INTRODUCTION

The use of Aluminium actually in developing cars is growing because of its properties and the technology that in the few last years has been improved. This is the reason for this essay: to discuss the actual use of aluminium alloys now and its future, and the projects that have been carried out. But before all that, let's take a look at the background, why and when the use of aluminium in cars started.

BACKGROUND:

To understand this essay, I must explain some facts and backgrounds of this issue. Also, I include an explanation of the aluminium manufacturing process, to understand why the weight difference between an aluminium and a steel car is ½, and why the use of aluminium in cars is better.

When car companies started to look for an alternative metal to build cars, they found aluminium, because of its properties. But the property that called their attention was the density. The aluminium (in general) has 1/3 of the density of steel, which means a new car with a weight of 1/3 of the old one! That was the theory. But in the real world, they found that the aluminium is not as strong as the steel, and is not as easy to work with as well. So the ideal of build a car just with aluminium was negated: the reason why aluminium is not used today in structural applications is an accident of history. When the modern, spot−welded steel structures were first introduced, sheet aluminium was in its infancy and, thus, was not available as a viable alternative material to steel[2]. This doesn't mean that experiments and projects were not done. On the contrary, the engineers believed (and now is a fact) that there was a way to build and actually use the aluminium in cars.

The first uses of aluminium were in non bearing components, such as hoods and doors; all external parts, and some of the engine parts, such as the piston, the radiator but never used to build the frame. After this attempts, a new car was built from sheet aluminium, the Dyna−Panhard (1950's), where the whole body structure, including the floor pan, was built from formed and spot−welded aluminium panels[2]. From this time, a decision was made: because of the part−by−part change from steel to aluminium adoption was achieving good results, the development of a specific technique for aluminium was needed.

At the beginning of the developing of a design and manufacturing system for building aluminium structural frames, a few requirements were set to assure that the new car had more advantages than the old steel one. These requirements, briefly, were:

- a lighter car,
- Costs minimised (no more than the steel construction).
- The develop of a new joining technique.
- The resulting vehicle structure should be highly corrosion resistant.[2]

To deal with these problems, a different manufacturing system was developed by Alcan International and Gaydon Technology, and it was called the Aluminium Structured Vehicle Technology (ASVT), which it is covered and explain later in this essay.

If we take a look at the history, we can find different examples of aluminium cars: the Land Rover, the UPS vehicle, and the United States postal vehicle, to coat a few examples. But the aim of the ASVT goes further, and actually, GM and The Aluminium Company (ALU) have made a deal, in which the ALU will maintain the aluminium coiled alloy price (it will be very slightly changes), and in exchange, GM will have to buy a certain amount of that aluminium[6]. This means that GM is starting an aluminium vehicles production.

Another prove of this technology is the new Audi A8. This is a full equipped(ABS brake system, intelligent suspension), big, low−fuel consumption new car, comparable with any BMW 7−serie, with an affordable price. The reason of this price is because the whole frame is made of aluminium, and this doesn't only mean less money expended in metal, but also less weight. And if the car is lighter, the engine is smaller, and therefore the fuel need falls down.

The success of this technique resides in the fact that aluminium needs a different process than steel, and at the beginning, they tried to develop aluminium with the same process.

ASTV SEQUENCE:

To achieve a proper aluminium coil, which can be used in manufacturing, it must go throughout a process system (Figure 1). This system has the following sequence:

1.− ALUMINIUM COIL PRODUCTION (Al−Mg alloy)
2.− PRE−TREATMENT AND PRE−LUBRICATION For stamping in coil form
3.− PART STAMPING−PART DESIGN Optimised for aluminium with flange configuration designed for adhesive bonding
4.− ROBOTIC APPLICATION OF ADHESIVE with no prior cleaning of parts
5.− STRUCTURE OR BODY−IN−WHITE ASSEMBLY Using local spot−welding (for part fixing and to enhance peel resistance)
6.− ADHESIVE CURE
7.− CLEAN AND PAINT (if aluminium structure must be obscured for aesthetic reasons)
8.− FINAL ASSEMBLY

Figure 1[2]

1.− Aluminium coil production: this refers to the type of aluminium is better to use. According to a previous research and experiments, the conclusion gives a family of aluminium alloys, which are the Al−Mg alloys (Magnesium), because of their properties.

2.− Pre−treatment and pre−lubrication: needs to be applied in coil form for good economics and to be storable and, yet, provide the same type of bond strength and durability that has been achieved with the batch system. Additional requirements are that the pre−treatment must not impede spot−welding and should be suitable as the pre−treatment for painting, should this be required[2]. The aluminium is dunked on the pre−treatment and then, the lubricating is applied by a flow, on both sides. Then, it's ready to pressing and storage.

3.− Part stamping−part design: the aluminium coil will go through the stamping robots, who will apply a force in order to get the appropriate shape. Due to the pre−treatment, the aluminium can be storable, with no properties losses.

4.− Robotic application of adhesive: a robot will apply the adhesive in the aluminium, and therefore get the actual shape.

5.− Spot−welding: to avoid peeling failure, the aluminium is spot−welded. This is made after the adhesive application. The reason of this process order is that the car structure won't move, and it's easier then to weld it. After this, the assembly is finished.

6.− Adhesive cure: in order to assure good adhesive results, the adhesive must be cured. This is achieved by a thermal cure, in which the adhesive will settle down.

7,8.− At these moments, the structure is cleaned and painted, and ready to assemble to the rest of the car.

This process describes step by step, how to accurate a good aluminium car frame.

STRUCTURAL DESIGN CONSIDERATIONS:

In order to understand the aluminium behaviour, properties must be studied. I present here the aluminium properties that are important in the ASTV, and comparing them to the steel properties:

Yield strength: even though that steel exhibits more yield strength at the same thickness, the advantage here is that aluminium is 2/3 less heavy. Therefore, if aluminium thickness is doubled, yield strength will be as big as steel, but with a ½ weight saving. This property can be observed in table 1, where aluminium and mild steel are compared. Here we can see the yield strength, compared with the density. Also, buckling and bearing aluminium behaviour is 100% better than for the comparable steel beam (Figure 2[2]).

Fatigue: this property in aluminium doesn't show a great variation, and therefore is comparable to steel in the way that aluminium achieves the fatigue needs, with the same results as steel (no advantages in this issue).

Impact: Aluminium vehicle structures absorb energy exactly the same as steel: by the deformation, folding and concertinering of the front longitudinal−box−structural beam members. The amount of energy absorbed is related to the yield strength of the material, its thickness and the rate at which the material work hardens as it is deformed. The aluminium can be in the form of sheet structural assemblies, extruded beams or even as ductile castings. Comparative tests with steel show that a spot welded and bonded aluminium box beam will absorb as much energy as a similar steel beam at 55% of steel's weight. This same relationship applies for bending collapse. Also, just as with steel, the geometric design and dimensioning of the energy absorption members are critical to ensuring that folding collapse develops and that premature buckling does not occur at the base of these units[4]. Therefore, a light car doesn't have to be a small car. Proof that aluminium can do the job includes the following examples:

- The GM EV1, with a full aluminium frame, has met the U.S. safety requirements.
- The Audi A8 extruded aluminium front end has been designed in order to be changed in case of collapse, without disturbing the bulk front end structure.

Joint parameters: there are two different joint shapes: the T and the lap joint geometry. Both of them are used in different cases. The first shape (T geometry) shows less stress resistance in yield failure, but has a bigger stress in peeling failure. This is because the overlap direction has 90 of difference. So, for specimens in yield stress only, it's recommended the use of overlap bonded. But, if the joint has yield and peel stress, the use of T geometry would be more appropriate.

Joint stiffness: the performance of the aluminium adhesive bonded joint is a lot better than the steel and the spot−welded joints. Therefore, the use of this joint is the most accurate for the aluminium frame.

In general, aluminium tests shows that an aluminium adhesively bonded sample is better than the aluminium spot welded, and therefore the choice of the first one is the result of all these experiments.

ACTUAL USE OF ALUMINIUM IN CARS:

The use of aluminium alloys in cars is no longer a dream. Actually, a lot of cars built with a high percent of aluminium can be seen on the roads. Automakers are discovering the many advantages aluminium affords them in the manufacture of vehicles. An example, already quoted, is the new Audi A8 (figure 3,4[5]). This all−aluminium A8 employs a first−of−its−kind aluminium spaceframe body technology that gives extraordinary weight savings with safety, performance and luxury features.

Another examples of the actual production cars are:

- Audi AL2: Audi's starting build year: 1999. It will use aluminium spaceframe technology pioneered on the A8.
- GM's EV1: this electrical car is built with an aluminium unibody structure with a body structure weight of 295 lbs.(134 Kg), and it will be on the roads of North America this year.
- Honda Acura NSX: it is the most aluminium−intensive vehicle on the road today (up to 1000 pounds (450 Kg) used in the whole car) and with a weight savings of 450 pounds(204 kg).

Figure 4: frame and detail of the joints of the new A8, by Audi.

The aim that carmakers are seeking with the use of aluminium is not only weight savings, but another advantages, which are:

- today, aluminium is like 10% of a car's total weight, but it represents 35−50% of the total material scrap value at the end of its useful life.
- Aluminium has 1/3 of the density of steel, which means that a component can be 1.5 times larger than steel version and remaining 50% lighter.
- It can absorb 50% more energy than steel.
- It's corrosion resistant. This advantage is not as important, given the fact that steel can be coated with other materials to accomplish the corrosion resistant; and steel Automakers assure this by giving a 10 years corrosion proof guarantee.
- Aluminium's lighter weight and stiffness can also enhance a vehicle's acceleration, handling, and reduce its noise, vibration and harshness characteristics.

Also, aluminium is environmental friend as well. All post−manufacturing automotive aluminium scrap is recycled. Up to 70% of automotive aluminium is sourced from recycled metal. It doesn't loose its properties at the moment of recycling, so there's no cycling limit. It's a theory, but it will come one day in which we will just rent the aluminium, and give it back at the end of the car useful life[6].

Lightweighting savings lead to other secondary weight savings, such as the engine, brakes, suspension, wheels, in order to achieve the same car development (torque power, max. speed,). The following chart shows how hypothetical secondary weight savings could give a total weight reduction of over 700 lbs. (400 Kg)

Figure 5[4].

Figure 5: Hypothetical secondary weight savings[4]

If this saving is accomplished, it would be a lot of savings, not just in car price, but also in petrol and in emissions to the atmosphere.

POTENTIAL USE OF ALUMINIUM:

The future use of aluminium is, in such way, obvious. Eventhough steel manufacturers believe that aluminium is not going to replace steel, there are a lot of facts that assure that. As an example, there are new a lot of new car tests, that are doing a great job, and meeting all the standards of safety, comfort and quality. An example of one of these projects is the new P2000, by Ford. This car is designed to be the world's lightest weight, midsized sedan. In total, the P2000 weights 2000lbs (900 Kg), a mass reduction of 40% compared to the 1997 Ford Taurus GL.

In sum, all Automakers have found aluminium the substitute for steel, and they are all trying to get new cars based on it. My opinion of this is that 20% of brand new cars by 2000 are going to be aluminium based cars. The market demands vehicles with the same characteristics, but more efficient, because of the continuos rising price of petrol. This derives into two options:

More efficient engines, or

Less total weight.

Because the engine is more difficult to improved, the Automakers have decided to use aluminium. And they are changing steel and cast iron engines for aluminium ones.

An example of this improvement is the new Rover K16 engine. Rover engineers agreed that a change on the all−iron `A' series engine was an essential part of the future of Rover. So, they started the new one. The explanation of the new engine is given in reference [1]. The develop of this engine is designed for a mid−size sedan, and its develop is as good as the old one, but with a weight saving, and an easier way to build it.

In general, the tendency is the use of aluminium in cars because the properties mentioned before. The future of aluminium is to prosper in this field, and engineers are working to get as many parts of the car as possible using this material.

ADVANTAGES OF USING ALUMINIUM(Vs Steel and Cast Iron):

Physical properties:

Corrosion: aluminium is one of the most non−corrosive material. Knowing this characteristic, is much more easy to protect the material, and it can be assured a long life of the frame. Also, this frame won't have to go to revision due to corrosion. In the other hand, steel and cast irons do fail by corrosion, and a special treatment has to be done before. That means a big final sale price.

Shape: aluminium's behaviour in this issue is very good, because it can be build any shape with it.

Weight: as mentioned before, aluminium is 1/3 steel weight, so it's a lot less heavy.

Yield strength: aluminium is ½ less tough than steel, but this is compensate with the weight saving.

In general, the other physical properties are more less the same, and in some cases aluminium is better than both of the others.

There are many more advantages besides the physical ones, which are:

Acceleration: a weight reduction from 3400 to 2600 lbs. would reduce the 0 to 60 mph acceleration time for a mid −sized sedan from 10 to 8.2 seconds − an 18% improvement(Figure 6[4]).

Figure 6[4]

Handling: reduced vehicle weight leads to improved stability and turning response. It also decrease the slip angle between the tire and the road, allowing the car to respond quicker and more accurate(Figure 7[4])

Figure 7[4]

Noise, Vibration and Harshness: A car's torsional rigidity influences the way the road−generated noise and vibrations are transmitted to the passengers. To reduce this, it has been proved that aluminium reduces significantly this issues.

Cost: actually, aluminium is not a very cheap material in order to get it from mining. But the good part of aluminium is that it can be recycled and doesn't loss its properties. This, therefore, will affect final price, and it will be lower.

Recycling: as I said before, aluminium can be melted over and over again without loosing any property. Compared to steel, this is a great advantage because usually steel has to go throughout a process to get the same alloy as before, and it suffers from corrosion, in which case part of the steel is lost.

Another advantages that must be overlook, in order to develop a vehicle, is reparability. While aluminium can be easily repaired, the methods sometimes differ from those used for steel. Two things are required for cost−effective repair: proper equipment and properly trained repair personnel. To accomplish this the not difficult, just different theory has been applied. Aluminium is a very easy to repair metal, and this is an advantage as well as the others.

CONCLUSIONS:

The aim of this essay is to explain the use of aluminium in cars, and its characteristics and advantages. After reading it, it can be said that aluminium is the best option in this matter, and that this metal is better than steel.

The properties of aluminium compared to iron give so many advantages that Automakers have tried to replace it since 1900's. Now we can see cars with a great percent of aluminium.

The use of aluminium in cars is now a very important matter, because aluminium has demonstrated to be suitable in this issue. This is the reason why I, as a student, must know about aluminium and how to work with it. After reading all the information, and according to what I quote here, the develop of aluminium is very advanced, and it's tomorrow's car metal.

I must include here that aluminium can be recycled. This point is very important to me, not just by the fact that this saves energy, but because this helps to keep the atmosphere clean of smog.

We can infer from this paper that thanks to engineering, and its constant goal of optimise and find alternative solutions, another problem has been solved and industry has been improved as well. This all leads to the common aim that all engineer must think: make life easier and better, by a better use of materials.

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[4] Aluminum Association Home Page, www.aluminum.org.

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Module 23.2SB1 − Assessed Exercise No. 4

Mini−project: The use of aluminium alloys in automotive engineering

Figure 3: the new Audi A8