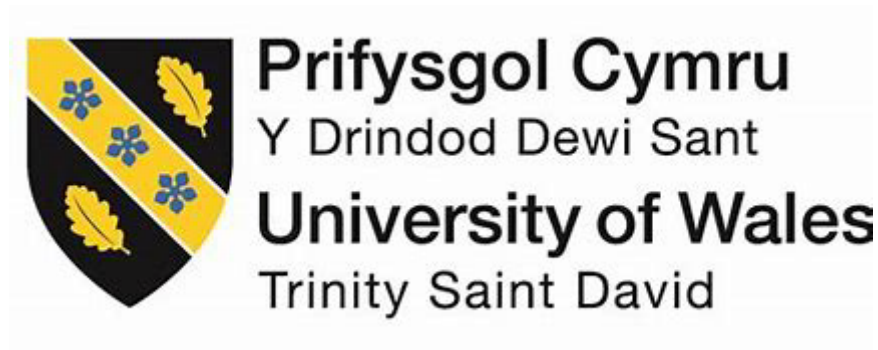


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Automotive Chassis Systems ACHA5013

1 Introduction

The Body in White (BIW) is the base layer of the car. The design of a BIW must consider its crashworthiness, bending, torsion, and extreme road loading. During the design for any BIW, the former load paths must be considered as well as where they will be placed, its packaging constraints, what materials should be used and the thickness of the materials, the capabilities of the structure (which will change with each type of chassis design more than other major decisions), the weight of the structure and its manufacturing process. However, these questions have become more complicated as time goes on, due to the advancement of structure, materials and manufacturing processes.

2 History

The earliest forms of car structures were called 'body on chassis' as all chassis' were mostly the same, as they were all manufactured by companies who specialised in manufacturing them and selling them to automotive companies who then built the cars, whereas time went on, companies began manufacturing their own chassis, which also led to the several unique types of chassis types. The earliest type of chassis' that was manufactured was ladder frames, as they are very simple to make, as they are two open C-sections connected by open lateral cross sections riveted together.



Figure 1- Ladder frame chassis

Since ladder frames are so simple and cheap to manufacturers, most small modern automotive manufacturers, such as TVR, still use ladder frame chassis to save money, and so most, if not all, have the same chassis.

The first type of suspensions used at the early age of cars were leaf spring suspensions, which dated back to horse carriages and so carried on in used in automobiles, as they were simple to manufacture and had a progressive load as early automobiles were heavy.

Automobiles today use much more advanced suspensions; however, the leaf spring suspension is still in use today in vehicles that require heavy duty loads.



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Figure 2- leaf spring suspension

Old chassis did not consider torsional stiffness, and so they had very poor torsional rigidity, however with steel clads and roofs on the cars, they were inadvertently stiff and resistant to torsion. However Due to the vehicles being so stiff, they began to rattle between the body and chassis and the bodies began cracking and squeaking, due to also unintentionally carrying load.

As time went on, wood in vehicles were replaced with steel as it enabled manufacturers to mass produce vehicles. This softened the body of the vehicle, combined with more springs in the body and the stiff chassis resulted in solving unwanted load transfer in vehicles.

Manufactures also began adding cross sections and closed sections to stiffen the chassis, specifically increasing the torsional stiffness. Cross sections are so efficient at increasing

torsional stiffness that modern formula 1 cars replaced the doors with cross section in the chassis.

From the 1930s and onward, manufacturers realised more integrated body-chassis design were stiffer, which eventually evolved into the modern BIW.



Figure 3- modern integral chassis

Apart from the ladder chassis, another special chassis design was the backbone chassis, used in the modern automotive industry by manufactures like lotus and TVR. The backbone chassis is used for specialist sports cars and is a separate structure from the body that will eventually be added to it, resulting in cheaper manufacturing to be used for all the companies' cars. The backbone chassis is essentially just a tube with walls, with cross sections to reinforce the torsional stiffness, and often made from glass-reinforced plastic. This type of chassis can also be combined with a roll cage to increase the torsional stiffness as there are more cross sectioned reinforcements.

The third special chassis made is the monocoque chassis, which is essentially a closed triangulated tube with many cross sectioned, and only one hole for the driver to enter. This chassis is very light and weight efficient and is therefore used in motorsport applications to provide better performance, however the use of this chassis is restricted only for motorsport applications. The shell of this chassis has to be reinforced to prevent buckling and out of plane loads.

The fourth special chassis structure is a punt/platform structure. This chassis has a closed floor section, with good joints between sections, and a grillage structure with members for

high torsion. This chassis is typically low produced, and is therefore made by manufacturers such as Lotus, for cars like the Lotus Elise, and is used for numerous cars with different bodies.

The fifth special chassis type is a spaceframe/birdcage chassis, which consists of small section tubular structures built into stiff jointed 'ring-beam' bays. Nodes must be stiff in bending, and considerable increase in torsional rigidity when skin panels are added to the 'Integral' body.

The sixth type of chassis, which is also the most widely used chassis in road vehicles, is the 'integral' or 'unitary' body structure. The unitary chassis is comprised of spot welded, compressed steel sheets, making it more favourable for mass production, making it the most widely used. This type of chassis is also self-supporting, and not needing another chassis. It is a mix between the monocoque chassis, for its more elongated shape, and the birdcage chassis, for its enclosed box shape. The unitary chassis contains a roof, floor and bulkhead skins, with side frames and windshield frames.

Before the integral chassis was manufactured and used in 1938, the body on chassis was the main form of structure, which for the Hillman 10hp, had a load of 934Nm/Deg of torque through the car, whereas in the Hillman 10hp with an integral body, had a load of 3390Nm/Deg of torque.

Due to advancements in manufacturing, there are different ways in creating an integral body, which consists of hydroforming, laser welding, and adhesives to make stiffer and tighter builds. As discussed, the value recorded for the Hillman 10hp in 1939 was 3390Nm/Deg, whereas for modern everyday cars, the torsional stiffness value is typically 8,000 to 10,000Nm/Deg, and for more luxurious cars such as sport cars, that torsional stiffness is typically 12,000 to 15,000 values to account for the added load on faster cars.

3 Crashing and safety

Most Modern cars are tested by the 'New Car Assessment Program' for each location such as Euro NCAP, ANCAP, ASEAN NCAP, CHINA NCAP, GLOBAL NCAP. IIHS, JAPAN NCAP, KOREAN NCAP, LATIN NCAP, and U.S. NCAP, who are independent to automotive manufacturers, and specialise in measuring the safety of auto vehicles and safely crashing them with human like mannequins and objects with dedicated sensors for which aspect they are measuring, such as side, frontal or rear impacts.

Euro NCAP was founded in 1997, and one of the first tests they performed to assess damage to adult occupants was the offset- deformable barrier (ODB), where the car would collide with a barrier on the left/right side of the front of the vehicle, as this type of crash was found to be the most common and responsible for the most deaths. The second test, introduced the same year as the ODB, is the side mobile barrier, had a long rigid barrier on wheels crash into the side of the vehicle being tested at a 90-degree angle, with a small crush space. The third test for adult occupants was the side pole, introduced in 2001, which had the vehicle be thrown into a rigid, cylindrical, vertical barrier, to simulate objects such as trees and lampposts. The fourth kind of tests performed is the full width ridge barrier (FFB), introduced in 2015, which has the car crash into a rigid barrier from the front. The barrier was typically very stiff and rigid and strong, to test the restraint systems of the vehicles under high stress from the vehicles high deceleration. Another test performed for adult occupants is the whiplash test, which had the vehicle quickly accelerate from uniform, to assess the damage from whiplash.

For children, they would test the child restraint system in collision tests performed for adult occupants, child provisions, and the child restraint installation.

For road users, there are 5 tests performed to assess the impact of vulnerable people walking on the roads. The first being the head impact, which had a vehicle crash into the simulated road user and assess the impact of their head on the vehicle. The second and

third test being the impact of a collision on the upper legs and lower legs. The fourth and fifth being the autonomous emergency braking on a pedestrian and a cyclist.

The fourth category of tests performed on the vehicles revolves around testing the vehicles safety measures themselves. Its electronic stability control in the event the vehicle loses control and begins to swerve and slide, the seatbelt reminders, speed assistance, autonomous emergency braking (AEB) interurban, and its lane support.

Modern anthropomorphic test devices (ATD'S), or more commonly known as dummies, used by Euro NCAP and manufacturers are full of sensors, and are designed to tailor to specific body types and the tests that will be performed on them. The dummies themselves are biofidelic, and are designed to mimic the shape, mass, size, energy absorption and dissipation of the person they are mimicking, whether it be an adult female or male occupant of any size, or a small child.

The dummies are tested whilst restrained and unrestrained under braking, and during a crash, to test how the occupants are affected under slow and fast deceleration.

Before modern ATD's, and even test dummies for cars in general, the effect of crashing on occupants in the vehicles were tested other ways. Instead of dummies, manufacturers used cadavers to analyse the trajectory and impact of crashing on occupants, however because they did not breathe, and were rigid, the results were far from accurate. During the late 1940s, the US air force began using dummies in order to test seat ejections, and so dummies began being used in the automotive industry, however, not to analyse crash and safety, they were used to measure lap and shoulder belts/harnesses. Because the typical shape and size of the average dummy used was relatively accurate to the average man, the dummies were then used to measure the trajectory of occupants under different deceleration speeds, however due to their rigid bodies, they were not very accurate for any other evaluations.

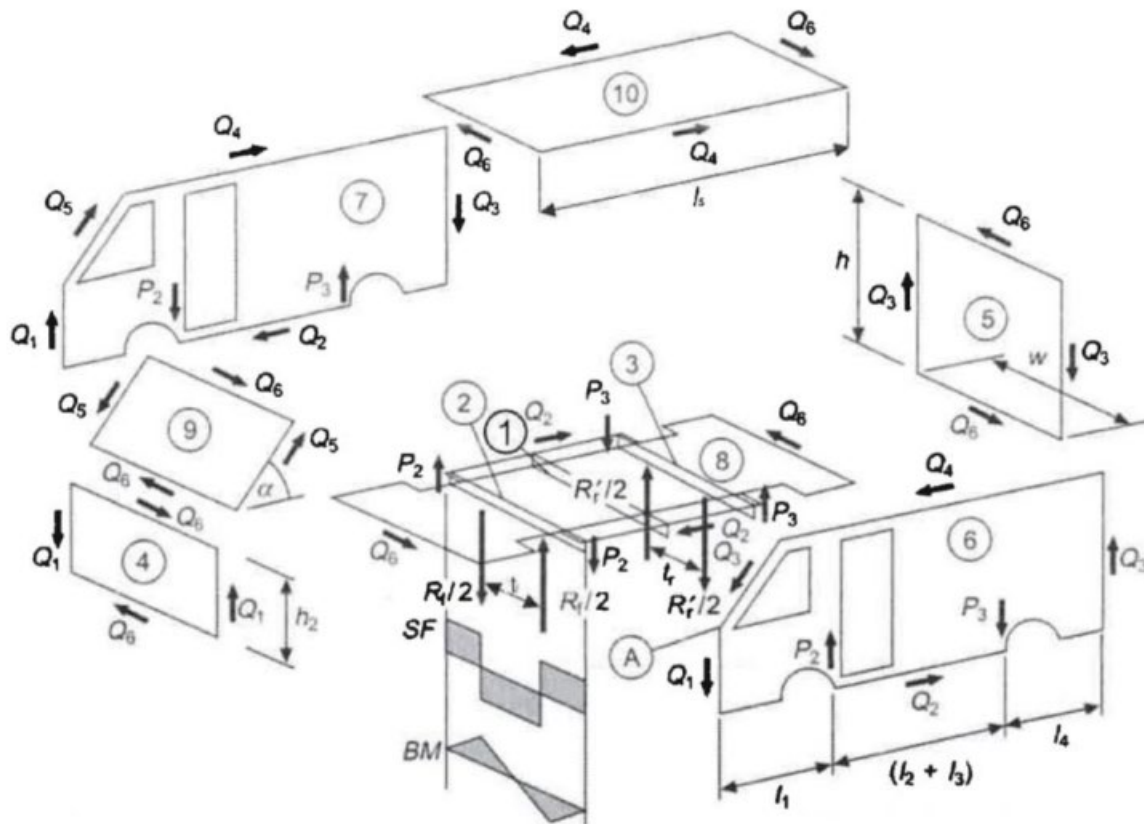
A revolutionary step was made during the early 1950s when a new dummy was engineered which encased sensors in the skull of the dummy to better analyse the effect of impact on occupants, this dummy was known as the 'Mark 1' Dummy. Besides the issue of a rigid head seen in the previous dummies, the mark 1 was also an improvement of the previous dummies' rigid spine, so the mark 1 had a spine made of ball-and-socket joints to mimic the flexibility and range of motion of a real person's spine. The mark 1 also consisted of steel

tubing ribs and softer, flesh-like skin. As time continued, more variants of the mark 1 were made in the late 1950s to mimic more diverse range of body sizes and mass.

The next advancement in dummy technology was funded by the American and European space programs, for their own purposes, and so came the invention of the Grumman-Alderson Research Dummy, which allowed crash and safety research teams (especially in the automotive industry) to measure the inertia of the dummies.

In 1966, the automotive industry became the biggest investor in test dummies, as manufacturers began adding joints to the dummies, and making 2d models and workings. In 1995, manufacturers began using MADYMO with FEA to simulate the effects on occupants under stress from deceleration and safety measures such as air bags.

4 Task 2 & 3- Van in torsion



Using the following information:

$w=2.1\text{m}$

$h=2.5\text{m}$ $h_2=1\text{m}$

$l_1=2\text{m}$ $l_2+l_3=3.5\text{m}$ $l_4=1\text{m}$

Overall weight = 3500kg

Weight distribution = 50:50

$t_f=1.5\text{m}$ $t_r=1.5\text{m}$

$\alpha=45^\circ$

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

I calculated the value of the panels to be:

$Q_1 = 177.1\text{N}$

$Q_2 = 1151.12\text{N}$

$$Q3 = 442.74\text{N}$$

$$Q4 = 885.48\text{N}$$

$$Q5 = 375.68\text{N}$$

$$Q6 = 371.9\text{N}$$

If the van were to have an electric powertrain, with the battery being interchangeable, and compromising the join between the rear and floor panel to allow access to the battery, then the rear door being removed would prevent Q6 existing, and therefore Q2 and Q3 would equal zero, and so all moment must go through the floor, which would be very inefficient. Without the rear or floor panel, the torsional stiffness of the van would also greatly reduce.

5 References