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EVs

Automotive Chassis Systems (ACHA5013)

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1. Introduction

One of the most complex mechanisms known to man is the automobile. From the first steam-powered vehicle invented by Karl Friedrich Benz in 1885 (Mercedes Benz Group 2023), to today's modern, sophisticated vehicles, there has been a significant improvement in automotive technology, especially in the vehicle structure developed over the years. Given the huge impact an automobile has on our lives in this modern age, the automobile industry has influenced the world's economy very significantly. Car manufacturers are now competing to outdo each other by producing more efficient, stylish, and environmentally friendly vehicles. The automobile industry is a very challenging environment for designers and engineers, as they must meet increasingly tough safety standards imposed by government legislation and customer requirements and many more. The electric car structure has been gaining popularity over the last decade and they are the strongest opponent of internal combustion-powered vehicles at this time. There are many benefits that come with electric cars, such as a reduction in emissions and less fuel costs. This report will discuss how the current electric car's body in white is developing and how body structures are historically developed over the years and how this may change if electric powertrains become more common. In addition, the impact of manufacturing and materials development of the vehicle will be discussed. This will be done by bending, aerodynamics, and crash requirements.

2. Automotive Chassis

Since the advent of the automobile in the early 1900s, automotive chassis structures have evolved greatly. In the beginning, vehicles featured a traditional ladder frame structure that provided a strong and durable base for the body panels. This basic structure remained largely unchanged for nearly 80 years until manufacturers began to introduce monocoque chassis designs in the 1950s. The monocoque chassis design was first used in Formula One in the 1960s by Lotus (CNBC, 2023). This approach replaced the frame with a single metal unit which had increased stiffness, safety, and rigidity while also saving weight and freeing up more interior space. This design allowed automakers to provide the most economical and reliable vehicles possible. However, over time, improvements in manufacturing and materials science allowed automakers to develop more advanced chassis structures that offer even greater rigidity, comfort, and efficiency than the old ladder frame. Today's modern cars feature unitary or unibody construction. This type of chassis involves forming the frame out of one piece, creating an integrated structural shell. Compared to older designs, this type of frame is stronger, lighter-weight, and more efficient. These advances include components such as four-wheel independent suspension, shock absorbers, and stiffening elements such as hydroforming or ultrahigh strength steel to increase overall rigidity. The introduction of electric vehicles has seen yet another evolution in automotive chassis structures. In these cars, motors are used instead of engines and there is no need for a conventional transmission system since the power source is already located within the car's wheels. This type of vehicle design often features shorter wheelbases than its petrol counterparts in order to create more interior space without sacrificing too much stability. Additionally, the battery packs can be placed in different locations depending on vehicle specifications to provide greater levels of flexibility when designing a chassis. Internal combustion engines tend to take up huge amounts of space compared to EVs, it's because of their electric motors. The electric motors are much smaller and don't need oil to power on. Most EVs have extra storage space under the hood in the front and the same space as normal vehicles in the trunk, which is a great advantage.

2.1 Unibody design

The unibody structure is a single structure that many elements that are welded, bonded, molded or connected together (Markus, 2020). This structure is first used on the “torpedo-bodied” in 1922-1931 by Lancia Lambda and the structure helped to reduce the weight as well as the height of the car. The majority of modern SUVs, sedans and crossovers feature unibody chassis, and some still use the Airflow principle of welding what nearly seems to be a whole frame below to increase stiffness and strength and lessen harshness.



Figure 2.1.1 Unibody chassis

2.2 Monocoque chassis

In French, monocoque means single shell or single hull. Similar to exoskeletal insects, monocoque structures have structural skin that supports compression and tension stresses. In the beginning, it was a common method for building ships and then airplanes. It is a shell around the car that is made by using both chassis as the frame in a single construction. Although true monocoque constructions haven't been used much in normal cars back then, the racing sector has embraced the concept. The body and chassis of the Lotus 25 Formula 1 race vehicle were first made of aluminum in 1962. With the 1981 MP4/1, McLaren invented the now-common carbon fiber reinforced composite monocoque racing car structure. The 1992 McLaren F1, was the first passenger road-legal vehicle to incorporate carbon-fiber monocoque construction (Markus, 2020). Nowadays, this chassis structure can be found in most cars on the road due to the number of advantages over the other types of chassis.

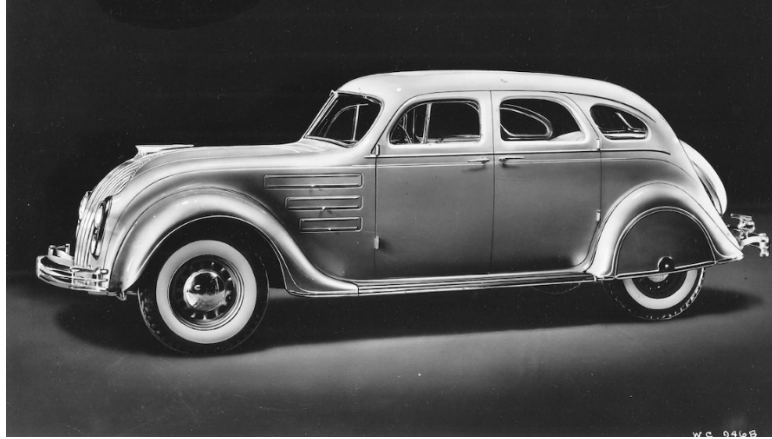


Figure 2.2.1 Monocoque chassis vehicle

2.3 Tubular chassis

The tubular frame chassis is the most used type of chassis in the car racing industry. These were an improvement over ladder chassis since they were stronger and three-dimensional. To increase overall robustness, they used a sturdy framework behind the doors. The interiors are removed in racing cars due to extra weight and the car is covered and constructed with thick tubular pipes or aluminum. The advantages of this chassis are due to no interior accessories, the chassis is lightweight and stronger than a regular monocoque design. The big disadvantage of tubular chassis is its impracticality and it is not suitable for daily driving (Harsh, 2021).

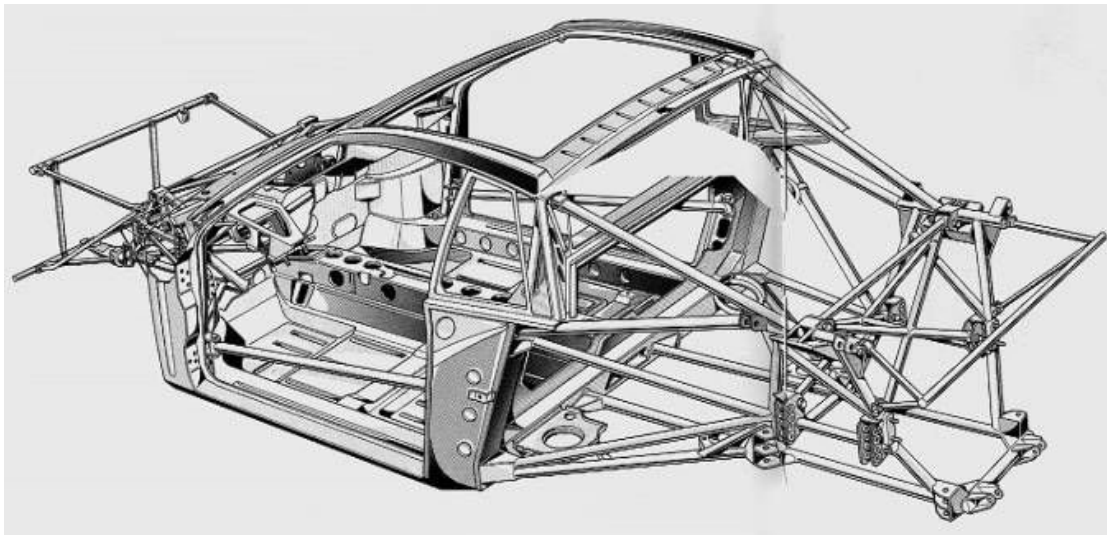


Figure 2.3.1 Tubular chassis

2.4 Ladder frame chassis

The ladder frame chassis is one of the most popular types of chassis. This chassis can be found in off-road vehicles like SUVs, and pickup trucks practically any off-road vehicle has it. The cabin or the body of the vehicle is mounted on top of the frames and independent axles can travel better which makes the chassis articulation better than any other chassis structures. These kinds of vehicles are generally 4-wheel drive and It is common in off-road racing. The advantages of the ladder frame chassis are;

- The body of the vehicle can be changed and have another vehicle's body on it.
- The suspension travel can be increased depending on the body.
- They are incredibly agile and flexible.
- In the interior, they tend to be quieter due to the chassis insulating the body.
- They are easy to change damaged components and mend.
- Very practical.

The disadvantages of the ladder frame chassis are;

- Poor handling due to the heavyweight and high clearance from the ground.
- Heavy components and overall heavy compared to other chassis types.
- Generally expensive.

They are usually made from steel and are exceptionally strong (Harsh, 2021).



Figure 2.4.1 Ladder frame chassis

2.5 EV Chassis

Electric cars are becoming increasingly popular as people look for more environmentally friendly ways to travel. As most people know, there are many benefits that come with electric cars, such as a reduction in emissions and less fuel costs. In traditional gasoline-powered cars, unibody structures are also commonly found in electric vehicles such as Tesla and Nissan Leaf. This allows electric vehicles to be incredibly energy efficient without sacrificing safety or performance. Electric vehicle chassis differ from conventional models in that they lack internal combustion engines and other components associated with them. As a result, EV designs must take into account battery placement as well as proper weight distribution for improved stability and handling. To maximize efficiency and minimize noise vibration harshness (NVH), designers utilize materials such as carbon fiber-reinforced plastic which offer strength and stiffness while reducing weight. Overall, the automotive structure has evolved dramatically over the years with each new generation offering increased safety, performance, efficiency, and comfort than ever before. From the earliest ladder frames to today's electric car unibody designs, these innovations have revolutionized the way we move from place to place every day.

The advantages of the electric car;

- Low profile
- Very quiet
- No emissions and environmentally friendly
- Lower maintenance due to efficient electric motor
- Low cost to maintain
- Most of them are practical
- Faster acceleration
- The chassis is easier to produce than an internal combustion vehicle

The disadvantages of the EVs are;

- Tend to be expensive
- Hard to find new parts and they are expensive at the dealers.
- The chassis is heavyweight
- High fume-able risk of the battery
- Takes longer to charge compared to gasoline cars



Figure 2.5.1 EV chassis

2.6 Safety & Durability

The evolution of automotive structures has seen major advances over the past century, especially when it comes to safety and durability. Traditionally, vehicles had a chassis frame made of steel which was supported by an independent suspension system and wheels. This arrangement was considered strong enough for passenger cars. With improvements in technology, automakers began using high-strength steel alloys in their frames to provide better crash protection for passengers. Along with this came advances in computer-aided design that allowed for even more sophisticated chassis structures that could absorb impact forces more effectively and spread them evenly throughout the vehicle. In recent years, many manufacturers have started utilizing aluminum or composite materials in their car bodies, reducing the overall weight of vehicles without sacrificing strength. This helps increase fuel efficiency and reduces emissions from vehicles significantly. In addition to traditional gas-powered cars, electric cars also have distinct structural needs due to the heavy battery packs they require. These cars must have specialized chassis designs with greater strength so they can handle the extra load while maintaining performance. This often includes more reinforced joints and higher-strength materials in order to keep up with the extra strain electric cars can put on them compared to traditional gas-powered vehicles.

2.7 Crashworthiness

The Crashworthiness of a vehicle is a measure of its ability to protect the occupants during an impact. To ensure maximum crashworthiness, a vehicle should be designed with considerations for torsion, bending, aerodynamics, and crash requirements.

Torsion: A vehicle's body should be able to absorb and deflect energy in the event of an impact.

Torsional stiffness helps to prevent twisting of the body which can cause occupant injury. The frame and components of the vehicle should be designed to flex while still maintaining integrity during impacts.

Bending: Vehicle parts that are subjected to load during impacts must be designed with enough strength and flexibility so they will bend and absorb energy instead of breaking apart. Components such as bumpers and side skirts should have sufficient rigidity so that they are able to resist deformation.

Aerodynamics: Aerodynamic performance is important in a crash situation as it helps to reduce drag on the vehicle when impacted, reducing the force of the collision. Designing for aerodynamics includes making sure there are no large obstructions such as wings or spoilers which may cause turbulence or lift during a crash situation. Additionally, elements like spoilers, air dams, and diffusers can be used to direct airflow away from vulnerable areas like windshields, roofs, and engine bays, thus improving aerodynamic performance during a collision.

Crash Requirements: Vehicle safety standards are often set by national regulatory agencies in order to ensure minimum protection for occupants during an accident. Standards often include regulations regarding bumper height, seatbelts/airbags, child restraints, side-impact protection, head restraints, and more, all aimed at ensuring maximum protection for occupants in case of an accident. By designing with torsion, bending, aerodynamics, and crash requirements in mind. It is possible to build vehicles that have enhanced levels of crashworthiness. This ensures maximum safety for occupants in case of a collision, thereby reducing injury risk associated with traffic accidents significantly.

3. Simple Structural Surfaces Calculation

Task 2 of the assignment is calculated on the pictures below.

TASK 2

$$\ast P_2 = \frac{R_f t_f}{2w} \quad P_2 = \frac{5000 \times 1.5}{2 \times 2.1} \quad P_2 = 1785.78 \text{ N}$$

$$\ast P_3 = \frac{R_f t_f}{2w} \quad P_3 = \frac{5000 \times 1.5}{2 \times 2.1} \quad P_3 = 1785.78 \text{ N}$$

$$\ast Q_6 = \frac{W[P_3(l_1 + l_2 + l_3) - P_2 h_1]}{h_1(l_1 + l_2 + l_3 + l_4) + l_5(h_1 + h_2) + h_2(l_1 + l_2 + l_3 + l_4)}$$

$$Q_6 = \frac{2.1[1785.78(2 + 3.5) - 1785.78(2.5)]}{2.5(2 + 3.5 + 1) + 5(2.5 - 1) + 1(2 + 3.5 + 1)}$$

$$Q_6 = \frac{2.1[1785.78(5.5) - 1785.78(2.5)]}{2.5(6.5) + 5(1.5) + 6.5}$$

$$Q_6 = \frac{2.1(9821.79 - 4464.45)}{16.25 + 7.5 + 6.5}$$

$$Q_6 = \frac{2.1(5357.34)}{30.25} \quad \boxed{Q_6 = 371.91 \text{ N}}$$

$$\ast Q_1 = \frac{Q_6 h_2}{w} \quad Q_1 = \frac{371.91}{2.1} \quad Q_1 = \boxed{177.10 \text{ N}}$$

$$\ast Q_2 = \frac{Q_6(l_1 + l_2 + l_3 + l_4)}{w} \quad Q_2 = \frac{371.91(2 + 3.5 + 1)}{2.1}$$

$$Q_2 = \boxed{1151.15 \text{ N}}$$

$$\ast Q_3 = \frac{Q_6 h_1}{w} \quad Q_3 = \frac{371.91(2.5)}{2.1} \quad Q_3 = \boxed{442.75 \text{ N}}$$

$$* Q_4 = \frac{Q_6 l_5}{w} \quad Q_4 = \frac{371.91(5)}{2.1} \quad Q_4 = \boxed{885.50N}$$

$$* Q_5 = \frac{Q_6(h_1 - h_2)}{w \sin \alpha} \quad \sin 45^\circ = 0.71^\circ$$

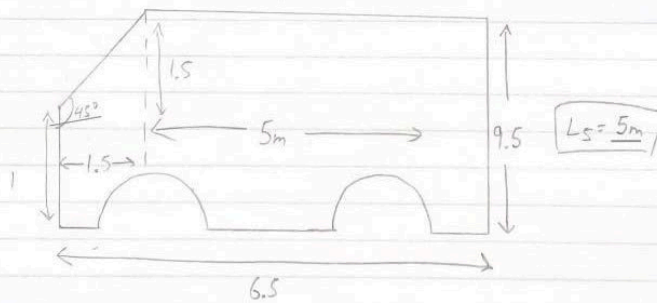
$$Q_5 = \frac{371.91(2.5-1)}{2.1(0.71)} \quad Q_5 = \frac{557.86}{1.491} \quad Q_5 = \boxed{374.15}$$

* Considering the Vertical loads going into the vehicle.

$$T = P_2 W = P_3 W \quad \text{is} \quad P_2 = P_3$$

ALSO

$$P_2 W = \frac{7500}{2} \quad T = 7500 \text{ Nm}$$



$$\tan 45^\circ = \frac{1.5}{adj} \quad adj = \tan 45^\circ = 1.5 \quad adj = \frac{1.5}{\tan 45^\circ} = 1.5$$

4. Discussion

There is little doubt that the automobile industry is moving toward electrification. It's a challenging, delicate political issue. Change is painful, particularly in light of advancing issues like constrained charging infrastructure, constrained range, and high prices. Most car manufacturers are now making electric versions of their popular platforms, for example, Jeep announced that a new electric jeep wrangler is on the way and electric F-150 lighting is already started to deliver to their new costumer's hands. It can be seen that the electric platform is overtaking the internal combustion engine and it is a matter of time. Electric cars are built with different structures than normal car bodies. They don't have an engine, unlike internal combustion engine-powered vehicles that we see everywhere but, the structures are the same. For example, an electric car company called Rivian Automotive LLC produces a family-size SUV and a pickup truck similar to ford F-series. The chassis is ladder frame chassis and the main difference is the drivetrain and the components are placed in different parts of the car. The materials and manufacturing of electric cars are different from normal vehicles. Electric motors, inverters, batteries, and other components are used to build electric cars. An electric car has a smaller range compared with an internal combustion engine-powered car due to the heavy weight of its high-capacity battery on the chassis. The future of electric cars is very promising and they will probably replace gasoline-powered engines because they are becoming more efficient and practical in terms of energy consumption. Electric vehicle conversion kits are now available for crossovers, sedans, and some SUVs which is a great way to convert into electric but, it may cost higher than some small electric cars. The manufacturers are now using aluminum to produce new vehicles due to their lightweight and most electric cars have an aluminum body because they are heavy with the battery. Another factor of the car manufacturers is that cars used to be hand built since the beginning and now most mass-produced cars are built by robots. The car-manufacturing robotic arms make unbelievably identical products compared to hand built and they are efficient as well. Car manufacturing has developed significantly over a century and yet most chassis structures are still used on modern vehicles. A number of car brands are now producing more electric vehicles than internal combustion vehicles and also downsizing engine sizes as well.

5. Conclusion

The car chassis has developed significantly over the years and almost anything about the vehicle has changed. The base of the old chassis structures is still being used on the new production vehicles today. The crashworthiness of modern vehicles has developed far better than the cars of last century. As a result, the automobile design process is characterized by a combination of many different factors, such as, safety, economy, and practicality in a unique manner. EVs have gained more interest over the last decade and many urban citizens are buying new electric cars due to their practicality, environmentally friendly and efficient. Electric cars have almost the same chassis structure as a normal car; the main differences are electric batteries are usually located under the floor due to its large and heavy lithium-ion batteries and weight distribution wise as well. In the future, electric cars might take over internal combustion engine-powered cars. In fact, some European countries already started to sell more electric vehicles than the gasoline cars; moreover, dealerships won't be able to sell any internal combustion vehicle near future due to new laws and legislation by their governments. In addition, many car manufacturers are aiming to produce more EVs than internal combustion engine vehicles.

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