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Introduction to Automotive Engineering

ACHA4009

Technical report

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Contents

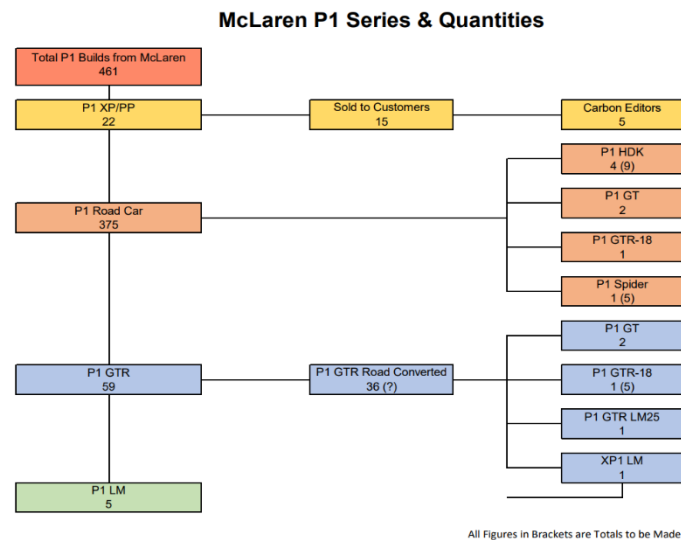
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1 Introduction

- 1.1 The aims of this report are to choose 6 subtopics and to discuss how they have been used effectively to produce a car of choice. This report is about the McLaren P1, which hit the market in October 2013 for £866,000 (Ingram, 2020), but since then the sale price of most models has risen to over £1 million (Ingram, 2020). These days it is reasonably common to see the mainstream McLaren's, such as the 765LT or the 720s, but there are quite a few special additions to the P1 that make it so valuable.

Lanzante



[Figure 1.1] a table direct from Lanzante that shows how many P1 models were made and are expected to be made road legal (D. Lanzante, 2023)

To start with, there was a total of only 461 cars built, and only 375 of which have been made into road legal cars, the others are just track cars. There are then 4 different models of the McLaren P1, including the spider which was specially designed and made by Lanzante, and released at the Goodwood Festival of Speed in June 2022 [Figure 1.2].



[Figure 1.2] McLaren P1 spider at its unveiling at Goodwood Festival of Speed (captured by Catriona Burn)

2 Impact of chosen topics

2.1 Materials

The chassis of a McLaren p1 is made of mostly carbon fibre. Carbon fibre is popular with high performance vehicles and companies because it has one of the lowest strength:weight as well as stiffness:weight ratios. This means it is light but still strong enough for manufacturing purposes.

There are 2 sizes of carbon fibre used, one larger and one smaller, both 2x2 Twill weave. This style weave is good for “complex shapes as its weave is looser” (Est Carbon, 2023). This means it moulds around corners nicely and creates a beautiful, smooth, strong shape, perfect for a McLaren chassis. The use of different sized weaves is purely for aesthetic purposes. The smaller weave looks neat and is used for the surfaces of the chassis that are exposed when the car is put together. The larger weave is only visible when the bodywork is off the car as it looks less tidy.

Carbon fibre is preferred to fibreglass because it is less flexible. It is preferred for manufacturing purposes due to its rigidity and stiffness. (González-Estrada, Pertuz and Quiroga, 2018)

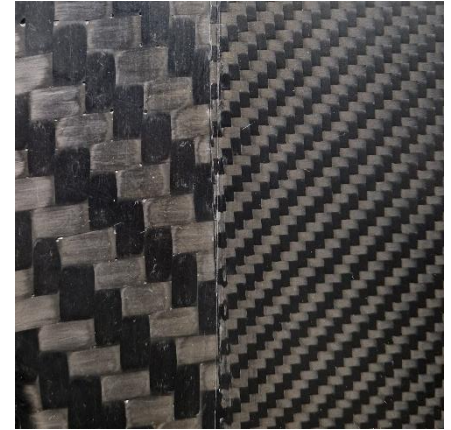
The brake discs on the P1 are made of ceramic carbon. Ceramic carbon can “absorb 50% more energy than conventional ceramic rotors” (McLaren Automotive, 2023), making them less likely to crack under the high speed braking.

Another material used is aluminium. The rear chassis is made of aluminium because lightweight and malleable, making it easy to manipulate into any design necessary while keeping its strength to hold the . It is preferred to steel because “Aluminium requires fewer welds than steel, eliminating many potential failure points.”(Lukkassen and Meidell, 2007)

The aluminium of a P1 chassis is not bonded directly to the carbon. It is bolted into a super strong resin which is then bonded to the carbon. Using a strong adhesive such as resin for bonding materials reduces the stress concentration and is less likely to cause cracks or breakages.

Pirelli collaborated with McLaren to produce bespoke tyres for the McLaren P1, as well as the Senna. “The objective for the tyre structure was to ensure flexibility and grip, while at the same time guaranteeing enough rigidity to cope with high aerodynamic loads” (McLaren Automotive, 2013). The tyres were created for all weather types: cold, warm, wet, as this car is built for road and track use.

Gold foil is used on the outer rear of the cockpit to defer heat from the fuel cell. If heat is gathering in one area of the engine, the gold will absorb it and disperse it across the panel. This will decrease the overall temperature protecting the fuel cell which is located directly on the other side of this wall.



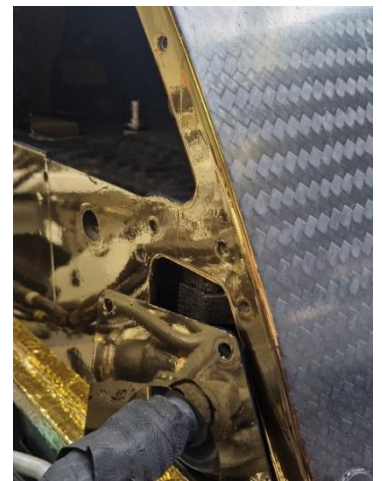
[Figure 2.1.1] 2 sizes of carbon used on the chassis. (by Catriona Burn)



[Figure 2.1.2] Ceramic carbon brake discs. (photo by Catriona Burn)



[Figure 2.1.3] Aluminium bonded to carbon fibre with a strong resin. (photo by Catriona Burn)



[Figure 2.1.4] Gold foil coated rear cockpit. (photo by Catriona Burn)

2.2 Aerodynamics

Aerodynamics is measured by drag coefficient (C_d) is a measurement of how efficient the shape of a car is. Spoilers on a car are used to produce more downforce. Downforce is required at high speeds to keep the car stable and help it 'stick' to the ground, assisting with the aerodynamic efficiency. It directs the airflow up which in turn pushes the car down. The downforce on the P1 is "over 600kg" (Sheriff, 2012).

The spoiler on a the P1 is different to common spoilers seen on most McLarens. It is controlled by 3 hydraulics. The 2 outer ones control the height, and the middle controls the angle. "It can extend rearwards by up to 300mm on a racetrack, and by up to 120mm on the road." (McLaren Automotive, 2012). This wing moves when braking, increasing drag and helping slow the car, and the does the opposite when accelerating.



[Figures 2.2.1 & 2.2.2] Hydraulic control system of the rear wing. (photos by Catriona Burn)

The flooring of the P1 is designed to direct the air under the front and out the rear sides to pull the car down. This also helps with control, especially on corners and when accelerating to high speeds.



[Figure 2.2.3] P1 flooring. (photo by Catriona Burn)

Bernoulli's principle states that an increase of velocity of a fluid causes a decrease in pressure, which is an example of conservation of energy. To create high velocity airflow on high performance cars, smaller gaps are used on the bodywork to squeeze the air through. Low pressure makes it easier for the air particles to move, therefore causing less drag on the car. And low pressure under the car creates a lifting force that helps keep the car low to the ground.

"In flowing fluid, the total energy is the sum of kinetic and static energy" (Wong *et al.*, 2018)
The equation for Bernoulli's principle is:

$$P + \frac{\rho}{2} V^2 + \rho gh = \text{constant}$$

Where P is pressure, ρ is density, V is velocity, g is gravity and h is height above a reference level. This and more complex equations will be used in computer programs (i.e. CFD) to show the levels of high and low pressure on a vehicle.

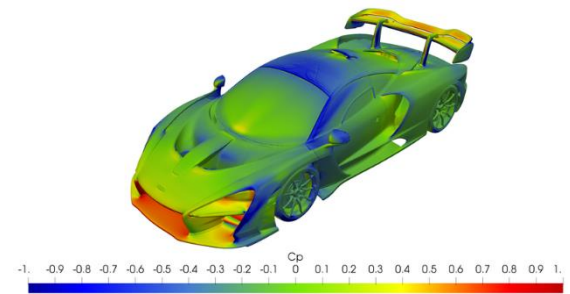
The McLaren P1 was put through a series of aerodynamic testing before release, and this included testing in a wind tunnel. In a wind tunnel, air is accelerated at high speeds past the vehicle to simulate how the car would act under normal driving conditions.

A factor that contributes to the aerodynamics of the car being effective is the total weight of it. If the car is heavy, this increases the drag and the aerodynamics would be less effective. The kerb weight of the P1 is 1,490kg, with the monocoque (a development of the MonoCell originally used in the MP4-12 model) weighing only 90kg.

2.3 Computer design

Computer design is a huge part of designing a car, specifically at the start when testing the strength and aerodynamics of the chassis and exterior is necessary. CAD models are part of the first few steps of car design, after the basis has been thought up, and CFD (computational fluid dynamics) is a good way of carrying out aero testing before manufacturing the object and doing physical testing (i.e. in a wind tunnel).

CFD models show where the levels of high and low pressure on the vehicle. **Figure 2.3.1** shows a CFD model of a McLaren Senna. It shows high pressure on the front, but little everywhere else which proves the McLaren is well designed. McLaren will have tested hundreds of designs before making a final decision.

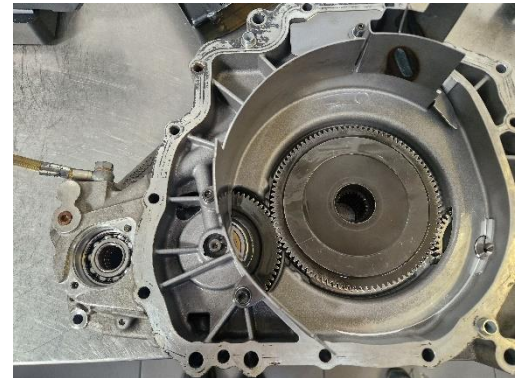


[Figure 2.3.1] CFD model of McLaren Senna.

2.4 Hybrid systems

While the P1 is powered by a 3.8L Twin-Turbo petrol engine, which puts out 727bhp, it is also powered by single electric motor, that gives it an extra 176bhp. This motor is connected to the gear shaft, so the car can be run in full electric mode. When in electric mode the clutch is disconnected and therefore not turning over the engine. "The electric motor offers a range of 11 km (6.8 miles) in full electric mode" (Automotive, 2013).

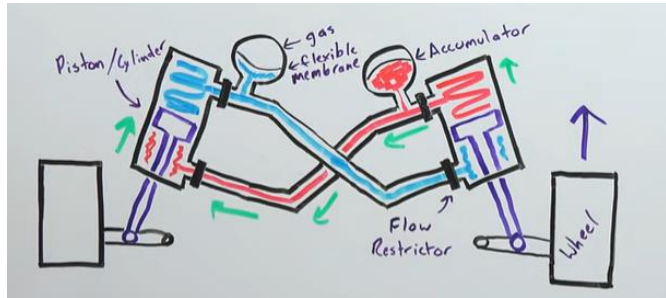
The motor creates more torque, producing a larger amount of power from the powertrain (a total of 900Nm of torque and 903bhp (Automotive, 2023)).



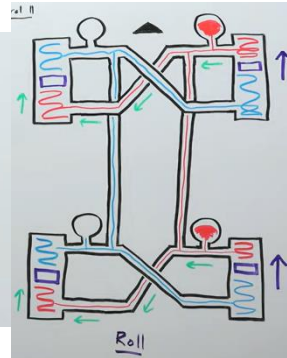
[Figure 2.4.1] Gears on top of McLaren P1 engine (photo by Catriona Burn)

2.5 Engineering Interpretation: Suspension

The suspension on a P1 is a bit different to what you'd see on any other high performance car (**figure 2.5.1**). Instead of a normal damper system, it uses fluid and air pressure (nitrogen) to assist with balancing the car during braking, accelerating, and turning. Each corner is linked by a fluid pipe and they all have a different pressure rating of nitrogen (i.e. rear left 9.5 bar, rear right 9.1 bar), stored in a carbon fibre accumulator (**figure 2.5.2**). This accumulator has a flexible membrane that the fluid compresses and decompresses depending on where the fluid needs to be. **Figure 2.5.3** is a diagram of how the suspension works.



[Figure 2.5.3] (Fenske, 2019)



[Figure 2.5.1] Fluid suspension system (photo by Catriona Burn)



[Figure 2.5.2] Carbon fibre accumulator (photo by Catriona Burn)

When steering to the right, the wheel will push up on the suspension, causing the damper to also push up. This then compresses the fluid (red), which will travel to the other 3 dampers. These move with that fluid and stop the car from leaning, making cornering smoother at higher speeds. Flow restrictors are positioned at the exits of the shock absorbers to control the rate of the fluid passing in and out of the chambers or into the accumulator. Having a small hole in the flow restrictor will create a very stiff suspension, and a big hole will give a soft suspension.

When it was released in 2013, this suspension system was specific to the P1. It has been highly successful and since then also been used in the 720s model (released in 2017).

2.6 Emissions

The P1 is not high on emissions for a high performance car. It "still returns 34.0 mpg (8.3 l/100km) on the EU combined cycle, with CO₂ emissions of 194 g/km" (Automotive, 2013) In the EU it is likely that by 2030, the emissions of cars will have to be reduced by 55%, which is where big engine cars like the P1 will be pushed out of the market.

3 Current state of the industry

For the past so many years, the automotive industry has been trying to find a alternative fuel to (our current). There has been a lot of disagreement between use of electric and alternatives such as hydrogen or biofuels. In some worlds electric vehicles may be the way to go, they definitely generate more torque when used in hybrids, but there are a few ways electric would fail if the world went electric. To starter with, the national grid would struggle to keep up with charging all the cars. Although, “ If all EV drivers charge their cars at night, the National Grid estimates that the increase in overall demand would only amount to 10 percent” (Pulkit, 2022) which is manageable with the correct system.

Another issue the automotive industry could face is exchange rates (Hitchcock, 2023). If the exchange rates of the pound falls further than it has, the car industry will see a drastic increase in prices, even more than it has in the past few years.

4 Conclusion

The biggest challenge that is yet to be faced is most likely to be fuel and how it can be overcome. The battle for which alternative fuel is likely to go many ways and there may end up being a lot of different options that not everyone can agree on. The industry will almost definitely try to keep the love for racing and motorsport, no matter what fuel, because it is where a large percentage of the money is.

It is likely in the future that a very small number of high performance internal combustion engines will still be around as long as they are hybrid. This would make the McLaren P1 perfectly fit into the automotive industry.

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