Applications – Chassis & Suspension

Introduction

The chassis is considered to be one of the significant structures of an automobile. It is the frame which holds both the car body and the power train. Various mechanical parts like the engine and the drive train, the axle assemblies including the wheels, the suspension parts, the brakes, the steering components, etc., are bolted onto the chassis. The chassis provides the strength needed for supporting the different vehicular components as well as the payload and helps to keep the automobile rigid and stiff. Consequently, the chassis is also an important component of the overall safety system. Furthermore, it ensures low levels of noise, vibrations and harshness throughout the automobile.

Suspension is the term given to the system of springs, shock absorbers and linkages that connects the vehicle to its wheels. The suspension system serves a dual purpose. It contributes to the car's road performance, the braking characteristics for good active safety and the driving pleasure. It also keeps the vehicle occupants comfortable and reasonably well isolated from road noise, bumps, and vibrations.

Chassis design concepts

Originally, automobile designs used the body-on-frame construction where a load-bearing chassis consisting of a ladder frame, the powertrain, and the suspension formed the base vehicle which then supported a non-load-bearing body. In the beginning used on almost all vehicles, the ladder frame has been gradually phased out on passenger cars around the 1940s in favor of perimeter frames. In the second half of the last century, the frame chassis design was more and more displaced by monocoque constructions, integrating the body and chassis into a single unit. Today, the monocoque concept is more or less standard for passenger cars. The traditional body-on-frame concept is nowadays mainly used for heavy trucks and buses.

The lightweighting potential of aluminium can be exploited in all the different automobile chassis types:

Frame Chassis: The ladder frame with two straight longitudinal beams interlinked by several cross members is the oldest and simplest forms of all automotive chassis designs. In the perimeter frame, the middle section of the longitudinal beams was displaced outboard of the front and rear rails. This design allows for a lower floor pan, and therefore a lower overall vehicle height. A perimeter frame design offers more comfortable seating positions and higher safety in case of a side impact. On the other hand, the transition areas from front to center and center to rear reduce the beam and torsion stiffness of the chassis. The perimeter frame is still used today on full frame cars, i.e. many SUVs.

Backbone Chassis: The backbone chassis has a rectangular tube like a backbone that is used to join the front and rear axle. This type of automotive chassis is easy to make and cost effective, but lacks the required stiffness and asks for specific precautions regarding passenger protection. Nevertheless, it is still strong and powerful enough to provide support for small sports cars.

Monocoque Chassis: The monocoque chassis is a one-piece structure which prescribes the overall shape of the vehicle. This type of automotive chassis is manufactured by joining the floor pan and the other body components together to form a “unibody” structure. Compared to the older vehicle designs where the body is bolted to a frame, a properly designed monocoque car is lighter, more rigid, and offers better occupant protection in a crash. Since the monocoque structure is cost effective and suitable for robotised production, most of today’s vehicles make use of this design concept.

Subframes: Subframes are boxed frame sections that are attached to a monocoque car body. Subframes are primarily used on the front end of the car, but sometimes also in the rear. Most prominent are axle subframes which are used to attach the wheels and suspension to the vehicle. Subframes may also contain the engine and the transmission. Subframes or partial subframes are typically employed in otherwise monocoque constructions as a way of isolating the vibration and noise of power train or suspension components from the rest of the vehicle.

Suspension design concepts

The main purpose of the suspension is to keep the wheels as much as possible in contact with the road surface. A close road contact is most important since all forces which have an influence on the vehicle act through the contact area of the tires. On the other hand, the suspension must also provide a comfortable ride and protect the vehicle from damage and wear. These goals are generally at odds, i.e. the proper design and fine tuning of the suspension involves finding the right compromise. In general, the design of the front and rear suspension of a car will be different.

Springs and shock absorbers: Most conventional suspensions use passive springs to absorb more severe road impacts and shock absorbers to control the spring motions. The shock absorbers damp out the otherwise resonant up and down motions of the vehicle on its springs. They must also damp out much of the wheel bounce when the unsprung weight of a wheel, hub, axle and brakes bounces up and down on the springiness of a tire.

Today, externally controlled suspensions are applied more and more. Semi-active suspensions include devices such as air springs and switchable shock absorbers, various self-levelling solutions, etc. Fully active suspension systems monitor the vehicle conditions electronically in order to, coupled with the means to impact vehicle suspension and behaviour in real time, directly control the motion of the car. With the help of such control systems, semi-active and active suspensions enable the realization of an improved compromise among different vibrations modes of the vehicle.

Suspension geometry: Suspension systems can be broadly classified into two subgroups – dependent and independent suspensions. A dependent suspension normally has a stiff beam or a driven axle that holds the wheels parallel to each other and perpendicular to the axle. An independent suspension allows the wheels to rise and fall on their own without affecting the opposite wheel.

Dependent front suspensions are not used anymore today. Dependent rear suspensions may be used in a front engine, rear drive vehicle. In this case, the dependent rear suspension is either a "live axle" or a “de Dion” axle, depending on whether or not the differential is carried on the axle. A driven axle - where the differential is carried on the axle - is simpler, but the higher unsprung weight contributes to the wheel bounce. A de Dion suspension includes universal joints at both the wheel hubs and the differential and uses a solid tubular beam to hold the opposite wheels in parallel. Nevertheless, compared to a fully independent rear suspension, the ability to refine the dynamic response of the vehicle is somewhat limited.

In a semi-independent suspension, the wheels of an axle are able to move relative to one another as in an independent suspension, but the position of one wheel has an effect on the position and attitude of the other wheel. Semi-independent axles are often used on rear suspensions of front wheel drive vehicles. The most common type of semi-independent suspension is the twist beam axle. A horizontal beam connects the two rear wheels. The beam can twist to reduce the effect of one wheel's motion on the other wheel, but their motion is still inter-linked to a greater extent than in an independent rear suspension. On the other hand, a twist-beam axle is less expensive than a fully independent suspension and also more compact.

The variety of independent suspension systems - which allow each wheel on the same axle to move vertically independently of each other - is even greater. Most modern cars have an independent front suspension and more and more vehicles have also an independent rear suspension. Independent suspensions on all wheels typically offer a better ride quality and improved handling characteristics. This is due to lower unsprung weight and the ability of each wheel to address the road undisturbed by activities of the other wheels. However, independent rear suspensions require also additional engineering efforts and development expenses compared to a beam or live axle arrangement and can result in higher manufacturing costs.

Because the wheels are not constrained to remain perpendicular to a flat road surface during turning, braking and under varying load conditions, the control of the wheel camber is an important issue. Some early independent suspension systems used swing axles. Modern cars use mostly Chapman or MacPherson struts, trailing arms, multi-link or wishbone suspensions. The term Chapman strut designates strut devices used on the rear wheels, while the very similar MacPherson strut is used in the front. Struts are designed to act as both a shock absorber (with an integrated coil spring) and a wheel location device. Wishbone and multi-link offer more control over the suspension geometry than the other suspension designs, however, the cost and space requirements may be greater.

The MacPherson strut is the dominating suspension design used for front wheel applications. Double wishbones are usually considered to have superior dynamic characteristics as well as load-handling capabilities, and are often found on higher performance vehicles. Trailing-arm and multi-link suspension designs are much more commonly used for the rear wheels of a vehicle where they can allow for a flatter floor and more cargo room. Many small, front-wheel drive vehicles feature a MacPherson strut front suspension and trailing-arm rear axle.

Aluminium in chassis and suspension

On average, European produced cars contain 40 – 45 kg aluminium in chassis and suspension (about 30% of the total average aluminium content). For cars produced in North American and Southeast Asia, this fraction is slightly smaller (25 – 30%). However, the aluminium content in chassis and suspension applications varies strongly between different models. With more than 50%, the dominating contribution to the overall aluminium content in chassis and suspension is made alone by the wheels.

Cast parts contribute with more than 80% to the overall aluminium content. With about 10%, the share of the forged components is quite significant whereas rolled and extruded aluminium alloys only contribute a relatively small amount.

The application of aluminium in chassis and suspension will grow also in future as a consequence of the general lightweighting trend. Significant growth potential is still foreseen for aluminium wheels, in particular also because of their improved aesthetic appeal. Another important driver for the application of lightweight aluminium components in suspension systems is the possibility to reduce the unsprung mass and thereby to contribute to smoother driving performance and fuel economy.

On the other hand, chassis and suspension components are top priority safety parts. Wheels and suspension parts are subjected to high dynamic loads, aggressive environments, and - at the same time - they have to resist misuse. Therefore it is essential to use only high quality aluminium components made from carefully selected alloys using properly controlled fabrication procedures and to maintain strict quality control standards in production.

The design of chassis and suspension components is characterised by the co-existence of many different solutions. The wide variety of possible design concepts with highly differing material requirements must be taken into account when evaluating the substitution of components made from cast iron and steel by lightweight aluminium solutions. This section provides examples of current production parts and components in all major areas of the chassis:

- Subframes (in particular front and rear axle subframes)
- Suspension parts (control arm, struts, knuckles)

- Wheels
- Steering system
- Braking system.

Some lightweight aluminium solutions for frames and subframes will be also covered in the Car Body section due to the similarity of the applied design and manufacturing concepts.

Future developments

The basic design and functionalities of the structural chassis and suspension components will not significantly change in future vehicle concepts. But further lightweighting of these components will remain a most important challenge. Therefore, additional lightweight aluminium solutions will be intensively evaluated. But aluminium applications will also be challenged by new lightweighting solutions based on carbon fibre reinforced composites which offer the possibility to adapt the design even better to the predominant load paths. Carbon fibre reinforced composites already find applications in chassis and suspension for upper class niche models despite their higher cost. On the other hand, in very cost-conscious markets, also new high strength steel grades offer interesting lightweighting possibilities.

Other new developments in automotive design and in particular in the design of automotive stability control systems may influence future aluminium applications to a bigger amount. Such topics may include in particular the more extensive introduction of existing and the development of new vehicle stability control systems, active suspension systems and adjustable shock absorbers, electronically controlled active steering and braking systems, brake energy recovery systems, all-electric steer by-wire, and other x by-wire systems. With the introduction of electric power trains, also the integration of electric motors into the single wheels will be an option, which might develop to a decisive factor in the selection of the optimum wheel material.