Technical Article

"Automotive Light Weighting" – A Journey and Not a Destination

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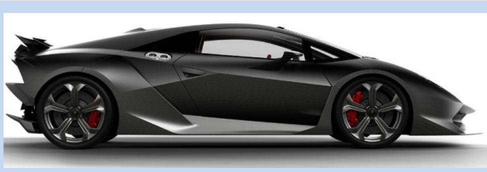
Over the past few decades "Light weighting in engineering applications" had been widely discussed and endorsed topic across various industries across the globe such as aviation, wind energy and most particularly in automotive sector. Automotive sector is undeniably the largest and most complex in industrial antiquity and in the current too. The very much evolved robust design methodology and state-of-art manufacturing techniques of the automotive segment has outstretched the same to a level to meet tauter demands of safety, price, performance, reliability and other needs. As known to all the field had witnessed several developments regarding light weighting and still paving way for further developments. What remains unknown is "How it is made possible? And what is the potential source behind the development?" The answer is simply "The Material". This is a topic that remains important ever, as every kilogram you take away from your vehicle improves the vehicular performance, driving dynamics, vehicular agility and fuel economy, thereby reducing the emission level in automobiles. Studies say that for every 100 kg saving vehicular weight (unsprung mass), one can achieve fuel saving up to 3%. The above said, reasons out why OEM's are investing more on carbon fibre and aluminium. Also other automotive giants are looking forward for industrial plastics for their components such as plastic fuel tanks and more. Due to higher capital to be invested in light weighting options and end user's minimal interest to pay for light weighting in automobiles, light weighting did not take its place significantly. However the introduction of authoritarian environmental regulations and its enforced penalties has levered the light weighting targets in the automotive industry significantly.



The Lamborghini "SESTO ELEMENTO" (Sixth element in English, referring to Carbon's atomic number) is a high performance limited edition Italian car whose body, chassis, power shaft and suspension parts are made of Carbon Fibre, making it a 999 kg vehicle. Its weight is on par with sub-compact cars in automotive industry and is the lightest car produced by the company. Lamborghini's collaboration with Boeing is the key behind developing this concept with Carbon Fibre, more particularly with Carbon Fibre Reinforced Plastic (CFRP).

Materials and Weight impact in a vehicle:

Reduction in vehicular mass paves way for mass de-compounding in vehicles, for example a vehicle with lighter weight will result in smaller brakes, and lighter drive trains will result in lesser support structures leading to still lesser vehicular mass / weight. As studied, to meet the light weighting targets of automotive industry there will barge out three imperative options as follows:

1. High Strength Steel on par with conventional steel is estimated to be used by over 60 % of the vehicles produced, mainly passenger cars (small and medium sized)
2. Another well recognised automotive light weighting option would be the use of aluminium and magnesium in alloy form. The estimated usage would be around to 30% of the executive class vehicles and battery run vehicles.
3. The third widely spoken and attractive option would be the use of carbon fibre in concept cars or most advanced high end sports cars and forte luxury cars.

The following table describes the Percentage Usage of materials in current road vehicle application

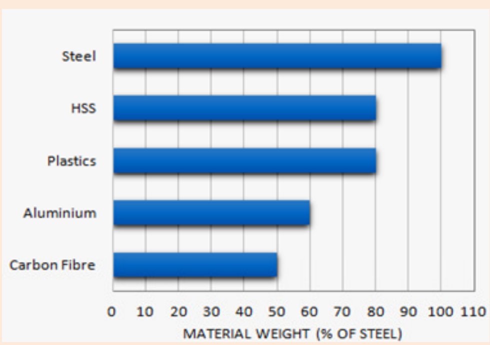
Mild Steel	43.7
HSLA Steel	8.2
Stainless Steel	1.4
Other Steel	1.5
Cast Iron	13
Plastics / Composites	7.8
Aluminium	5.6
Rubber	4.3
Glass	2.8
Copper	1.4
Powder Metal	0.8
Lead	0.8
Die Casted Zinc	0.5
Fluids / Lubricants	6
Other Materials	2.2
TOTAL	100

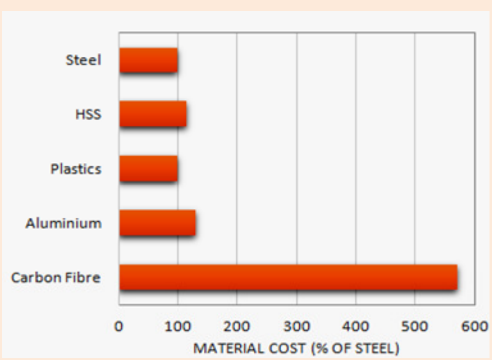
Source: Wards Automotive Year Books 1993, 1991, 1989, and 1981

There are still varied light weighting options in the automotive industry such as Austempered Ductile Iron and Titanium whose usage will be discussed too.

Various light weighting options are into consideration, but the use of a particular material is fully application adapted. For example one particular material may offer superior strength, while the other may offer higher toughness. Also the major constrain in the use of these materials is their cost. Cost of light weight material worsens its application but as said earlier the environmental regulation forces the use of light weighting option into automotive engineering forcing a trade-off between the application and cost. The below plots describes the material weight and cost of the same as compared to steel for various materials of light weighting options.

Not all the vehicular parts can witness light weighting in them. The major vehicular parts that can expect material change or the parts where hands can be laid on are the Power train and Chassis followed by exteriors and interiors. The following table describes the expected material usage in automobiles.





	CURRENT MAJOR OCCUPANTS	FUTURISTIC OCCUPANTS
Power Train	Iron, Steel, Aluminium	Aluminium, HSS, AHSS
Chassis	Steel, HSS	HSS, AHSS, Composites
Exteriors	Steel, Aluminium, Plastics	Steel, Aluminium, HSS, AHSS, Plastics
Interiors	Steel, Plastics, Composites	Plastics, Composites

Hood outers and frames in some automobile application employ aluminium in its construction

High Strength Steel and Crash Worthiness

Steels with yield strength of not more than 360 MPa has met the industrial usage for long. However the usage of High Strength Steels in automotive industry can be dated back to more than 3 decades for light weighting and its very properties of formability and weld ability with strength ranging to 1400 MPa. Domineering automotive safety standards in automotive sector, particularly the crash resistance in automobiles stood for employment of HSS in the same. Some of the developed steels where even able to absorb energy in axial crash test to more than 90% of the imparted. Henceforth cold rolled HSS and AHSS have been into automotive light weighting applications because of their crash resistance and impact resistance. There are various methods to produce such steels such as: 1. Strain Hardening, 2. Thermo-mechanical treatment 3.Alloying, and 4.Grain Refinement.

Aluminium and Magnesium in Automotive Application

Aluminium has already crept in automotive applications years back. The average usage of aluminium in passenger cars has reached 144 kg by 2000. Since 2010 the share on aluminium in automotive application did not find any significant increment. The main challenge in the usage of aluminium is where the component's cyclic loading is predominant. To achieve on par fatigue life with steel, aluminium did not yield any light weighting, for example the wheels used in passenger cars made of aluminium as well as steel possessed similar mass. The above said phenomenon can be very well reasoned out by the lower fatigue life of aluminium alloys and their manufacturing process such as casting possess inherent defects such as porosity and dendrites, which warrants higher factor of safety. Aluminium has took a good position in automobiles and its components for the very reason of light weight, high specific strength, energy absorbing characteristics, corrosion resistance and easier recyclability of the metal. Aluminium cannot replace steel directly, it has to be engineered or alloyed to make it usable in automotive application. Pure aluminium has also been employed for luxury cars and other niche cars. Magnesium is another light metal that has found its way into automotive application. One of the major advantages of magnesium over aluminium is that due some peculiar material properties, magnesium primarily pressure die casted paving way to produce complex structures and geometries.

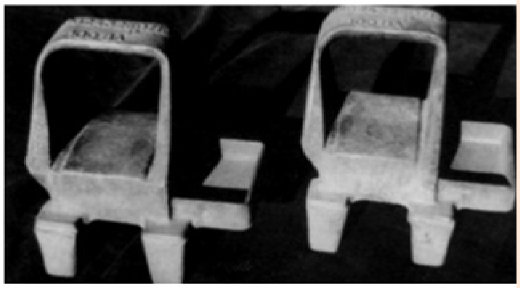
The following vehicles employs a minimum of 10% aluminium in their curb weight since 2012

Fiat 500	**10.5**
Chrysler 300	10.6
Ford Explorer	9.9
Hyundai Elantra	9.6
Merc-Benz ML Class	11.6
Ford Escape	10.9
Ford Focus	9.8
Saab 9-4X	11.6
Honda Civic	10.4
Honda CR-V	10.9
VW D-Sedan	9.10
Chrysler/Fiat C-Sedan	11.3
Dodge Viper (ZD)	10.7
Merc-Benz GL-Class	9.6
Ford Fusion	10.2
Lincoln MKZ	11.3
Cadillac XTS	10.3
Honda Accord	11.2
Nissan Altima	10.7
Toyota Avalon	10.7

Some of the auto components that use aluminium in raw or alloy form is the automotive body, exteriors, engine blocks and more. Similarly magnesium in automobiles exists as transmission housings, doors components and bonnets. Magnesium applications doesn't stop with housings it also extends to fuel cells, engine parts and hybrids, even taking over aluminium in some cases. Some of the intrinsic application of magnesium include valve covers, intake manifolds and casings. Magnesium is 30% less dense than aluminium and solidifies faster which makes manufacturing easier.

Austempered Ductile Iron (ADI) in Automotive Application

Austempering heat treatment process produces ferrous materials which has superior properties than those which are processed in conventional methods, and hence are used in widely in automotive applications. Austempering in Ductile Iron is a process where Austenitizing is done followed by rapid quenching to a temperature above Martensite start temperature. ADI with hardness magnitude of up to 550 BHN were produced and employed where high wear resistance in of importance in automotive engineering. Softer ADI (275 – 325 BHN) can transform in to martensite when subjected to physical strain, hence in application such as transmission gears worn out regions can be freshly replaced by strain hardened ADI thereby increasing product life. Transmission gears and crank shafts find themselves built with ADI for higher wear resistance. Knuckle joints such as in steering systems are a potential auto component to be built with ADI to meet the safety standards. There are varied application of ADI in Heavy Trucks as well as Passenger cars. Heavy trucks employ ADI for suspension components and power trains and light vehicles employ them for engine parts.



Cast steel replaced with ADI in truck suspension support

Engineered Automotive Plastics:

Plastics in automotive sector did not find its way until 1950, when thermoplastics played a major role. Polymers in various structures were engineered to make way for plastics in automotive industry. Other than weight reduction plastics offered various other advantages such as good aesthetic appeal, colouring and self-colouring properties. They also offer excellent corrosion resistance, intricate and undercut design options and good toughness factor. Plastics in automobiles are the second most used material by volume next to ferrous components.

Even though a dozen type of polymers are used for automobile construction, only a hand full of them are used in majority which include, Polypropene, Polyurethane, and Poly Vinyl Chloride (PVC).

Fuel intake manifold in thermoplastic serves to a viable light weighting option in automotive engineering

They also offer excellent corrosion resistance, intricate and undercut design options and good toughness factor. Plastics in automobiles are the second most used material by volume next to ferrous components. Even though a dozen type of polymers are used for automobile construction, only a hand full of them are used in majority which include, Polypropene, Polyurethane, and Poly Vinyl Chloride (PVC). The following components in today's automobile are in plastic: Seating, Bumpers, Dashboard, Body panels, fuel system, Bonnet components, Exterior convolute, lightings, fuel tanks and more. More over safety components such as air bags and seat belts are made of plastics. One of the greatest challenges in using plastics is recyclability of the material. Automotive industry is the best of all engineering industries in recycling with an average of almost 75%, but targets are being made still stringent with the usage of plastics. Plastics have reached the heart of an automobile in recent past, like the thermoset polymers being used in engine cage offers higher temperature resistance and noise reduction possibilities. The better known engine applications include intake manifolds, cooling systems and fuel containers. Plastics in chassis systems help reduce vibration and serve as supports, floors, and in brake systems.

Titanium in Automotive Sector

Titanium attracts designers from automotive field for its very properties of Higher Strength, Lower Density and excellent corrosion resistance even though being a metal. The excellent performance characteristics of vehicles with the usage of titanium simply eclipses the higher cost involved in the usage of the same. The usage of titanium in automobiles have far been restricted to racing segment. For over years race car makers have adhered to the usage of titanium for their engine components such as intake valves and connecting rods since they offer higher resistance to deflection and enhances performance. Titanium has also been employed in mufflers and exhaust parts. The only thing that stands in way of titanium usage is its cost of manufacturing, but the recent past has seen an alternative way of producing titanium in form of powder metallurgy. They are mainly used in valve spring retainers and suspension coils. Titanium reduces noise, vibration and delivers better performance. Some of the potential auto components to be employed with titanium are: valves, retainers, springs, coils, power shafts, brake pad supports, exhaust components, suspension components, bumper supporters, and shock rods.

Summary

As this article is entitled, so is the current automotive scenario, Automotive light weighting is a never ending phenomenon wherein in automobile makers are facing a high time situation where they have meet the stringent environmental regulations, which his becoming the need of the day, by fuel saving and emission control. And the potential option being light weighting of automobiles. While the aviation sector is predominantly into light weighting with a light weight share of 80%, the automotive sector aim at a stunning 70% light weighting share from a mere 28% by 2030 sources say. Also carbon fibre shall slope down on its rate from about 76% difference with steel to 25% difference with steel in the not too distant future as anticipated and shall become the material of regular usage. Hence automotive light weighting happens with on par improvement in vehicular performance as a never ending process.