Aluminium, its Alloys and their Manufacturing Technologies for Reduction of Weight of Automobile

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ABSTRACT

It has been studied that aluminium, its alloys and their manufacturing technologies applied on vehicles in EuroCarBody conference. Using percentage of Aluminium alloys on Body In White(BIW) are summarized and analysed.Aspects of material selection and innovative concepts of car construction using aluminium as best suited lightweight materials was presented.5xxx and 6xxx series aluminium alloys were presented that have been improved for increase in demands regarding higher strength greater formability,resulting mass reduction and improved crashworthiness.Multimaterial SUPER LIGHT CAR(SLC) was also presented for mass reduction.The results regarding the studies on car hood indicates that the optimised Aluminium hood structure shows similar performace and better pedestrian protection as that of steel further reducing the weight up to 46.4%.

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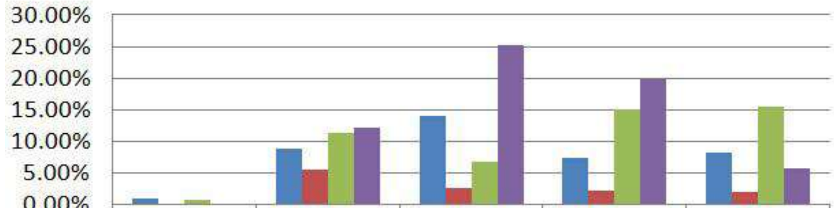
1 INTRODUCTION

Car safety,energy saving and environmental protection these three have been considered while designing a car. On average,100kg mass reduction on passenger car saves 0.315 litre of petrol per 100km and 9gm of CO_2 per km.Here due to use of aluminiumthe weight of the body has been safely reduced by 40%and 10% reduction in consumption of fuel.Each of the car body presented in EuroCarBody conference was evaluated in following categories:

A. Efficient development and construction concepts
B. Effective material developments and applications
C. Production efficiency
D. Customer benefit conveyed by bodywork
E. Completeness and engineering orientation of presentation

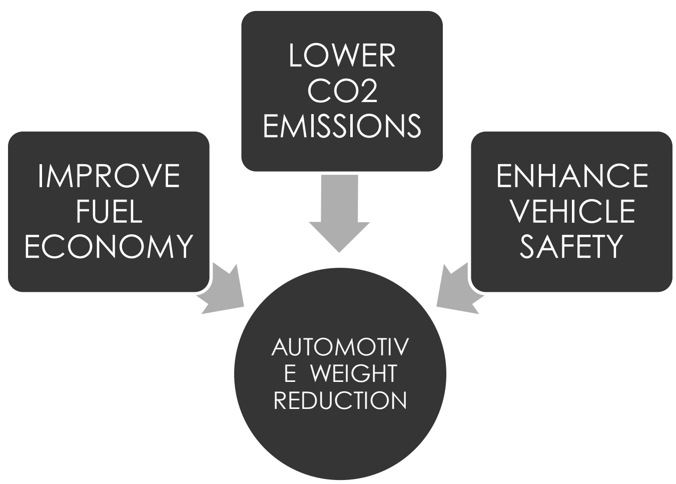
Here aluminium alloys and their manufacturing technologies were discussed.For light weight design of vehicle. A combination of extrusion parts,complex casting nodes and sheet parts of aluminium are used.In this paper the average aluminium alloy percentage applied on vehicles presented at EuroCarBody have been summarised and analysed.



	7xxx series sheets	6xxx series sheets	5xxx series sheets	Extrusion profiles	Cast aluminium
2013	0.95%	8.71%	14.04%	7.27%	8.10%
2011		5.55%	2.67%	2.10%	1.90%
2010	0.80%	11.33%	6.64%	15.05%	15.52%
2009		12.10%	25.27%	19.74%	5.63%

By light-weighting with Aluminium, weight savings of parts up to 50% can be achieved. Aluminium solutions are already well established in power-train, chassis, car body, hang-on parts, bumpers and interiors.Full aluminium bodies allow weight saving of 70 to 140kg (i.e. 30–40%) depending on the size of the car.Here he concept of multimaterial(SuperLightCar) also discussed.

2. OBJECTIVES OF LIGHTWEIGHTING



3 ALUMINIUM ALLOYS FOR CAR BODY APPLICATIONS

Applications of Aluminium and it's alloys has been discussed in this section.The four types as follows:

3.1 Age-hardening Al−Mg−Si alloys

6xxx series alloys contain magnesium and silicon. Current 6xxx alloys used for autobody sheet are A6016 (Europe), A6111 (America), and A6181A, which were added more recently because of recycling aspects. In USA, A6111 is often used for outer panels in gauges of0.9−1.0 mm which combines high strength with good formability. In Europe, EN-6016 is preferred and applied in gauges of 1−1.2 mm. It shows a superior formability and filiform corrosion resistance and allows flat hems even on parts with local pre-deformation. However, the bake-hardened strength of 6016 is significantly lower than that of A-6111.New alloy and processing modifications have been introduced in recent years to meet the increased requirements . Higher strength alloys may allow outer panel thickness reduction with no loss of dent resistance, provided stiffness requirements are met. As paint-bake temperatures decrease, there is increasing demand for a significantly higher age hardening response. However, for some parts formability remains the major difficulty. Therefore, special alloy modifications with either improved formability or strength have recently been developed by European aluminium sheet manufacturers and agreed upon as standards by the automotive industry.

3.2 Non heat-treatable Al−Mg−Mn alloys

Al−Mg−Mn alloys show an optimum combination of formability and strength achieved by the mechanism of solid solution and deformation-hardening due to their specific high-strain-hardening. Further improvement inproperties required for specific applications (e.g. surface appearance, corrosion resistance, thermal stability) has been achieved by small additions of other alloying elements and/or modified processing routes e.g. stretcher strain free (“SSF”) sheet, avoiding Lüders-lines.Non heat-treatable Al−Mg−Mn alloys are applied in Europe for automotive parts in larger quantities as hot and cold rolled sheet and hydro-formed tubes due to their good formability which can always be regained during complex forming operations by inter-annealing where quenching is needed for age-hardening. In chassis parts or wheel applications the benefit is twofold since the mass reduction in the unsprung mass of movingparts additionally enhances driving comfort and reduces noise levels. A well-established alloy with high magnesium content, AlMg5Mn (A5182), is used for high strength and complex stampings. For 5xxx alloys containing >3% Mg the precipitation of β-Mg5Al8 particles at grain boundaries can result in susceptibility tointergranular corrosion cracking (ICC) by long term exposure at >80 °C. For these conditions special high-Mg-content alloys have beendeveloped with a good compromiseforsufficient strength and ICC resistance. For all other cases, special high-Mg-content alloys (>6% Mg) have been introduced which show high- strength and strain-hardening, thus also enhancing formability. Al−Mg−Mn alloy sheet has also been successfully applied or is currently being tested in many parts for structural support, pedal boxes, heat reflectors, lever arms etc. Al−Mn EN-AW 3xxx alloys are applied to heat-exchangers which is another success story of aluminium sheet and extrusion applications that started in Europe many years ago. It is an increasing market with intensive R&D, established for advanced light- weight technology for radiators and air conditioning systems in cars (and elsewhere) worldwide.

3.3 Extrusions

A wide field of aluminium solutions and applications is opened by making use of the well- established technology of aluminium extrusions. Here quite complex shapes of profiles can be achieved, thus allowing innovative light-weight design with integrated functions. In Europe completely new and flexible car concepts (e.g. the aluminium space frame) and complex sub-structures (e.g. in chassis parts, bumpers, crash elements, air bags) have been developed using aluminium extrusions. Their high potential for complex design and functional integration is most suitable for cost-effective mass production. Medium strength 6xxx and high strength 7xxx age-hardening alloys are used since the required quenching occurs during the extrusion process. Formability and final strength are controlled by subsequent heating for age-hardening. Extrusions are applied to space-frame design ,bumper beams and crash elements/boxes.

3.4 Castings

The highest volume of aluminium components in cars is castings, such as engine blocks, cylinder heads and special chassis parts. The substitution of cast iron engine blocks continues. Even diesel engines, which continue to gain a substantial increase in market share in Europe, are being cast in aluminium, due to the high requirements on strength and durability. Cast iron has generally been used before. However, progress in aluminium alloy development (Al−Si−Cu−Mg−Fe type) and new casting techniques come up with improved material properties and functional integration that enables aluminium to meet these requirements. Aluminium castings are also gaining acceptance in the construction of space-frames, axle parts and structural components. Complex parts are produced by special casting methods that ensure optimal mechanical properties and allow enhanced functional integration .For high pressure die cast (HPDC) new AlSiMgMn alloys have been developed with enhanced strength and ductility combination. In the SLC project structural parts in the wheel house architecture have been designed using advanced aluminium die cast with an integrated striker plate.

4.SLC (Super Light Car):

The final SLC-body concept (Fig.1) shows anoptimum between mass reduction of 95 kg (34%), i.e. a mass saving of 41% vs. reference (from 65 kg to 110 kg) and an additional part costs of 5 €/kg. It has amagnesium roof and a steel

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floor frame (i.e. lighter on top than underneath) and a torsion ring in the side structure made of form-hardened high strength steel combined with an aluminium sheet frame. For the inner B-pillar TWB steel sheet is used with an externalaluminium skin. Aluminium is used as sheet panels and as extrusion in front rails, bumper, crash elements, in the rear underbody rail, and in the wheelhouse structure as HPDC (high pressure die cast).

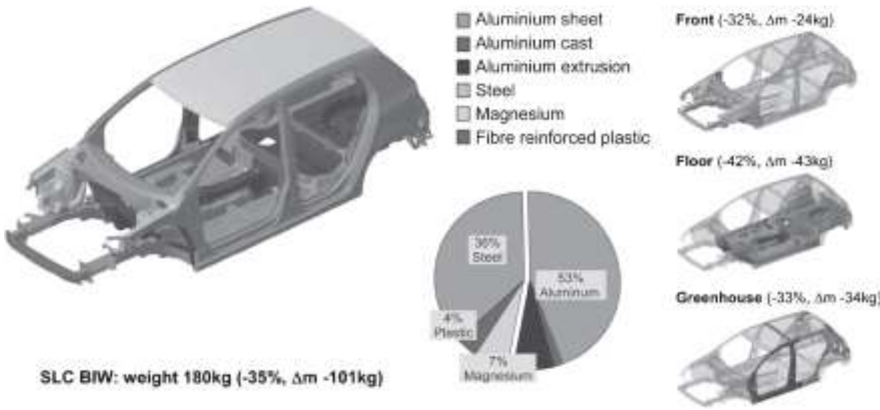

Fig1: Final BIW and selected materials for the innovative multi material SLC concept

5. New manufacturing technologies

The three new manufacturing technologies have been discovered under this section as follows:

5.1 Self-piercing riveting(SPR)

Requires no pre-drilling of holes into the mating work pieces. A punch and die are used to complete the joining operation in a single step. With solid rivets, the punch drives the rivet which pierces the sheet plies completely. Using semi-tubular rivets, the punch drives the rivet which pierces the top sheet and is set into the work-piece by partially piercing the bottom layer. A shaped die on the underside reacts to the setting force and causes the rivet tail to flare within the bottom sheet. This produces a mechanical interlock which includes the added rivet joining element and creates a button in the bottom sheet. The length of the rivet tail, hole diameter and hole depth to shank diameter, and the design of the tooling mainly determine the final shape of the rivet and of the button on the underside of the joint. There is a wide choice of rivet forms. The rivet is generally semi-tubular but may also be solid[7]. Aluminium self-piercing rivets can be used in special cases. Fig.2 shows Self-Piercing Rivet technology of aluminium alloy applied on Range Rover Sport. It can be noted that the processing of SPR is: **1**. Place two or more layer of materials on top of a die**. 2**. Clamp the layers of materials between the blank holder and die. **3**. Drive a semi-tubular rivet piercing through the top layers. **4**. Flaring into the bottom layer to form a mechanical interlock**. 5**. Lift the blank holder and move to next SPR position. It can pierce 2 or 3 layers of sheets (see Fig2).

Fig 2. Self-Piercing Rivet applied on Range Rover Sport

5.2 Friction stir welding (FSW)

Itis a solid state welding process performed at temperatures lower than the melting point of the alloy. The work pieces are rigidly clamped in a fixed position and a specially profiled rotating tool traversed through the joint line produces the friction heating. The tool is crushing the joint line, breaking up the oxide film by a mechanical stirring and forging of the hot and plastic material. The resulting joint exhibits a finer grain structure than the base metal ,Friction stir welding has application in the aerospace industry, and it also has been applied in the automotive industry gradually. The FSW tools can permit over 1500 m of weld to be produced in 4 mm thick aluminium extrusions without changing the tool. Fig. 10 shows the friction Stir welding technology applied on Mercedes-Benz SL R231 class, it can be noted that the main floor made of friction stir welded profiles and shows outstanding rigidity in the floor area.

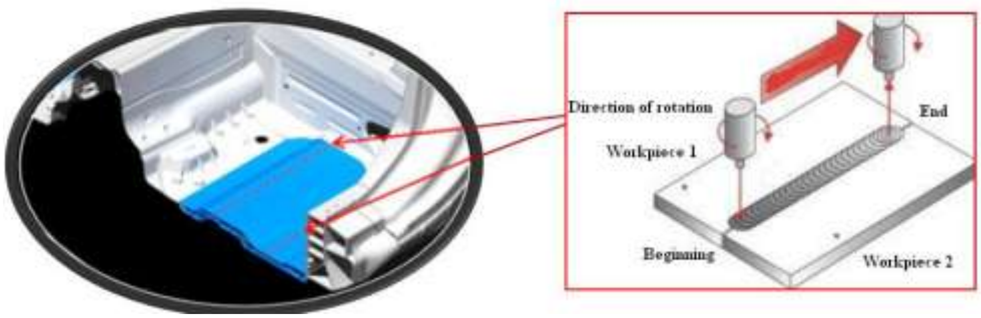

Fig.3Friction Stir welding applied on Mercedes-Benz SL R231 class

5.3Electromagnetic forming (EM forming or magneforming)

It is a type of high velocity, cold forming process for electrically conductive metals, most commonly aluminium and copper. The workpiece is reshaped by high intensity pulsed magnetic fields that induce a current in the workpiece and a corresponding repulsive magnetic field, rapidly repelling portions of the workpiece. The workpiece can be reshaped without any contact from a tool, although in some instances the piece may be pressed against a die or former. The technique is sometimes called high velocity forming or electromagnetic pulse technology. Lexus company adopted electromagnetic forming technology which is a high-speed and non-contact forming method to manufacture aluminium rear bumper system, the processing of electromagnetic forming shown in Fig,4 it can reduce weight 38% from conventional structure.

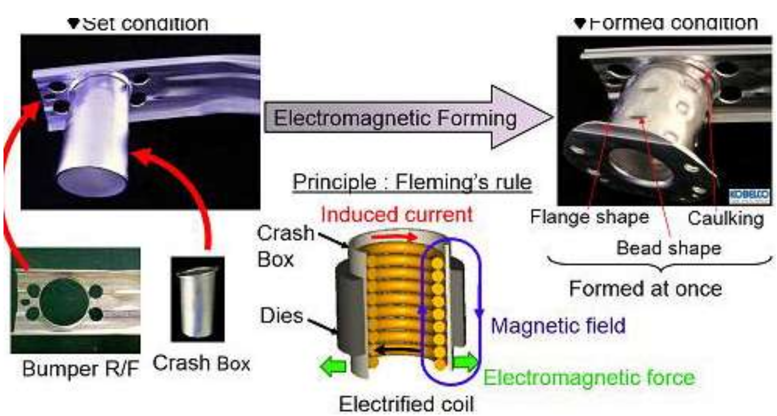

Fig.4 Electromagnetic Forming technology applied on Lexus New IS

6. Pedestrian protection property analysis

According to the requirements of the European New Car Assessment Program (Euro-NCAP) pedestrian protection V5.3.1 version, it need to define zones of car hood for analysis, as shown in Fig.5, it can be noted that when the collision projection point locates between WAD 1000 and WAD 1500, the head type will use the children head type. The adult head type will be used while the collision projection point locates between WAD 1700 and WAD 2100. When the collision projection point located between WAD 1500 and WAD 1700 line, if the point is on the moving parts with the lid moving (for example, surface of hood), the children head type will be used, if the point is on the without moving parts with the lid moving (suchas the bottom of the windscreen or the wiper arm), then the adult head type used.

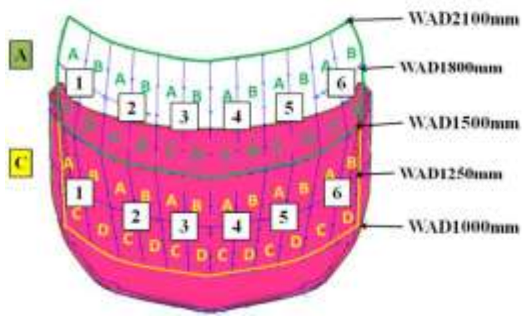

Fig.5 Pedestrian head impact protection zoning for ENCAP

In the simplified model, the head impact area on hood region is observed, so the zone between WAD1000 and rear line of hood is analysed, namely the children head will be used to impact on the hood. Child's head impact model established in accordance with regulations, the impact speed of head type is set as 11.1m/s, the impact should be directed to the vehicle longitudinal vertical plane which relative to the horizontal plane of impact angle is 50°, relative to the front structure, the direction should be downward and backward ,36 collisionanalyses are achieved by adopting children head type for pedestrian protection, and the results shows in Table 1, the Head Injury Criterion (HIC) is an important parameter to evaluate the pedestrian protection level.

Impact Point	HIC		Impact Point	HIC		Impact Point	HIC	
	Steel	Al		Steel	Al		Steel	Al
C1A	360	376	C4A	470	261	A1C	982	832
C1B	525	438	C4B	455	235	A1D	625	684
C1C	417	374	C4C	529	499	A2C	539	635
C1D	504	460	C4D	530	446	A2D	386	474
C2A	585	361	C5A	590	272	A3C	410	368
C2B	584	273	C5B	590	354	A3D	309	335
C2C	553	442	C5C	557	451	A4C	309	335
C2D	557	452	C5D	555	432	A4D	420	368
C3A	454	231	C6A	525	432	A5C	379	467
C3B	467	260	C6B	362	379	A5D	530	631
C3C	532	445	C6C	499	457	A6C	640	680
C3D	533	498	C6D	420	375	A6D	988	830

Table 1:**Comparison of pedestrian protection analysis between steel and optimized aluminium hood**

7.New Aluminium alloys for automotive applications:

Several new product developments were introduced in the SLC project to meet specific demands of the BIW that cannot be met by the present aluminium alloys. For instance, a high-Mg-content 5xxx alloy especially dedicated to warm forming. New 6xxx alloys for structural applications were introduced, used for the crash members in the front structure of the SLC model, or a new 6xxx alloy has been introduced as 'Roof alloy' when placed on a steel structure with fast paint bake response to withstand thermally induced plastic deformation.

8.Conclusion :

Due to its low density, goodformability and corrosion resistance aluminium is material of many components such chassis a,autobody,etc.The SLC concept shows that we can achieve up to 50% decrease in automobile weight without compromising with perfomance.In this paper we have also summarised % of Alalloys on BIW presented at EuroCarBody conference. More and more new technologies applied on hot stamping processing, suchas, casting, self-piercing riveting, electromagnetic forming,etc.The use of Aluminium hood instead of steel can achieve weight reductionup to 46.4% and better pedestrian protection.The HIC value of aluminium hood is lower than the original steel structure after head impact analysis of pedestrian protection, the optimized aluminium hood structure can achieve a better pedestrian protection.

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