Aluminium from Cans to Cars – An Update

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It is time for aluminium intensive low carbon vehicles that are both mass producible and affordable. For mass production this has to be a conventional vehicle made from pressed sheet parts and the only serious alternative to the excellent incumbent sheet steel for this type of vehicle is aluminium alloy sheet. To compete with steel on a cost and energy basis the aluminium sheet must be made predominately by the closed loop recycling of post consumer scrap. The main challenge is making aluminium sheet from recycled post consumer scrap that has properties that match those of primary metal based products. The maximised use of recycled production and process scrap is also important but this is a much simpler issue than sourcing and using post consumer scrap.

The UK automotive industry is a large (£52 billion) and critical sector within the UK economy. It accounts for 820,000 jobs, exports finished goods worth £8.9 billion annually and adds value of £10 billion to the UK economy each year. However, the UK automotive industry is currently facing great challenges as road transport released 132 million tonnes CO_2 in 2008, accounting for 19% of the total UK annual CO_2 emission and its global competitiveness is threatened by the emerging new economic powers, such as China and India. In addition, declining employment and hollowing-out of the domestic supply chain have been evident for the past decade and the UK government is committed to reduce CO_2 from transport by 60% by 2030 and the EU requires 95% recovery and reuse of end of life vehicles (ELVs) by 2015. A solution to these current difficulties and challenges comes from the development and manufacture of low carbon vehicles (LCVs). This is clearly presented in the vision of the UK automotive industry set by the New Automotive Innovation and Growth Team (NAITG) that envisions a competitive, growing, and dynamic industry making a large and increasing contribution to employment and prosperity in the UK, and playing a decisive global role in developing and manufacturing exciting, low carbon vehicle transport solutions. The use of recycled aluminium has a major role to play in making low carbon vehicles both affordable and mass producible.

Vehicle lightweighting is the most effective approach to improve fuel economy and reduce CO_2 emissions. As shown in Fig. 1, the CO_2 emission per km driven is linearly related to vehicle curb weight. Studies have shown that every 10% reduction in vehicle weight can result in 6-8% improvement in fuel efficiency. In terms of greenhouse effect, this means that every 100kg weight reduction results in CO_2 reduction up to 12.5g CO_2/km driven for the entire vehicle life. In addition to such primary benefits, vehicle lightweighting reduces the power required for acceleration and braking, which provides the opportunity for secondary weight reduction by employing smaller engines, and smaller transmissions and braking systems. Furthermore, if appropriate technologies are used, vehicle weight reduction can be achieved independent of size, functionality and class of vehicle. Similar benefits of mass reduction can be demonstrated for hybrid vehicles (HVs), as shown in Figure 1 and electric vehicles (EVs) as shown in Figure 2. For electric vehicles the primary benefit of mass reduction is the lower weight and hence cost of the power pack required to give the vehicle acceptable range.

Approaches to vehicle mass reduction include both deployment of advanced materials and mass-optimised vehicle design. One of the major vehicle systems is the body (or body-in-white) that represents about one-quarter of the overall vehicle mass and is the core structure and frame of the vehicle. The body is so fundamental to the vehicle that sometimes it is the only portion of the vehicle that is researched, designed and analysed in mass reduction technology studies. Over many years there has been a fundamental material shift from wood, cast iron and steel to high strength steel (HSS), advanced high strength steel (AHSS), aluminium, magnesium and polymer matrix composites (PMCs). Between 2000 and 2005, the use of aluminium increased by 37%, PMCs by 38% and magnesium by 150%. There have nearly 30 major R&D programmes worldwide on vehicle mass reduction. Compared to a steel structure, the HSS intensive body structure by the Auto Steel Partnership achieved 20-30% mass reduction, the aluminium intensive body structures of the Jaguar XJ, Audi A8 and A2 achieved 30-40% mass reduction and a multi-material body structure featuring more aluminium (37%), magnesium (30%) and PMCs (21%) by Lotus achieved 42% mass reduction. However, the increased cost of using advanced lightweight structural materials compared to steel acts as a major disincentive for vehicle manufactures and such materials are constrained to the high performance and high priced vehicle sectors and have made only a minor penetration into high volume production vehicles.

Consideration of materials recycling, however, has been missing from nearly all the LCV programmes worldwide, which have concentrated on the reduction of CO_2 emission during the use phase of vehicles produced from primary materials. The production energy of primary structural materials is always much greater than that of their secondary (recycled) counterparts. For instance, production of 1kg primary aluminium from the primary route releases on average 9.7kg CO_2e, whilst 1kg of recycled aluminium only results in 0.6kg CO_2e emission. Detailed life cycle analysis has shown that a primary aluminium intensive car can only achieve energy saving after more than 20,000km driven compared with its steel counterpart, while a secondary aluminium intensive car will save energy from the very beginning of vehicle life. It is also highly significant that the carbon burden of primary aluminium depends on the source of electricity used for smelting and this can be significantly reduced by the use of hydropower or nuclear power as the generating source. Hydro Aluminium have recently claimed that the carbon burden of their primary aluminium production in Norway (740kt/year) is lower than 2kg CO_2e/kg produced. Further reduction would require either the use of non-consumable anodes (not made from carbon) and/or carbon capture at the smelter.

Recycling can be either open loop or closed-loop. Open loop recycling refers to a system where the material is recycled into a new product or where the inherent materials properties change, while closed-loop recycling applies to products which are recycled to produce the same product or where the material properties do not change. The current recycling of ELVs is open loop as it involves some limited dismantling, removal of hazardous materials, mechanical shredding to produce mixed scrap, followed by air classification to remove automotive shredder residue (ASR), magnetic separation to remove steel, eddy current separation to remove non-metallic materials and then repeated sink-float separation of non-ferrous metals. Mechanical vehicle shredding takes only 15 seconds but is characterised by high materials waste and generally the down-grading of the recycled materials, and shredding inherently restricts the closed-loop recycling of ELV materials. For aluminium the main issue is that the resultant recycled scrap is a mixture of comingled wrought and cast alloys that is suitable for making into secondary casting alloys that are not suitable for structural applications in vehicles. Presently all the structural castings used in vehicles are made from primary aluminium and are the most expensive components of aluminium vehicle structures.

Although societal attitude towards recycling of materials is changing the potential accumulation of waste from ELVs is alarming from both a national and global basis. It has been estimated that there will be 3.65 billion tonnes of materials waste generated from vehicles between 2007 and 2030 based on a world vehicle fleet of 1.5 billion by 2030. It is important that materials are recovered from ELVs by controlled dismantling rather than shredding although this will require vehicles to be designed for dismantling and significant change to public policy on how end of life vehicles are handled backed by suitable legislation. In simple terms, vehicle manufacturers and or vehicle shredders should evolve into vehicle dismantlers to liberate this vital low carbon source of materials and components for future vehicle construction.

The success of the aluminium beverage can points the way forward for the use of aluminium in vehicle structures. Aluminium can body sheet competes favourably with steel can sheet for this application precisely because it is efficiently recycled back to the same product form with minimal compositional adjustment. The UK has the leading used beverage can recycling facility in the EU operated by Novelis at Latchford. The UK consumes about 6.7 billion beverage cans each year and with a current estimated recycling rate in the UK of 52%, compared to the EU average of 70%, this means a maximum of 45,000 tonnes/year being available for recycling; of which about 30,000 tonnes goes to Novelis, with the balance going to other secondary smelters, or ending up being exported for recycling outside of the EU. Novelis processes around 140,000 tonnes/year of UBC scrap at Latchford with the balance of this scrap coming from imported UBC's from the EU. Recycling rates globally of UBCs are generally determined by the available decoating and casting capability of plants like Latchford and similar facilities worldwide. The price paid for UBC scrap compared to the LME aluminium price is shown in Figure 3. Globally a significant proportion of UBCs still go to landfill and more than a trillion cans have already been lost in the US in this way. In the UK we still fail to recycle an estimated 3 billion cans back to cans each year representing a major loss of recyclable aluminium.

Jaguar Land Rover (JLR) are the leading UK manufacturer of aluminium intensive vehicles with 60% of the vehicle structure made from alloy AA5754 sheet. This alloy could be made from recycled scrap if its tolerance to impurities such as iron, silicon and copper was increased. JLR are leading a TSB supported project, REALCAR (Recycled Aluminium Car) with the goal of making AA5754 sheet with a 75% recycled content (50% process scrap and 25% post consumer scrap) as shown schematically in Figure 4. JLR are considering a range of post consumer scrap sources for alloy manufacture and also the use of continuous casting to increase impurity tolerance. The UBCs presently lost to landfill (45kt) or used in secondary casting alloy or exported as mixed scrap (15kt) are an obvious source of high quality pre-alloyed scrap for AA5754 sheet production. In the longer term the aluminium sheet for car construction would be made from dismantled cars or perhaps from shredded cars provided low cost alloy separation technology is available. This has the potential to make aluminium sheet cost competitive with steel sheet for affordable mass produced low carbon vehicle manufacture. Cans to cars is an appropriate metaphor for this both as a closed loop recycling exemplar and also as an appropriate source of post consumer scrap presently lost to landfill.

Figure 1: Effect of curb weight on carbon emissions for petrol, diesel and hybrid vehicles

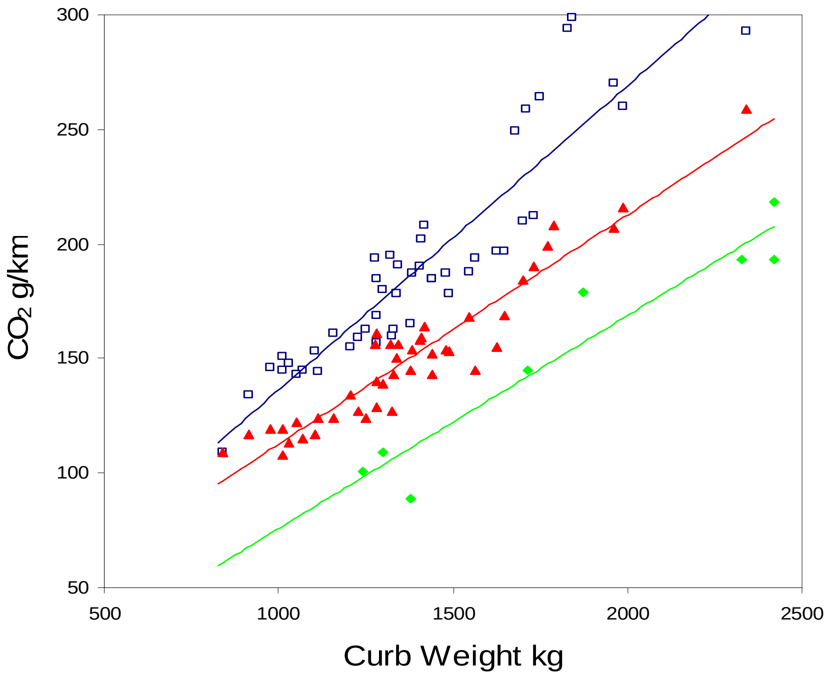

Figure 2: Battery cost for a 100 mile range electric vehicle based on a Li-ion battery with an energy density of 115 Wh/kg and a battery cost of $750/kwh (based on a Ricardo study for the Aluminum Association)

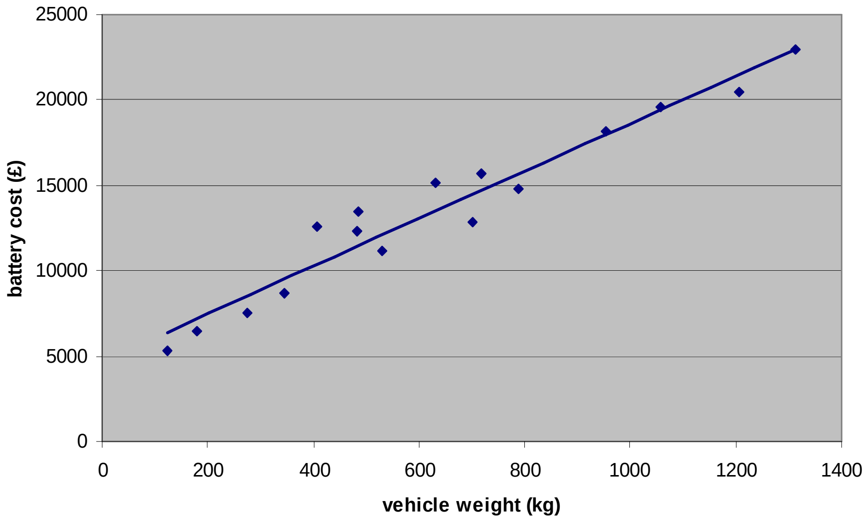

Figure 3: Relative price of UBC scrap compared to the average monthly LME aluminium price. On average it is 56% of the metal price

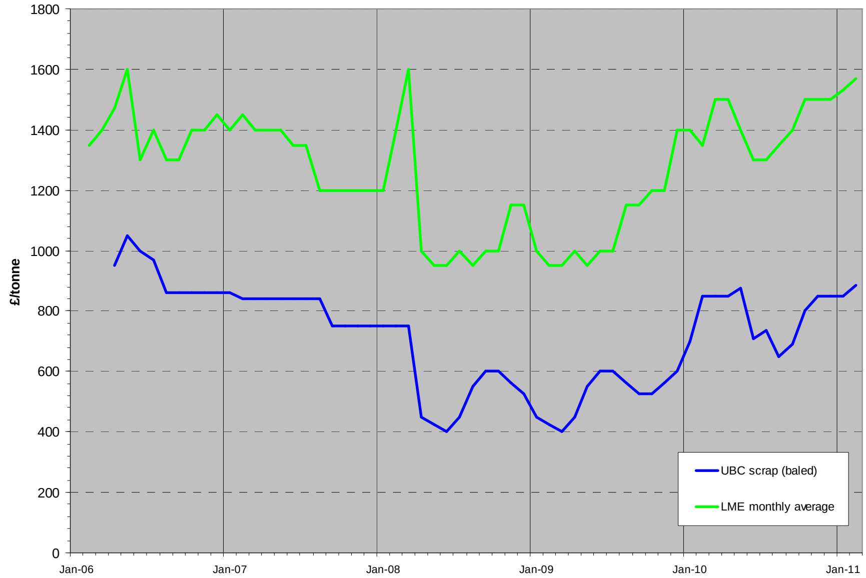

Figure 4: Jaguar Land Rover closed loop recycling plan and future end of life vehicle recycling