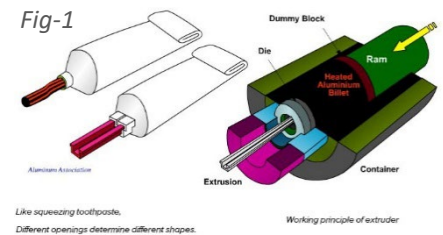


Vehicle Structure and Aero

Aluminium Bonded Chassis

Aluminium Bonded chassis are lightweight, stiff chassis designs made from extrusions of aluminium bonded through either welds, rivets or epoxy adhesive or a combination. It is a chassis style originally seen in mainly lightweight sports cars but is now being more widely accepted in larger premium EVs.

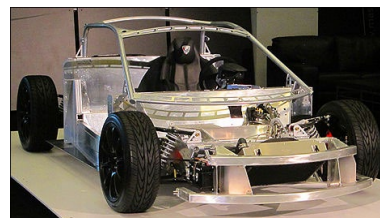
The most simplistic way to describe this chassis style is various boxes and sheets of aluminium formed through an extrusion process, which are adjoined, most commonly with adhesive, to form a versatile structure for a body to sit on. An aluminium extrusion process is not too dissimilar to squeezing toothpaste out of a tube (*Fig-1*), a heated billet of aluminium is pushed through a die, like a cookie-cutter, the shape of the hole is the shape the extrusion forms. This means the aluminium is fairly dense and strong with the pressure of the billet being pushed through a small space. The adhesive used tends to be epoxy for its strong and permanent grip. Lotus designs its extrusions to have grooves in the bonded areas, this allows the epoxy to really bed into the metal and gives a larger surface area for it to grip to. Lotus also tends to assemble its chassis with an orange epoxy, allowing the assembly team to clearly see if there is sufficient adhesive. It seeps out the edges in a so-called 'squidge', which suggests full coverage (*Fig-2*).



The surface area coverage is something that favours manufacturers to use adhesive over the more traditional metal bonding technique of welding. Welded joints tend to be weaker due to the lack of surface area again. This also means to make up for this the metal needs to be thicker for the same desired stiffness, meaning a heavier chassis (*Fig-3*).

(Fig-3)	Renault Sport Spider	Lotus Elise
Weight of chassis	80 kg	65 kg
Torsional stiffness	10,000 Nm/degree	11,000 Nm/degree
Thickness of extrusion	3 mm	1.5 mm

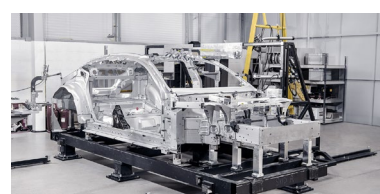
Bonded aluminium chassis traditionally were used in more lightweight sports cars, with lower production numbers, such as the Renault Sport Spider, various Lotuses and Lotus based cars, including the first Tesla, the Vauxhall VX220, Lotus Elise and Exige. Later the style was adopted by most post-2005 Aston Martins. More recently in big news, the Volvo subsidiary Polestar has opted for using the design in its EVs. Their reasoning is with



Lotus Elise



Renault Sport Spider



Polestar 5



Aston Martin

incorporated body panels the production is much faster, it is a lighter form of chassis than their previously used pressed steel, making up for the heavier batteries and finally, it has much better torsional rigidity, which is only amplified by the batteries. In the new Polestar O₂, they plan to mark the different grades of aluminium used in the build, making recycling the aluminium, a long-time problem, much easier.

The obvious benefits have been outlined a few times now, such as the stiffness and rigidity of the construction, and the lightweight final product. Traditionally it was suited for lower production numbers, as the less initial investment is needed, for construction equipment such as robotics to apply the adhesive. You also don't need to employ professional certified welders; you just need a team to use the easy to operate epoxy gun. A large space for a construction line isn't necessary either.

However, the hand-built process is less valid for higher production numbers, as it could become quite labour intensive and require a larger space. Aston Martin combatted this by building the James Bonder robot to apply adhesive. Another benefit that aluminium in general has over materials such as steel is its corrosion resistance, the most that can happen to aluminium is the top layer oxidising, but this isn't even a negative it just means the metal underneath is sealed and protected. Finally as mentioned about the Polestar, the sustainability of Aluminium is good, it can be recycled over and over without any loss of quality or purity (as long as it is only combined with the same grades).

As perfect as bonded aluminium chassis might seem, there are some negatives. Aluminium is an expensive material in comparison to something like steel, the other metal most commonly used in vehicle manufacturing. Steel is also a stronger material overall, it is less likely to warp and flex, pure sheets of aluminium aren't as strong in the same dimensions. However this is not taking into account the weight difference, the ratio of strength to weight is much higher in aluminium than in steel, with steel being much denser. The final extra process that has to be completed before bonding or welding aluminium is a chemical treatment.

Generative Design

Generative design is an iterative design process that utilises CAD and AI to automatically produce many design possibilities, using specific user inputs that outline certain constraints. With generative design, you can create a design and architecture that has optimal strength, all whilst making the parts as light as possible. Something to keep in mind is that the designs aren't originated by AI, rather the AI is just a tool for the designer to use as a refinement of the human-created concept.

Say for example you wanted to use generative design to create some sort of shelf bracket. The software would require a few starting prompts such as locations and number of holes for screws, the general dimensions, like width, height and so on, but most importantly the loads and strains you expect the bracket to withhold. In return for the data you enter, the software will create many iterations of potential designs.

There are five main steps from defining the problem the part is to solve to the final physical creation of the part. Firstly you need to identify the use of the final product and what it requires and doesn't, from this you can collect and input the data necessary. To begin with enter the constraints and requirements for model generation, then define parameters for Vehicle Structure and Aero

evaluation. Following this, the program will generate possible design solutions. These can then be looked over by human eyes, to be evaluated and refined, the engineer can select the iteration they think works best the evolve and refine it. For the manufacturing stage, there are a few methods that suit the process, the top three are as follows, **Casting(Fig-4)** - complex shapes can be created in one section, however, due to the unrefined nature of casting, air bubbles can form weakening the design. **Additive manufacturing(Fig-5)** - This often refers to 3D printing, material is added in layers, building up to form shapes. **CNC machining(Fig-6)** - Precision machining can mill and turn material, they are flexible and can twist and turn to manufacture complex parts.

The final products have an organic look to them(Fig-7), with bone-like structures, and harsh edges all but disappear, all that's left is what's necessary, mimicking years of evolution in its look. The final result when compared to the original is also astounding, the small sports car manufacturer BAC used generative design to improve upon its wheels, with the same strength intact, and they saw a 35% reduction in weight (Fig-8).

There are many upsides to generative design, but in my opinion one big downside. Firstly there are the unlimited choices and design iterations that are produced, despite the set-out constraints. Then there's the short timeframe a design can be completed in, freeing up time and skipping the ideation process to allow engineers to focus on other tasks. Although the initial fee of buying the required software is quite high, engineers won't need to run extra simulations as the simulation process is built-in, this means all adjustments are automated again shortening the time engineers need to spend on aspects of the project. The AI will also overcome creativity barriers of the human mind yet still produce a practical solution, the various iterations will be more than the human mind can envisage, still sticking to set constraints and avoiding human errors. The big negative in my opinion is that software like this could make humans redundant, technology like this will obviously threaten roles of designers and engineers. However, this is not to say there isn't a place for human interactions, this is more so just another tool for engineers and designers to use. This is further proven by the fact that despite the automation you still need manual intervention and someone who understands how to use the program. Bizarrely another issue is that the software could throw too many options and iterations at you and could end up being a little overwhelmed.



Fig-4



Fig-5

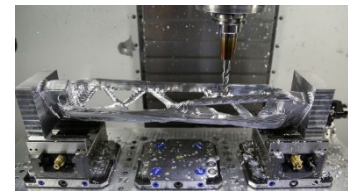


Fig-6



Fig-7



Fig-8

Aerodynamics: Importance, Drag & Wind Resistance

Having well designed and constructed aerodynamics is key to pretty much every vehicle on the road, it affects everything about the car and how it handles and accelerates just as much as say the engine or chassis set up. The most basic thing to look at is how fast you

can imagine a vertical shape, perpendicular to the ground going, versus a shape angled more at something like a 45° with the same force behind it. The air resistance of a vertical shape pushing directly into the air it is going through is much higher than an object lying at an angle cutting through the air much smoother. A shape more akin to the second is going to require much less energy to reach the same speeds, this is why a car with smooth airflow and low drag coefficient has a higher maximum speed, there are less forces acting upon the vehicle, that could restrict how it cuts through the air. On the other end of the performance scale, well designed aero will gift a reduction in fuel consumption, therefore less emissions again down to that lack of drag requiring more energy to push through. Well designed aero will also reduce wind noise in the cabin and reduce lift at higher speeds, which can obviously be dangerous, losing contact with the tarmac.

One big struggle when it comes to aero is the practicality we expect from cars, most cars on the roads have protruding objects that even if slight, add just a little drag, things such as door handles, wing mirrors and antennas, all stick out of the overall shape of a car increasing drag.

More powerful cars can also take advantage of the airflow over the car. Sometimes a wing is required for traction, most cars use the same principle seen in a basic aeroplane wing (*Fig-9*), the curve on the top of the wing means there is more surface for the air to travel over, this accelerates the air speed, underneath meanwhile the air is traveling much slower, meaning higher air pressure leading to lift. The opposite can be applied to cars to form the downforce required.



Fig-9

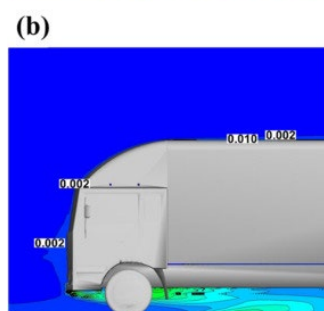
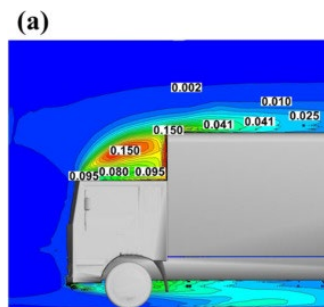


Fig-10

Figure 10 shows how trucks are sometimes designed to have cab deflectors, the half dome shape on top of the cab, for much better aerodynamic efficiency, before it was just an area that collected up air bouncing back off the vertical trailer onto the cab top and back round, it's much better to have a constant flow of fresh air flowing over the vehicle.

But good aero doesn't always mean smooth flowing air, super-cars, hyper-cars and race-cars all take advantage of this constant flowing air. A big catching spot and something that decreases aero efficiency a lot is the wheel wells, this area tends to be responsible for 25-30% of air resistance on a standard car, hence why a hypermiling car such as the VW XL1 covers the rear wheel arch (*Fig-11*). On performance cars that rely heavily on their brakes, air flow in the wheel well is necessary for keeping the brakes cooler, wings which increase drag are also sometimes useful, for better cornering and traction, this will decrease the top speed though. This is where active aero comes in, it means for braking the angle of a wing can increase, for cornering and stability it can rise up, but for straight acceleration it settles back into the body for smoother air flow.



Fig-11

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