

Automotive Chassis Systems – EV's

Introduction

The aim of this report is to perform tasks surrounding the subject of vehicle development through history. This report first discusses the development of vehicle structures over time, the impact that increased use of electric powertrains would have on vehicle structure design and BIWs will be discussed. Considering torsion, bending, aerodynamics and crash requirements to discuss this. In task 2, the use of the simple structural surface method will assess the structure of a van in torsion to determine the shear loads on each panel shown.

Task 1

Vehicle development

Vehicle development through history has had a massive impact on the change in society. People now look at vehicles in much more detail than they would years ago, they look at how it looks, what the performance is and all the specifications of the vehicle. Whereas before, it was just a form of transport.



Figure 1: An image of a vehicle structure design in the 1920s

Above shows a vehicle structure in the 1920s. In the 1920s structures were built using the concept of body on chassis. Vehicles of this decade usually had very low stiffness, they were 'coachbuilt' by carpenters and most cars were built open roof. Due to the cars having a low stiffness, they were very unsafe and couldn't withstand much overload. There are two types of overloads. Instantaneous overload, where the car would encounter a lot of force instantaneously, such as hitting a kerb or a large pothole. This happens rarely but has a force of approximately 10000N. The other type of overload is fatigue, this happens commonly but has an impact force of approximately 1000N which is significantly less. This overload happens when the car runs over cobblestones and medium potholes. With the structural design of cars in the 1920s, cars wouldn't be able to deal with these overloads. There are also two types of stiffness that are applied on a vehicle, torsional stiffness and

bending stiffness. Torsion is when one axle on a wheel hits a bump. In reference to the above car, torsion wasn't considered therefore, there will not be any features on the car that would typically increase torsion (Robertson, 2002). Bending however, is when both wheels encounter a load simultaneously, such as speedbumps. Bending was compared to resistance in the 1920s, so like torsion it wasn't considered.



Figure 1.1: Aftermath of a car crash in the 1920s

In this decade, there was no such thing as signs, traffic enforcement, signals and the roads were terrible. This model was the T Ford and was less than \$300. While cheap, these cars would encounter fatal accidents due to their sharp metal edges on some corners, non-shatterproof glass and potential for being thrown out of the vehicle. These cars were known as "Tin Lizzy" and were designed for fast production, not safety (Jr, 2013).



Figure 2: A Ford chassis model from the 1930s

In the 1930s, it was discovered that bending and torsion impacted body stiffness. Therefore, they started to integrate the body and chassis, instead of using the body on chassis method. After the 1920s, stiff bodies were built, they used steel clad, and were made with a roof. This improved safety on cars, however, was nowhere near a safe standard.

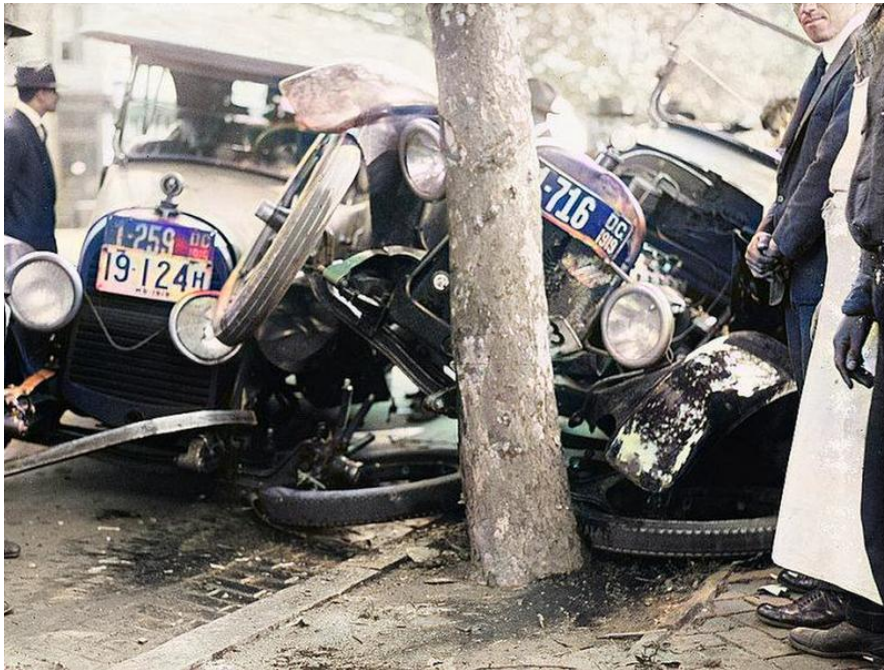


Figure 2.3: A car crash in the 1930s

In the 1930s, there were finally some new laws that set a driving age and prohibited drinking and driving. Manufacturers realised in this decade that their cars needed to be safer. Safety features such as breaks on all four wheels instead of just the front two, windscreens were made with shatterproof glass and cars were made to be more stable. There were other inventions of safety features in 1930s, however, due to the war these would be implemented in many years to come. These features included seatbelts, padded dashboards, all-steel bodies, shock-absorbing steering columns and hydraulic brakes (Harris, n.d). The development of stiffer bodies meant that they carried more unnecessary load. This led to rattling between chassis and body, squeaking and cracking in the body. To prevent this, they would stiffen the chassis but soften the body. To stiffen the chassis, springs were added in series, and to soften body they used something called cruciform bracing which still used open sections, but the diagonal members were in bending.



Figure 3: Modern-day triangulated tube structure

Although the triangulated tube structure wasn't as developed as this historically, this is a basis of what they looked like. These structures were best suited to low volume production due to the requirement of intense labour. The triangulated tube structure would surround the outside of the body and the coachwork connects directly to the chassis and requires no structure (Robertson, 2002). By adding a triangulated tube structure, this increased rigidity and flex of the car. It was a rigid structure due to the addition of a diagonal member meaning the connected corners are held at a fixed distance. This structure cannot be forced out of shape despite having pivots for corners. This structure also made the chassis lightweight but strong. Cars can be made faster with this structure incorporated as it would be safe to do so due to the strength, and they are simple as they are light (elephantracing, n.d).

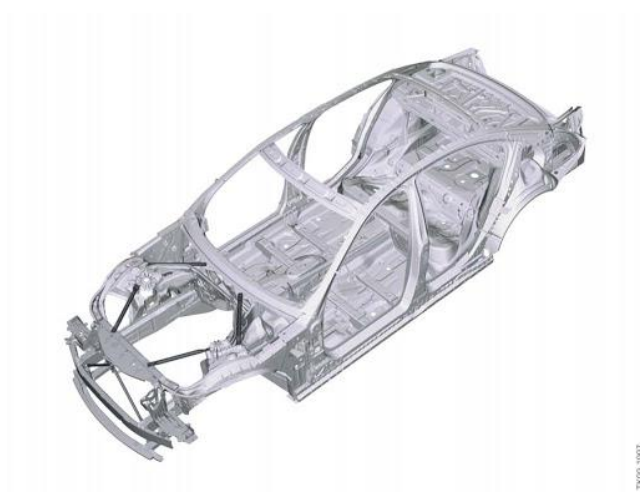
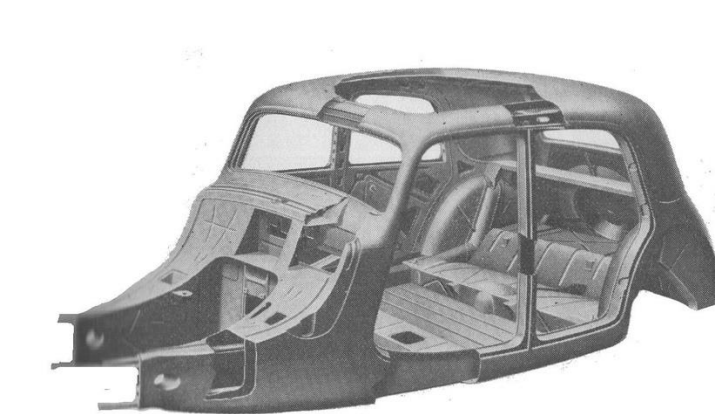


Figure 4: Monocoque structure

This is a widely used modern day chassis structure. A monocoque is a shell around car made by using both chassis as the frame in a single construction. The monocoque structure is safe due to its cage-like structure, the chassis is easy to repair, and it has a very high torsional rigidity. However, this type of chassis would not be used for race cars due to it being heavyweight because of an incorporated chassis and frame. It is also not financially feasible for it to be used for non-mass production vehicles (Rangam, 2020).



This is the most widely used modern day chassis structure. Above is a structure that was used by Citroen from 1934-1956. This structure is welded using a pressed steel sheet metal body and is well suited for mass production. Also, due to the body being self-supporting, a separate chassis is not needed. This also adds to the suitability of mass production (Robertson, 2002).



The testing company Euroncap were introduced in 1996. They test cars on their safety using test crash equipment. They test for four things on a car, the adult occupant safety, child occupant safety, vulnerable road user safety and the safety assist. I conducted research on the car I currently drive which is the Skoda Citigo. Using Euroncap, I entered the make and model, and it came up with two tests one from 2011 that had expired, and a more current one from 2019. It was found that the Skoda Citigo had a safety rating of 3 out of 5 stars, and scored 83 percent in the child occupant, 81 percent in the adult occupant, 46 percent in the vulnerable road users and 55 percent in the safety assist. The comments made about the adult occupant's safety in the vehicle were that it remained stable in the frontal offset test. The readings from the dummy indicated good protection of the knees and femurs of the driver and passenger. It showed a similar level of protection would be provided to occupants of different sizes and sitting in different positions. The chest protection was marginal. In the full width rigid barrier test, protection of the chest was marginal for both occupants, with other critical body areas well and adequately protected. In the side barrier

impact, all critical body parts were well protected, and the car scored maximum points. In the more severe side pole test, protection of the chest was adequate and that of other body areas was good. Tests on the front seats and head restraints demonstrated good protection against whiplash injuries in the event of a rear end collision. A geometric assessment of the rear seats indicated marginal whiplash protection. An AEB system is not available. For the child occupant safety, in the front offset test, protection of the neck of the 10-year-old dummy was rated as marginal, based on dummy readings of tensile forces. Protection of the 6-year-old dummy was good. In the side barrier test, dummy readings of accelerations in the chest of the 10-year-old dummy indicated poor protection of that body area. The front passenger airbag can be disabled to allow a rearward-facing child restraint to be used in that seating position. All the restraint types for the car can be properly installed and accommodated in the car. For vulnerable road users, the bonnet provided good protection to the head of a struck pedestrian over most of its surface but there were broad areas of poor performance along the base of the windscreen and on the stiff windscreen pillars. The bumper provided good protection of the legs, but protection of the pelvis was mixed. The safety assist test showed that the car has a seatbelt reminder system for the front and rear seats. A lane support system helps prevent inadvertent drifting out of lane and intervenes in some more critical situations. A speed assistance system uses digital mapping to determine the local speed limit and presents this information to the driver (euroncap, 2019). For a car to be manufactured, it needs to pass these tests. This shows how far the development of safety in cars has come, as the tests conducted cover the critical components of the cars ability to be on the road safely. However, this was only introduced in 1996 so cars before this could be released without knowing the true extent of its safety.

Today, electric vehicles are being used more commonly. This is because of the eco-friendliness of these cars. They produce zero harmful emissions, compared to combustion engine cars being one of the main contributors to CO₂ emissions. Even though it's still a long time before every car on the road is run by an electric powertrain, there is speculation that most cars on the road will be electric in the future.



Figure 6: An EV chassis

As seen in the photo, the chassis of an EV contains a battery as the main body with the power electronics in front. On the front right of the chassis there is a charging plug and on the left is an inductive charging panel. At the back of the car there is the drivetrain. Typically, with this design of chassis, there is more room inside for the passengers due to the battery being mounted low to the floor (Hanley, 2018). The chassis for EV are designed

from the ground-up ensuring a clean, cost-effective option. Automakers use formable ultrahigh-strength steels to ensure that the car is as lightweight as possible. The chassis of a Tesla model S2 is made up of battery (29%); motor drivetrain, brakes, and suspension (23%); frame (17%); interior (14%); closures (4%); electrical (4%); and other components (9%). The average sedan has a weight distribution of body structure (25%); powertrain (25%); chassis and suspension (21%); interiors (14%); closures (8%) and glazing, electrical and fluids (7%). As shown, it is obvious that the EV chassis have a better weight distribution to ensure the vehicle feels as lightweight and efficient as possible (Halonen, 2021).

Task 2 – SSS of a van in torsion

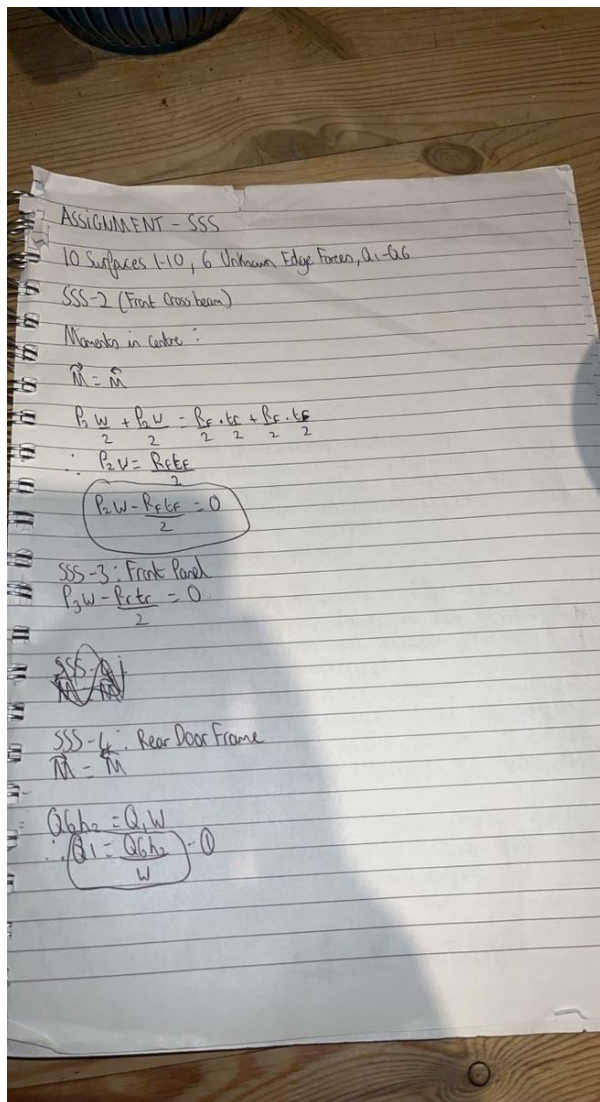


Figure 7: My method for SSS of a van in torsion

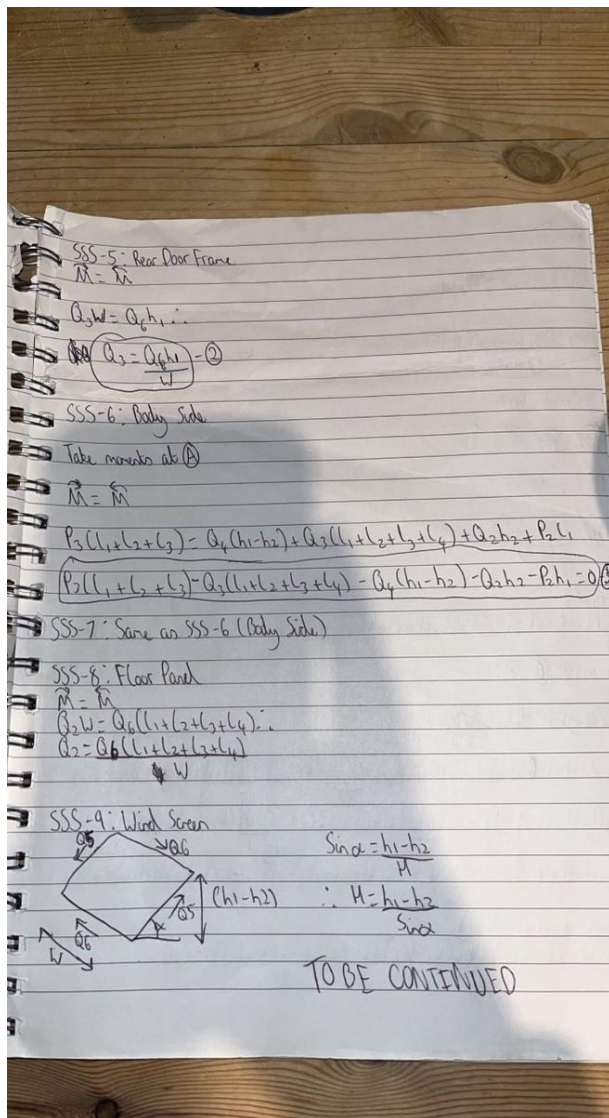


Figure 7.1: My method for SSS of a van in torsion

$\bar{M} = \bar{M}$
 $Q_6(h_1 - h_2) = Q_5 W$
 Since
 $Q_5 = \frac{Q_6(h_1 - h_2)}{W} \quad (5)$
 SSS to Roof
 $\bar{M} = \bar{M}$
 $Q_6 L_5 = Q_4 W$
 $Q_4 = \frac{Q_6 L_5}{W} \quad (6)$
 From (1)
 $P_3(l_1 + l_2 + l_3) - Q_3(l_1 + l_2 + l_3 + l_4) - Q_4(h_1 - h_2) - Q_2 h_2 - P_2 h_1 = 0$
 $\text{Put in (5), (6), (4)}$
 $P_3(l_1 + l_2 + l_3) - \frac{Q_6(h_1 - h_2)}{W} - \frac{Q_6 L_5}{W} - \frac{Q_6(l_1 + l_2 + l_3 + l_4)}{W} h_2 - P_2 h_1 = 0$
 $\therefore P_3(l_1 + l_2 + l_3) - P_2 h_1 = \frac{Q_6 h_1}{W}(l_1 + l_2 + l_3 + l_4) + \frac{Q_6 L_5}{W}(h_1 - h_2) + \frac{Q_6(l_1 + l_2 + l_3 + l_4) h_2}{W}$
 $P_3(l_1 + l_2 + l_3) - P_2 h_1 = \frac{Q_6}{W} [h_1(l_1 + l_2 + l_3 + l_4) + L_5(h_1 - h_2) + h_2(l_1 + l_2 + l_3 + l_4)]$
 $\frac{W(P_3(l_1 + l_2 + l_3) - P_2 h_1)}{h_1(l_1 + l_2 + l_3 + l_4) + L_5(h_1 - h_2) + h_2(l_1 + l_2 + l_3 + l_4)} = Q_6$

Figure 7.2: My method for SSS of a van in torsion

$$\begin{aligned}
 P_2 &= \frac{P_1 b_1 c_1}{2W} \\
 P_2 &= \frac{5000(1.5)}{2(2.1)} \\
 P_2 &= 1785.78 \text{ N} \\
 P_3 &= P_2 \therefore P_3 = 1785.78 \text{ N} \\
 Q_6 &= \frac{W(P_3(l_1 + l_2 + l_3) - P_2 h_1)}{h_1(l_1 + l_2 + l_3 + l_4) + L_5(h_1 - h_2) + h_2(l_1 + l_2 + l_3 + l_4)} \\
 &= \frac{2.1[1785.78(2 + 3.5) - 1785.78(2.5)]}{2.5(2 + 3.5 + 1) + 3.5(2.5 - 1) + 1(2 + 3.5 + 1)} \\
 &= \frac{2.1[1785.78(5.5) - 1785.78(2.5)]}{2.5(6.5) + 5(1.5) + 6.5} \\
 &= \frac{2.1(9821.79 - 4464.45)}{16.25 + 7.5 + 6.5} \\
 &= \frac{2.1(5357.34)}{30.25} \\
 Q_6 &= 371.91 \text{ N}
 \end{aligned}$$

Figure 7.3: Method and calculations for panel Q6

$$\begin{aligned}
 Q_1 &= \frac{Q_6 h_2}{w} \\
 &= \frac{371.91(1)}{2.1} \\
 Q_1 &= 177.10 \text{ N} \\
 Q_2 &= \frac{Q_6 (h_1 + h_2 + h_3 + h_4)}{w} \\
 &= \frac{371.91(2 + 3.5 + 1)}{2.1} \\
 Q_2 &= 1151.15 \text{ N} \\
 Q_3 &= \frac{Q_6 h_1}{w} \\
 &= \frac{371.91(2.5)}{2.1} \\
 Q_3 &= 442.75 \text{ N} \\
 Q_4 &= \frac{Q_6 L_5}{w} \\
 &= \frac{371.91(5)}{2.1} \\
 Q_4 &= 885.50 \text{ N}
 \end{aligned}$$

Figure 7.4: Method and calculations for panels Q1, Q2, Q3 and Q4

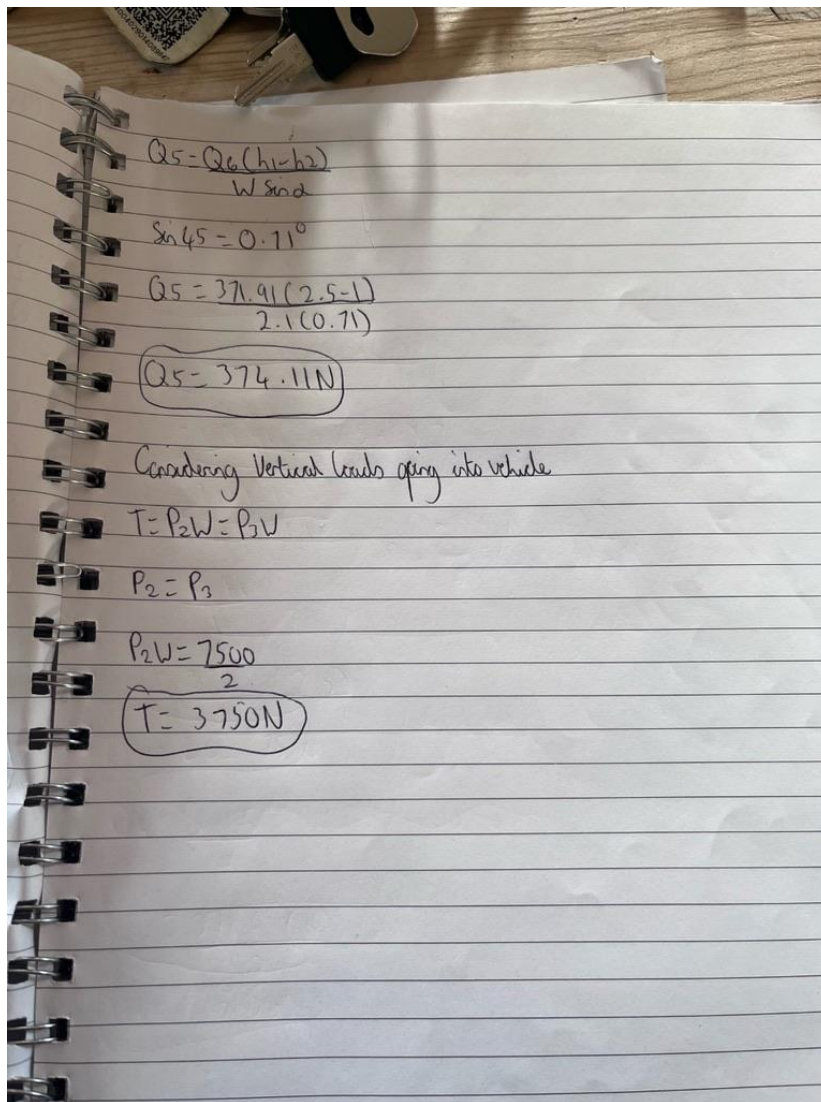


Figure 7.5: Method and calculations for Q5 and T

Panels

Q1 = 177.10N

Q2 = 1151.15N

Q3 = 442.75N

Q4 = 885.50N

Q5 = 374.11N

Q6 = 371.91N

Torsion = 3750N

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