing process and electricity generation, however this is anticipated to reduce in the long term as more renewable energy sources come on stream.

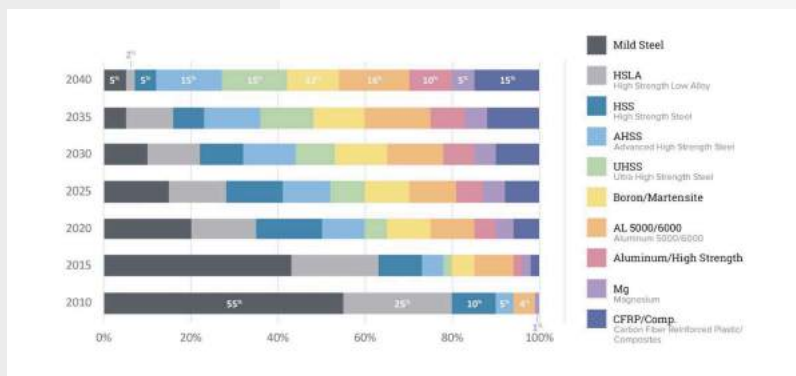


The move to EV powertrains does not resolve the lightweighting challenge, the technology shift merely alters the benefits being sought by consumers. For cars the priority moves to range between charges and maintaining the mass below a threshold requiring an additional license; in the commercial sector passenger and payload capacity can be maximised by minimising vehicle weight.

Battery assemblies are a significant contributor to the weight of an EV powdered vehicle. Lighter vehicles lead to smaller kW demand and lighter batteries reducing the environmental footprint, so there remains a significant incentive to lightweight EV's.

Materials for vehicle lightweighting

Body in white (BIW), the car body's frame before painting and before the motor, chassis sub-assemblies, or trim have been integrated into the structure, is estimated to hold the largest share of the automotive lightweight material market, by application. BIW comprises of three major parts - passenger compartment, cross and side beams, and front and rear structure and contributes around 27-29% of the total vehicle's curb weight. Hence, it is the primary target for vehicle weight reduction by OEMs. At present, HSS and aluminium are the major lightweight materials used in BIW for maximum weight reduction. Hence, BIW is projected to be the largest segment, by application.



Light-weighting strategies are centred around the philosophy of using the right material in the right place. Two key elements of the process are the use of materials with a high strength-to-weight ratio coupled with smart/intelligent design to maximise the properties and utilisation of the material.

Traditionally this was a two horse race between HS steel and aluminium, but the significant advantages offered by composite materials are being recognised and the outlook is a mixed material approach incorporating more fibre reinforced composite into the structure.

Thermoplastic composites are recyclable both in the manufacturing process and at end of life of vehicles and offer numerous additional benefits;

- short cycle times
- compatible with many processing techniques
- thermoformable
- weldable
- can be over-moulded
- offer excellent strength and stiffness to weight ratios

The combination of metallic and composite materials shows a synergistic improvement when combined in plastic metal hybrid structures, with anisotropic UD composites being strategically placed to significantly reduce part weight while increasing stiffness where required.

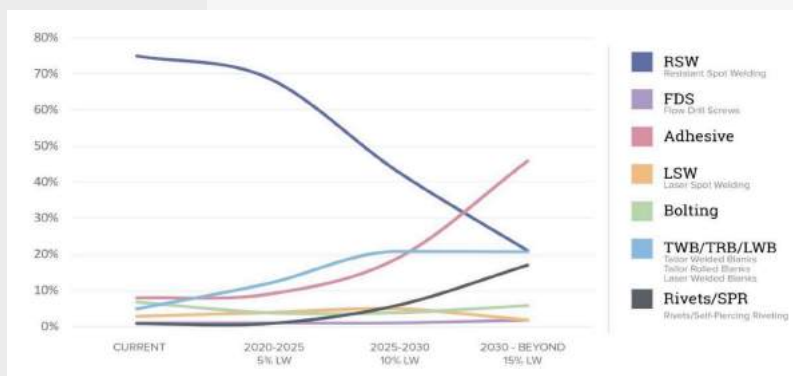
Bonding of dissimilar materials

However, before materials such as composites can be adopted into mainstream structural applications, some key challenges need to be overcome – primarily the bonding of dissimilar materials (composites, plastics and metals).



A variety of joining processes are currently employed in the bill of process with adhesive bonding being the fastest growing technology to join composite materials. Adhesive bonding offers performance benefits due to the ability to spread loads over large areas, in contrast to mechanical fasteners that create stress concentrations at the weakest point of the material due to fibre breakage resulting from insertion of the fastener.

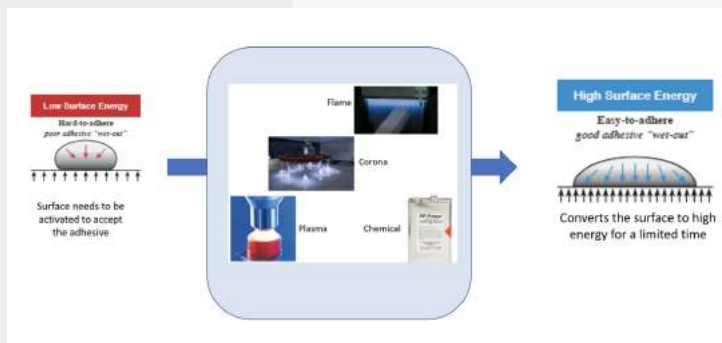
Due to creep behaviour of certain polymeric materials torque relaxation can present an additional challenge for mechanical fasteners. It is estimated that there are in excess of 250,000 grades of adhesive available from over 1000 suppliers (REF TWI REVIEW) yet still there remains a significant challenge to achieve structural bond strengths on low surface energy polymers (LSE).



Polypropylene – excellent credentials but averse to adhesives

LSE surfaces are typically apolar and include binder polymers such as polypropylene. The low cost, wide availability, good processability, hydrophobicity and excellent chemical resistance of polypropylene make it a desirable material for lightweight composites. With a wide variety of fibre reinforcements available, including the more commonly used E-glass and carbon fibre, the material is available in a large variety of forms including co-woven fabric, consolidated sheet, injection moulding granules and UD tapes.

Although there are adhesives designed to adhere directly to polypropylene, they do not offer structural bond strengths, particularly in wet environments. Prior to adhesively bonding this class of polymer it is common to functionalise the surface to raise the surface energy improving wettability and adding anchor sites onto which structural epoxy type adhesives can grab.



The methods used to functionalise the surface are accompanied by necessary health and safety measures which add additional complexity, time, cost and resource to the manufacturing operation.

There is an open time limitation of the functionalisation which generally necessitates an in-line process adding a considerable footprint to the line. The resulting bond strength is often much lower than achieved on metallic surfaces, even after surface functionalisation, and often falls below specification requirements.

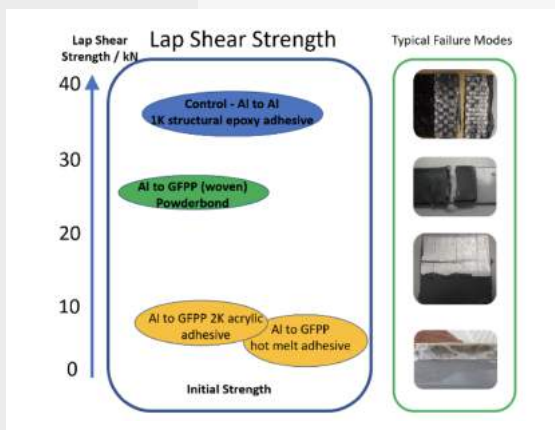
Quest for a solution

To date, the lack of a satisfactory joining solution has deterred designers from specifying PP based composite materials and more expensive materials are often employed to bypass the complexity of the joining process.

The determination to use GF-PP in multi-material structures within a collaborative research project drove the development of a new, adhesive-free joining process that enables the design of PP metal hybrid assemblies. This process, named and patented as PowderBond^{PP}, uses lean manufacturing principles and delivers exceptionally strong bonds.

PowderBond^{PP} can be accommodated into a range of forming techniques including compression moulding, injection/overmoulding, induction bonding and vac-bag moulding.

Exceptional bond strength



One of the key benefits Powderbond^{PP} delivers is unrivalled bond strength between PP and metals in hybrid structures. Mechanical testing of standard joints reveals the peak load on lap shear approaching that of traditional epoxy based adhesives used in metal to metal joints. In fact the common failure mode was cohesive failure of the parent material, with fibre breakage and inter-ply cleavage witnessed for GF-PP composite materials.

Having dual functionality, being a corrosion resistant coating system, leads to high bond strength retention following exposure to aggressive environmental conditions including corrosive, wet and humid atmospheres. The durability of the joint has been demonstrated through fatigue testing with full retention of joint strength following 100,000 cycles of HCF. The system can also act as a galvanic isolator when the composite is reinforced with carbon fibre

Lean manufacturing

PowderBond^{PP} delivers far reaching benefits which impact upon manufacturing systems. No pre-treatment of the composite surface is required, no adhesive application and no extended cure time. The PowderBond^{PP} system is applied to the metal component which is then heat-fused to the polypropylene in a variety of processes mentioned previously, making the process a rapid joining solution. The technology delivers a repeatable joint performance, essential for many applications.

Design benefits

	Aluminium chassis	Composite / Aluminium chassis
Weight	Equal	Equal
Part Count	142 Components 590 Fasteners	37 Components 150 Fasteners
Manufacturing Ease		✓
NVH		✓
Design Freedom		✓

Using PowderBond^{PP} reduces part count, improves NVH and enables lightweighting of structures, opening up new design possibilities for plastic-metal hybrid structures by removing the need to incorporate joining features into components.

The ability to enclose metallic components within the composite yields both strong and stiff structures and allows the designer to use the right material in the right place, removing the restrictive consideration of how the parts will be post-joined.

Use in a moulded design

Stalcom Automotive exploited the design benefits during the construction of its concept single seater, last mile delivery vehicle with the construction of mixed material sub-structures. PowderbondPP treated aluminium profiles were inserted into the compression moulding tool and bonded to pre-consolidated GF-PP sheet in a single operation. Upon removal from the tool the component had developed its full strength and proved to be a robust component with excellent torsional stiffness.

The technology facilitated design experimentation with a series of different geometry junctions being explored allowing the manufacture of complex shapes in a single stage process.



Potential use in fastening systems

For metal to PP joining purposes outside of moulding techniques, the excellent tensile bond strength, six times that of a plasma treated / 2 K epoxy structural adhesive control system, makes the system particularly suitable for the application of metallic fasteners to PP based composite materials.

This feature is being evaluated by bighead Bonding Fasteners as it looks to extend its own Lean Bonding® process capability to join metal fasteners to polypropylene, the most widely used thermoplastic material. The two technologies have a natural synergy and the collaboration looks specifically at creating strong reliable bonds with a simple, customer-ready process. The process is compatible with automated application lines and the removal of the need to functionalise the composite surface makes this a very attractive proposition.

Necessity is the mother of invention – and innovation

The previous inability to reliably bond PP, the most cost-effective thermoplastic, to metal, has certainly presented a stumbling block in affordable lightweight vehicle design. PowderBondPP opens up the field again, bringing far more freedom in design and with that, a wide range of exciting possibilities for new vehicles. Necessity has always driven invention and the need to redesign the vehicles on which we all rely, in order to reduce CO2 emissions, is now so urgent and overwhelming that new enabling technologies should be evaluated and adopted wherever possible, and sooner rather than later.

References

Ref 1: Alliance Report: A vision of the future of automotive lightweighting; Accelerating the decarbonisation of automotive mobility by means of lightweighting. http://lightweight-alliance.eu/wp-content/uploads/2019/11/alliance_vision-document.pdf

Ref 2. CAR Technology Roadmap: Intelligent Mobility Technology, Materials and Manufacturing Processes, and Light Duty Vehicle Propulsion, 2017. https://www.cargroup.org/wp-content/uploads/2017/07/Technology_Roadmaps.pdf

Please contact us if you would like
any more information on
Powderbond^{PP}

01869 248 218

EMAIL US