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1 Introduction

This technical report aims to investigate a chassis system of the vehicle and its historical development. As the technologies have evolved with the need for alternative fuel energy, since fossil fuels have become an environmental issue, the electric vehicle (EV) started to be a dominant part of the automotive sector (Ehsani, et al., 2018). Moreover, the crash requirements have been highlighted with their new materials technologies which have been fundamental to reduce the weight of the vehicle and minimize the emissions. In addition, the new chassis of the electric vehicle has been illustrated following the requirement of the Health and Safety of the driver and passengers.

In the results section, a simple structural surface (SSS) of the van has been analysed. Then, an investigation of carbon fiber reinforced polymers (CFRP) has been discussed and the compromised on the possible implication of that specific material.

Finally, a conclusive paragraph will summarize the key points and findings.

2 Literature Review

Nowadays, the chassis can maintain the suspension, engine, gearboxes, and various mechanical components (Ismail & Tuan, 2013).

The primarily requisite to produce a sustainable body structure for the vehicle are (Pawlowski, et al., 2002):

- A suitable structure for the vehicle is required.
- An appropriate design to secure a correct fitting.
- An appropriate fitment of panels with a favorable juncture in the join.

The fundamental part of a vehicle's structure, that needs to be considered is the stability of the edge simple structure construction, further, the vehicle has major support in torsion and stiffness.

Different types of body structures have been modeled through the years. Since 1920, the fabrication of the vehicles has become well settled, and the first body of the car was named as "body on the chassis" (Pawlowski, et al.2002,p.28). This model allowed other mechanical components to be added through the car (Pawlowski, et al., 2002).



Figure 1. Ladder on Frame Chassis (Bharadwaj, 2020)

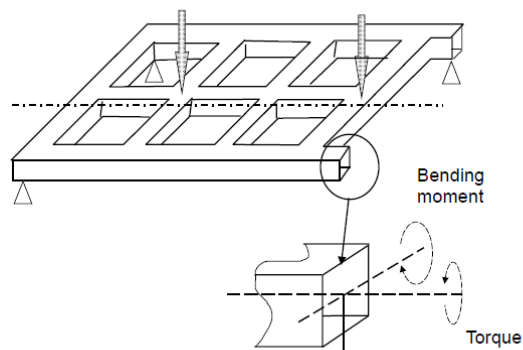


Figure 2. Grillage frame (Pawlowski, et al., 2002, p.29)

As illustrated in Figure 1, the ladder frame subsists of 2 metal frames, disposed of with a laying across each other to provide a solid structure. Also, a typical structure is defined as a grillages structure (Pawlowski, et al., 2002).

As demonstrated in Figure 2, the grillage frame is subject to a specific load, further, the effective force that is applied over the frame is divided into (Pawlowski, et al., 2002):

- The Bending Moment in relation to the lateral axis.
- The torsion of a specific longitudinal axis.
- The shear force which is in direction of the plane.

Between the 1920s and 1930s, the chassis frame had poor torsion stiffness, while it is fundamental to have a good torsion efficiency on the road. In addition, having an efficient torsional stiffness will

reduce the vibration through the vehicle, and secure comfort during the drive. In the area of 1920s, most of the cars were built with open bodies which were quite adjustable.

The metal-clad structure was the first body chassis with a roof. However, specific problems started to begin along the chassis and the body structure, as well as noise and cracking. The main reason was that the two main body chassis were not settled since they acted as torsion springs in parallel (Pawlowski, et al., 2002).

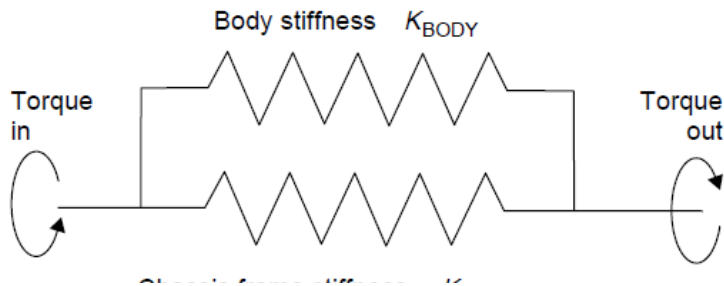


Figure 3. Springs in parallel (Pawlowski, et al., 2002, p.32)

Figure 3 illustrates the spring in parallel where the structure is “statically indeterminate”, and the torsion load of the chassis would pass at end of the vehicle. Then, the car structure has been improved in torsion using a flexible material, to achieve a good torsional on the chassis.

Subsequently, a wood structure was introduced, but the major problem of the wood-framed car body was not suitable for a massive production.

As the demand of the consumers increased, the steel has been taken into consideration in the 1930s. The first model created was a steel sheet, modeled into a shape and welded into the specific joint. Although in 1930 the sub-face of the chassis was open, at the same time, the spring in parallel was taken more in consideration to secure a higher stiffness.

Consequently, the model of springs in parallel was applied, but other different issues started to arise to the vehicle, and only around the 1930s, they discovered that a steel frame was more solid in bending and torsion, as it is shown in Figure 4 (Pawlowski, et al., 2002).

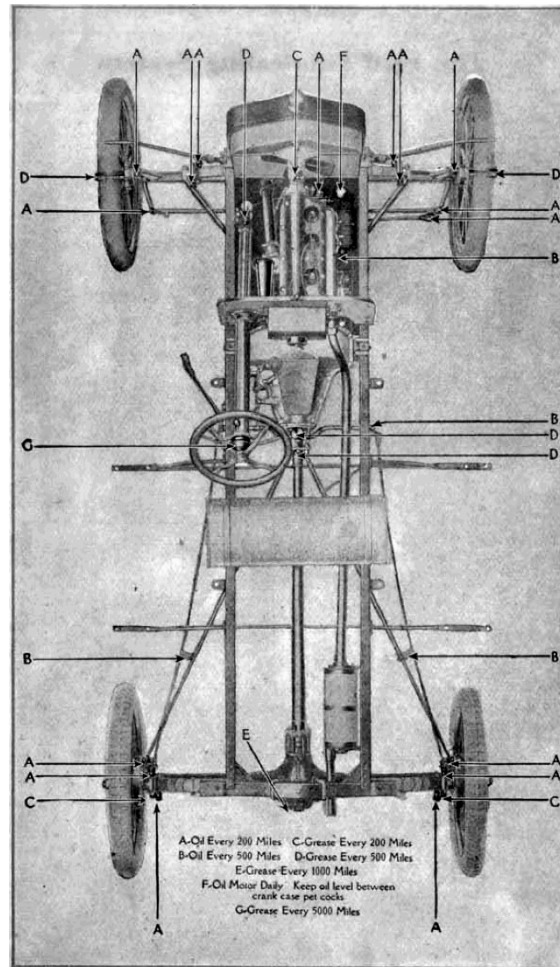


Figure 4. Multiple attachments (Pawlowski, et al.,2002)

Also, as illustrated in Figure 5, the twin-tube frame was used in a racing car between 1930s and 1950s (Pawlowski, et al., 2002).

car being an example of this type. A typical twin-tube chassis is shown in following figure.

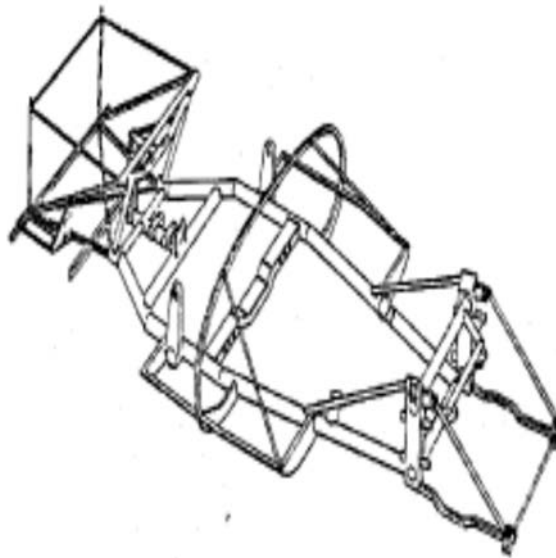


Figure 5. Twin tube (Ismail & Tuan, 2013,p.10)

The Backbone structure was the first sample for a modern vehicle in a large group section. The average size is about 200mm*150mm (Pawlowski, et al., 2002). Even though it has a quite strong and heavy structure, as demonstrated in Figure 6, at the same time, it is simple to be manufactured and less expensive to produce (Chandra, et al., 2012).



Figure 6. Backbone chassis ((Rangam, 2020),p.1)

The main part of a monocoque structure, shown in Figure 7, is that has a good weight efficiency for the Automotive industry, but on the other hand, it has not been taken into consideration in Motorsport as it is not safe.

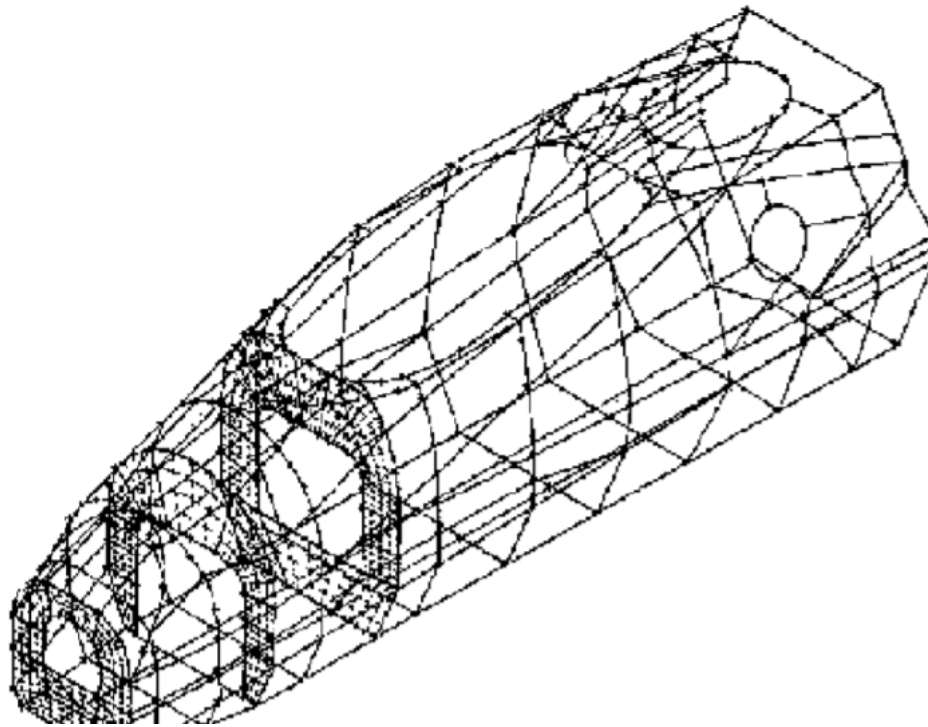


Figure 7. Monocoque frame (Pawlowski, et al., 2002,p.41)

Significant improvements started to appear when the structure was replaced from a body on the chassis to complete construction.

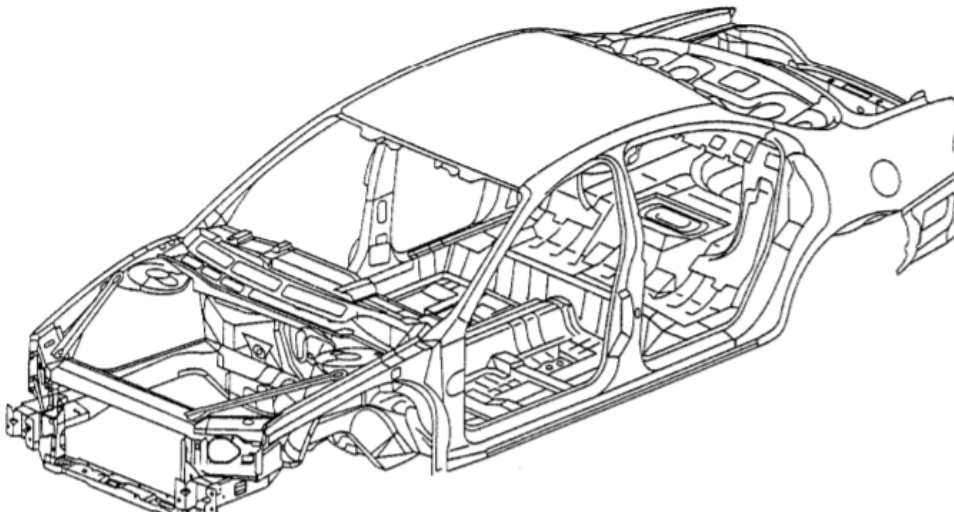


Figure 8. Current integral body in white (Pawlowski, et al., 2002,p.45)

Figure 8 illustrates a “body in white”, which is a combination of monocoque and birdcage type. At the same time, the frame has high stiffness and the base consists of thin panels (Pawlowski, et al., 2002).

Nowadays, the primary aspect that needs to be considered when a chassis is designed is the legislation disposed by the Government. However, electric cars guarantee that can potentially improve driveability and the ambient (Wenning, et al., 2020). Another, new technology as illustrated in Figure 9, through the chassis has been taken in place such as electric skateboard. The aim of this new technology is that each component can be fabricated individually and combined following the safety requirements (Genta, et al., 2019).



Figure 9. Electric Vehicle Skateboard (McIntosh,2020,p.1)

In the view of McIntosh (2020), the Audi is aiming to introduce the skateboard in the next five years, which then would be beneficial to reduce the cost and improve the efficiency of Electric vehicles (EV) (McIntosh, 2020).

3 Crash-requirements

The purpose of the structure is to maintain the solid body and to support the load to spread around the vehicle. Also, it is important to take into consideration the best structure for the vehicle, that does not affect performance and raises the cost of production. The check of a body structure is linked to strength and stiffness and reduction of the mass.

The strength of a vehicle is an action where it takes into consideration the road load.

The stiffness of a vehicle has a decisive element to consider in terms of vibration and handling. On the other hand, a pure stiffness could cause undesirable vibration through the vehicle named as “scuttle shake”. In addition, the benchmarks are fundamental to classify the different categories of stiffness required such as Bending Stiffness labeled as K_b , and Torsion Stiffness labeled as K_t (Pawlowski, et al., 2002).

3.1 Crash Electric Vehicle

Importantly with the advance of new technologies, the Electric Vehicle must secure the safety of the driver in case of a crash. As an Electric Vehicle consists of electronic elements, when the emergency of the crash appears at the same time, the powertrain system moves into a protection zone.

The main protection zone aspects are:

- The main clutch of the vehicle stops working, and the wheel just rotates without load.
- The entire power of the vehicle is switched off.

Following these two primary aspects, the energy reserved through the generator is no longer available in the vehicle. According to the Regulations, the DC-bus capacitor voltage must be reduced to a safe level, however, to complete this process a bleeder circuit is used. It is a parallel circuit with switches. Figure 10 illustrates the structure of an Electric Power Train System that is generally separated into three component such as Crumple zone front of the vehicle, a safe zone where the Driver is located, and a rear Crumple zone. If a crash occurs into the back or the front, the bumper fascia, bumper beam, and longitudinal beam all break to absorb the energy and spread through the vehicle, to safeguard the driver and insulate the rechargeable energy storage system (RESS) (Chao, 2021).

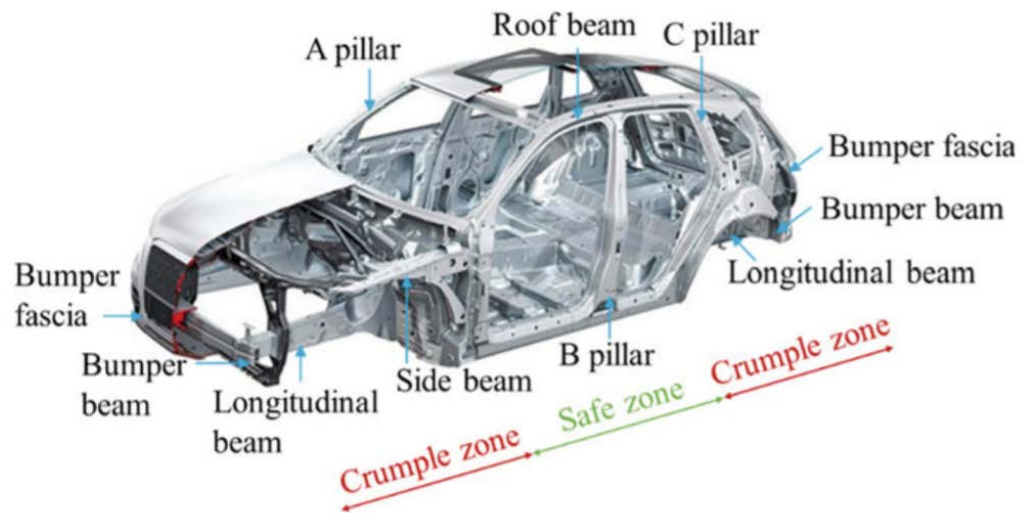


Figure 10. Structure of Electric power train stime vehicle (Chao,2021,p.9)

3.2 Development in manufacturing technology

As the new regulations are aiming to reduce the emissions and have become stricter, the automotive sector has been affected, which they have been forced of researching always for a light and green material. In addition, lightweight has become an influential technology that is used to improve the fuel efficiency of the vehicle. In the view of Milvanoff cited in Grosh (2021), the adoption of aluminum could reduce the accumulative life cycle greenhouse gas (GHG), therefore, can reduce the annual emissions by 11% through the 2050. Another alternative of lightweight is the Carbon Fiber Reinforced Polymer (CFRP). The downside of the CFRP is that demand excessive energy which can rise GHG emission but, recycling the CFRP requires low energy. (Ghosh, et al., 2021)

3.3 Development's materials technology

The crucial element of improving the material in a vehicle is having better combustion, and at the same time, reducing the waste of energy in the vehicle. In addition, lightweight has become important to advance the fuel efficiency by 6-8%, for every 10% reduction with an electric vehicle. In addition, another significant aspect is that as the weight of the vehicle reduces, at the same time, the risk of affecting the performance of the car is quite high. The new model which engineers are considering while designing a new chassis model is called integrated computational material engineering (ICME). The ICME aims to reduce the time needed to advance the upgrade material, which will reduce the time consuming on creating abundant of matrix and many tests. Additionally, for vehicle designers has become much easier because they can test on a computer with special software which the ICME is aiming to use (Joost, 2012).

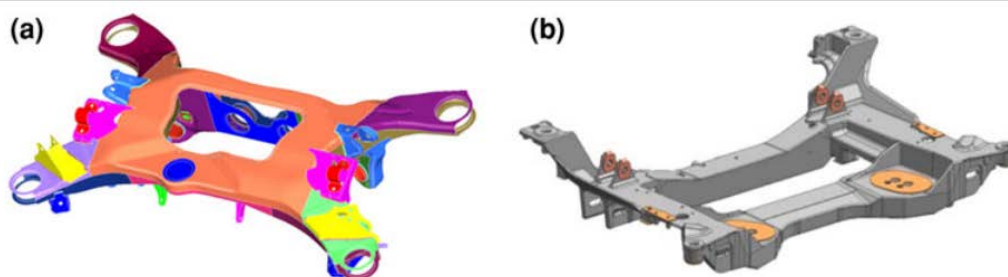


Figure 11. Rear chassis structure which reduce of the 28% (Joost,2012,p.1035)

As illustrated in figure 11, the advanced high strength steel (AHSS) labeled with (a), with an addition of a magnesium engine is able to reduce the weight by 28% with the chassis structure and 35% with the new magnesium engine, in comparison to a conventional steel baseline labeled with (b).

Although the material has been changed, the new materials are still able to maintain the same requirements and the equal performance of the car (Joost, 2012).

4 Results

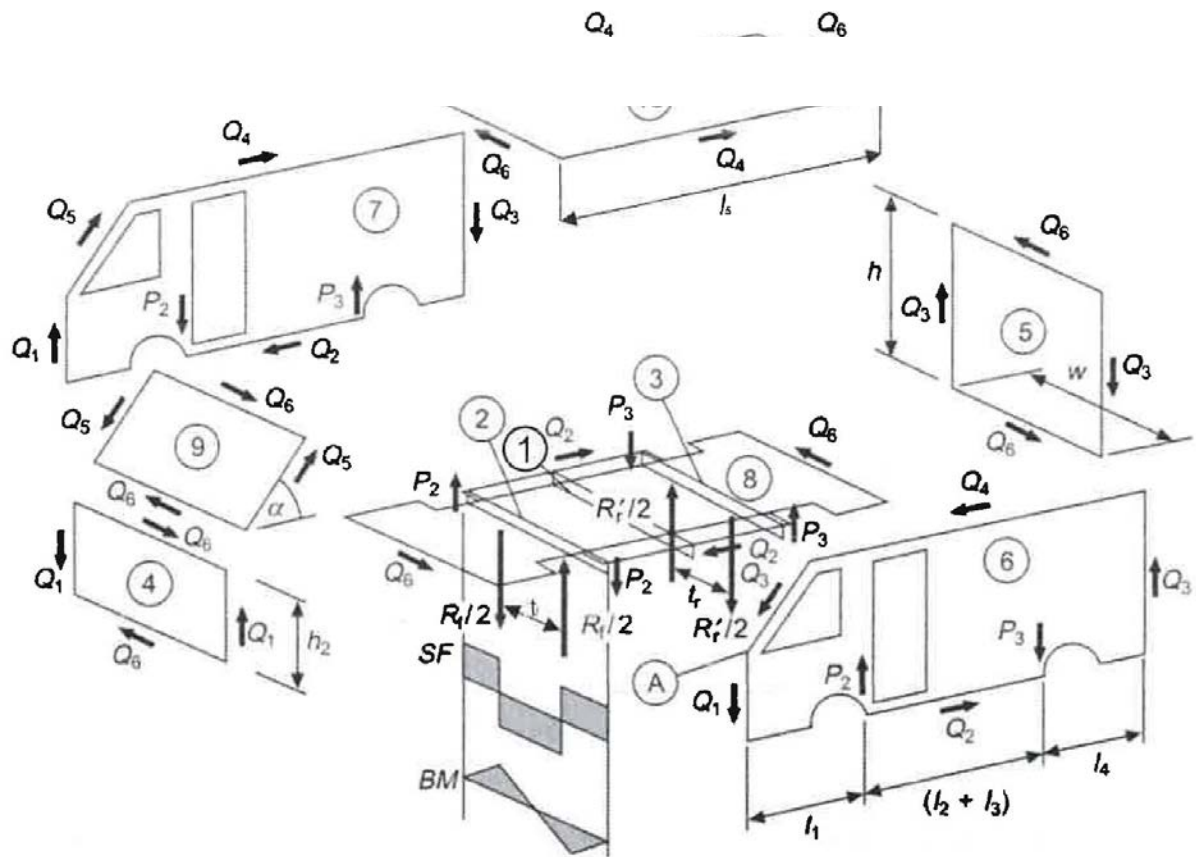


Figure 12. Van in Torsion

width=2.1m

hight₁=2.5m

hight₂=1m

l₁=2m

l₂+l₃=3.5m

l₄=1m

Overall weight = 3500kg

Weight distribution = 50:50

Tf=1.5m

Tr=1.5m

alpha=45°

$R_r = R_f = 5 \text{ kN}$

R_r = Reaction at the front

R_r = Reaction at the rear

T_t = Track at the front

T_r = Track at the rear

4.1 Calculation of Q_1 to Q_6 and the Torque enforced to the van

$$P_2 = \frac{R_r * T_r}{2 * w} = \frac{5000 * 1.5}{2 * 2.1} = 1785.71 \text{ N} \quad \text{Equation [1]}$$

$$P_3 = \frac{R_r * T_r}{2 * w} = \frac{5000 * 1.5}{2 * 2.1} = 1785.71 \text{ N} \quad \text{Equation [2]}$$

$$Q_6 = \frac{w[P_3(l_1 + l_2 + l_3) - P_2 * h_1]}{h_1(l_1 + l_2 + l_3 + l_4) + l_5 * (h_1 - h_2) * h_2(l_1 + l_2 + l_3 + l_4)} = \frac{2.1[1785.71(2 + 3.5) - 1785.71 * 2.5]}{2.5(2 + 3.5 + 1) + 5(2.5 - 1) + 1(2 + 3.5 + 1)} = 372 \text{ N} \quad \text{Equation [3]}$$

$$Q_1 = \frac{Q_6 * h_2}{w} = \frac{372 * 1}{2.1} = 177.14 \text{ N} \quad \text{Equation [4]}$$

$$Q_2 = \frac{Q_6(l_1 + l_2 + l_3 + l_4)}{w} = \frac{372(2 + 3.5 + 1)}{2.1} = 1151.43 \text{ N} \quad \text{Equation [5]}$$

$$Q_3 = \frac{Q_6 * h_1}{w} = \frac{372 * 2.5}{2.1} = 442.86 \text{ N} \quad \text{Equation [6]}$$

$$Q_4 = \frac{Q_6 * l_5}{w} = \frac{372 * 5}{2.1} = 885.71 \text{ N} \quad \text{Equation [7]}$$

$$Q_5 = \frac{Q_6 * (h_1 - h_2)}{w \sin(45^\circ)} = \frac{372 * (2.5 - 1)}{2.1 \sin(45^\circ)} = 375.78 \text{ N} \quad \text{Equation [8]}$$

Next, let's examine the vertical loads in the vehicle as illustrated in figure 13:

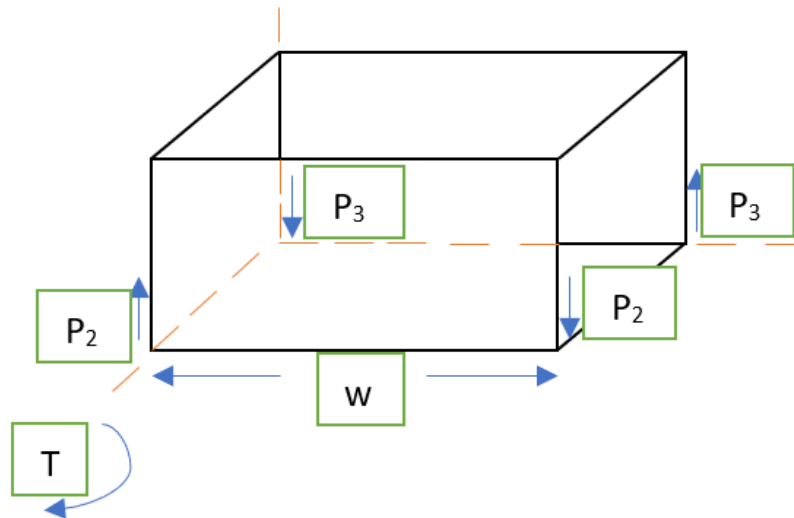


Figure 13. Force acting on the vertical loads

$$T = P_2 * w = P_3 * w \quad \text{Equation [9]}$$

Also $P_2=P_3$

Therefore, $T = 1785 * 2.1 = 3748.5 \text{ N/m}$

In addition, if the roof is made from 2mm steel, let's find the Van Misses Stress:

$$\sigma_v = \sqrt{(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2} \quad \text{Equation [10]}$$

Complex Stress Theory:

Q1=177.14N

$$\tau = \frac{F}{A} = \frac{177.14 \text{ N}}{5*3*10^{-3}} = 11809.33 \text{ N/m}^2 \text{ or } 11.81 \text{ KPA} \quad \text{Equation [11]}$$

$$\sigma_{1.3} = \frac{1}{2} * [(\sigma_x + \sigma_y) + / - \sqrt{(\sigma_x - \sigma_y)^2 + 4\tau xy^2}] = \quad \text{Equation [12]}$$

As $\sigma_x + \sigma_y = 0$

$$\sigma_{1.3} = \tau xy^2 = 11.81 \text{ KPA}$$

Now, let's find the Von Mess stress and $\sigma_2 = 0$

Therefore,

$$\sigma_v = \sqrt{(11.81)^2 + (11.81)^2 + (-23.62)^2} = 28.93 \text{ KPA} \quad \text{Equation [13]}$$

Q2= 1151.43 N

$$\tau = \frac{F}{A} = \frac{1151.43 \text{ N}}{5*3*10^{-3}} = 76762 \text{ N/m}^2 \text{ or } 76.76 \text{ KPA} \quad \text{Equation [14]}$$

$$\sigma_{1.3} = \tau xy^2 = 76.76 \text{ KPA}$$

$$\sigma_v = \sqrt{(76.76)^2 + (76.76)^2 + (-153.52)^2} = 188.02 \text{ KPA}$$

Q3=442.86 N

$$\tau = \frac{F}{A} = \frac{442.86}{5*3*10^{-3}} = 29524 \text{ N/m}^2 \text{ or } 29.524 \text{ KPA} \quad \text{Equation [15]}$$

$$\sigma_{1.3} = \tau xy^2 = 29.54 \text{ KPA}$$

$$\sigma_v = \sqrt{(29.54)^2 + (29.54)^2 + (-59.08)^2} = 72.36 \text{ KPA}$$

Q4=885.71 N

$$\tau = \frac{F}{A} = \frac{885.71 \text{ N}}{5*3*10^{-3}} = 59047.33 \text{ N/m}^2 \text{ or } 59.047 \text{ KPA} \quad \text{Equation [16]}$$

$$\sigma_{1.3} = \tau xy^2 = 59.047 \text{ KPA}$$

$$\sigma_v = \sqrt{(59.047)^2 + (59.047)^2 + (-118.094)^2} = 144.63 KPA$$

$$Q5 = 373.78 \text{ N}$$

$$\tau = \frac{F}{A} = \frac{375.78 \text{ N}}{5 \times 10^{-3}} = 25052 \text{ N/m}^2 \text{ or } 25.05 KPA \quad \text{Equation [17]}$$

$$\sigma_{1.3} = \tau xy^2 = 25.05 KPA$$

$$\sigma_v = \sqrt{(25.05)^2 + (25.05)^2 + (-50.1)^2} = 61.36 KPA$$

$$Q6 = 372 \text{ N}$$

$$\tau = \frac{F}{A} = \frac{372 \text{ N}}{5 \times 10^{-3}} = 24800 \text{ N/m}^2 \text{ or } 24.80 KPA \quad \text{Equation [18]}$$

$$\sigma_{1.3} = \tau xy^2 = 24.80 KPA$$

$$\sigma_v = \sqrt{(24.80)^2 + (24.80)^2 + (-49.6)^2} = 60.75 KPA$$

Figure 13 illustrates a Simple Structural surface (SSS) of a van which is subject to torsion. Also, Equation 1 to Equation 18 were able to find the shear forces and Von Mess stress of each panel. The crucial importance of task 3 is that engineers should pay more attention to which platform is suitable for that specific vehicle. Also, there is a major statement that engineers needed to consider such as customer requirements, and the possibility that the platform requires to do some adjustments during the assembly process. According to Pawlowski (2002), Figure 14 demonstrates that it is possible to use the same structure platform and create 7 different types of models. On the other hand, the crucial element to consider of the upgrade structures are the magnitude (σ), the Bending Moment (M), and torque (T) which apply to the platform construction (Pawlowski, et al., 2002).

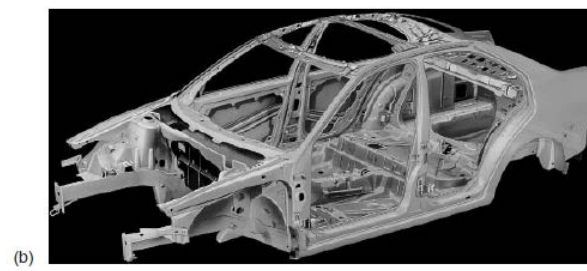


Figure 14. Volkswagen Bora body structure (Pawlowski, et al., 2002,p.254)

5 Discussion: Carbon fiber reinforced polymers

The Carbon fiber reinforced polymer (CFRP) has become one of the popular applications for lightweight material. Takashi and Suzuki cited in Ghosh (2021), examined that the CFRP is able to reduce by 36 % the mass of the vehicle and 16 % of fuel consumption in comparison to a steel chassis frame. Furthermore, Takashi and Suzuki compared two different vehicle structures with a high strength steel (HSS) and with carbon fiber reinforced polymer (Ghosh, et al., 2021).

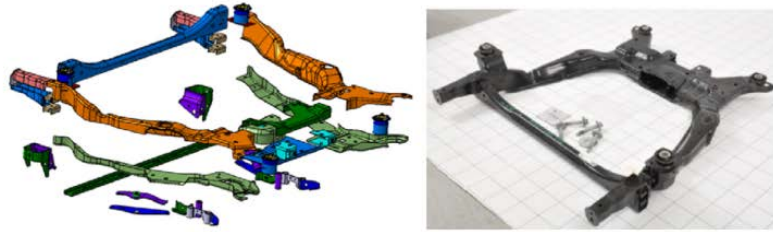


Figure 15.High Strength Steel chassis (Ghosh, et al.,2021, p.3)

Figure 15, illustrates a High Strength Steel (HSS) which consists of a mass of 26.3 kg and includes 34 different components. In addition, all the components are made using the metal inert gas (MIG) using a welding procedure.

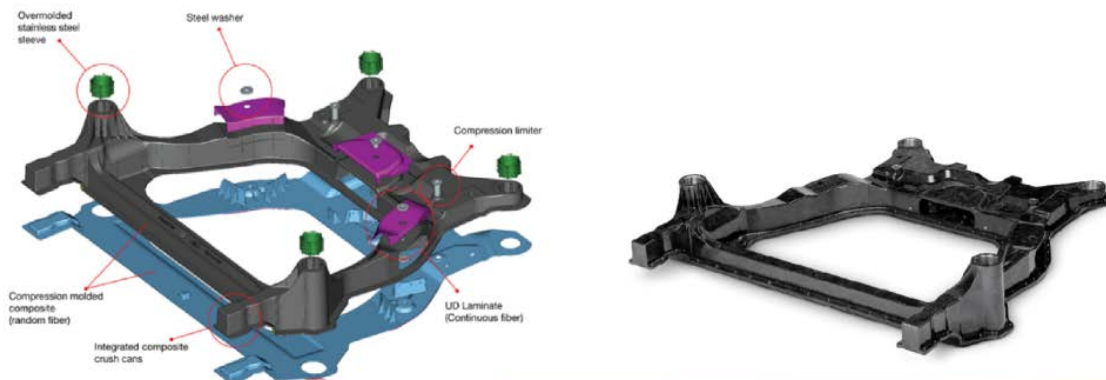


Figure 16.CFRP structures (Ghosh, et al.,2021, p.4)

On the other hand, as illustrated the Figure 16, the CFRP structure has a mass of 18.9 kg which subsists of 18 individual parts. To manufacture the CFRP chassis the sheet molding compound and compression molding procedures were adapted. Also, the force such as strength and durability of the CFRP was analyzed through a specific test. Additionally, as the mass of the entire chassis is reduced other elements such as braking can be adapted with reduced size of the braking, which then

can lower the entire mass and more fuel saving and at the same time lower the emissions. Also, the advantage of the CFRP is flexible and is resistant against crack compared to the steel frame (CCUK, 2021). On the other hand, changing the size or measurement of the CFRP structure, or adjusting the angle of the fiber tows could alter the anisotropic performance of the material design, which then can cause a further failure in strength and fracture through the design (Sun, et al., 2021).

For this reason, if the SSS van illustrated in Figure 13, was made from CFRP that would have caused a massive failure in the van structure due to the behaviors of the CFRP. Furthermore, the calculations of the 10 panels (Equation 1 to 18), have been made from steel with a torsional steel which is applied to the van. As the steel is much heavier than the CFRP, that would make the van unstable and unsafe.

6 Conclusion

To conclude, as discussed in the literature review there has been significant historical development of the chassis in the automotive world. Since the 1920s and 1930s, the car chassis were very poor in torsion, then the wood has been introduced, however, after a short period was not utilized anymore because was not suitable for the exponential demand of the consumer. Subsequently, other structures like twin-tube, Backbone chassis, and Monocoque frames were widely utilized in a classic car. Only with the advance of new technologies the main body chassis which is currently used is called body in white, further, for EV vehicle the main body that is used is named as Skateboard, as mentioned before it is safe for the driver and easy to manufacture and assembly.

The second paragraph has considered the importance of having a suitable structure for the vehicle and at the same time, being able to spread all the force through the vehicle if a crash happens. Then an important consideration of the electric vehicle and its regulation have been highlighted.

Also, as the technologies have improved with the chassis, the need of finding a new material to reduce the mass of the vehicle and the fuel consumption has been discussed.

Furthermore, in the results section, the calculation of the simple structure surface (SSS) of a van structure in torsion has been completed with the shear panel of Q1 to Q6 (Equation 1 to 18). In addition, a discussion of the 10 surfaces has been presented, in particular, in the view of Pawlowski (2002), it is possible to create the same chassis structure for about 7 different types of cars, which will be able to meet the customer requirements.

Finally, a discussion of the CFRP has been analysed with their implication on using the CFRP instead of the steel. Even though CFRP is a much lighter material and beneficial for any vehicle, if used can cause a significant problem for the van due to the calculation that has been specifically developed for the steel.

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