ME395
Automotive Mechanics
10. Chassis

Body In White (BIW)

- Assembly of a frame and panels, made up of homogeneous materials (for instance, steel or aluminium sheets or composites).
- Stage in automobile manufacturing in which a car body's sheet metal components have been welded together.
- BIW is termed before painting & before moving parts (doors, hoods, and deck lids as well as fenders), the engine, chassis sub-assemblies, or trim (glass, seats, upholstery, electronics, etc.) have been assembled in the frame structure.

Chassis Frame

Material

Rolled carbon steel or heat-treated alloy steel with thickness ranging from 0.8 – 1.5 mm

General form

Consists of two side rails (longitudinal member), variable number of cross members and sometime a X member. The side rails have a channel section with the open side turned inward or tubular section. Joints are made of riveting or welding.

Chassis Frame

General form

The frame is narrow in the front to allow for a short turning radius and widening out at the rear to provide ample room in the body. As looks, ride quality, and handling became more important to consumers, new shapes were incorporated into frames. The most visible of these are arches and kick-ups. Instead of running straight over both axles, arched frames sit lower — roughly level with their axles — and curve up over the axles and then back down on the other side for bumper placement. This type of construction is done to lower the CG of the vehicle.

Vehicle Body

It is superstructure of the vehicle. It is either integral to the frame or is bolted to the frame. The chassis and body make the complete vehicle. The vehicle body consists of doors, windows, cabin, seats, engine cover, roof, luggage space etc.

Requirements

1. It must be lighter.
2. It must be designed to have uniform stress.
3. Must have reasonable fatigue life.
4. Must have reasonable dimension and space for inside capacity and other engine access.
5. Should not be complicated.
6. Should be designed for possible future modifications.

Vehicle Body

Components

1. Structure – all the load carrying elements
2. Finish – all the unstressed units like the bonnet, lid etc.
3. Equipment – includes, seats, heating systems, doors etc.

The passenger car generally consists of a floor panel with engine beams, rear sills, front and rear bulk heads, door/side frames, wheel arches, roof, dash panel, wind screen, front and rear mud guards, radiator grille, rear window.

Vehicle Body

Design aspects

- Current vehicles have reached high engine standards. So the competition is heavy on the interior and exterior design of the vehicle body.
- Structural weight determines the total body weight of the vehicle. Any reduction in body weight will improve the load carrying capacity, improve fuel economy and other factors.
- Streamlining the body reduces drag and hence fuel consumption.

Vehicle Body

Design aspects

- Aesthetics and ergonomics have great influence on customer appeal – comfortable seats, dashboard layout, position of controls and instruments, ease of entry and exit, lighting inside and outside, HVAC and finally the overall appearance.
- The design should allow easy access to fuel tank, spare wheel, batteries, tools and other components.
- The design should also take the cost into consideration as 50-70% of the vehicle cost goes into the vehicle body.

Vehicle Body

Construction

Vehicle bodies are made of sheet metal forming with spot welding to joint the sheet metal parts.

Vehicle body is subject to three types of corrosion – chemical, electrochemical and fretting. These can be prevented by using improved sheet metal material, applying protective coatings and adopting corrective designs.

Types of construction

1. Non load carrying type
2. Semi integral type
3. Integral type

Top 9 car body types

Frame

- Purpose
  - Maintain the shape
  - Support the loads
  - Takes up the engine and transmission thrust.
- Design of frame is aimed at achieving sufficient *strength* and *stiffness*
- Strength – maximum force that the structure can withstand without failure

Failure may be caused by

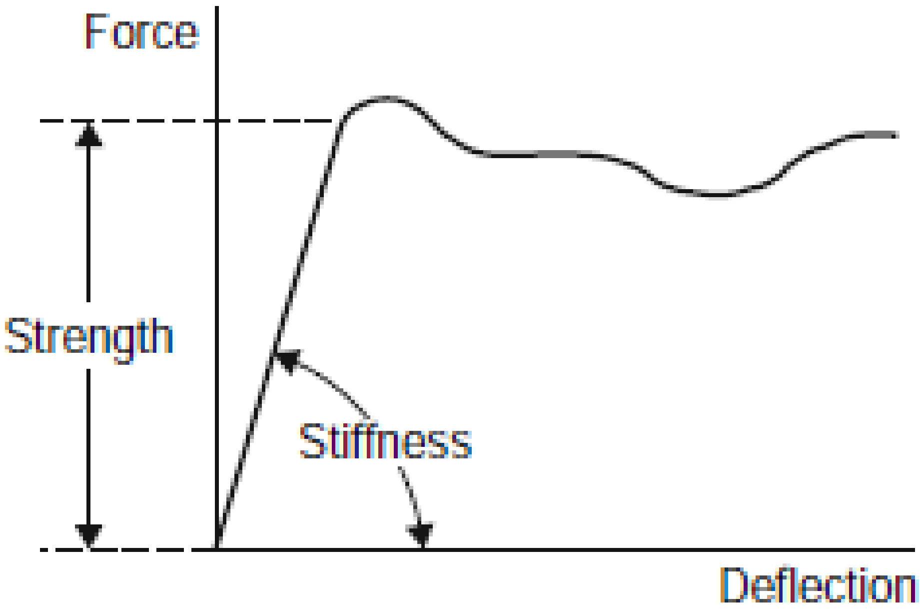
(a) overstressing of components beyond the elastic limit,

(b) by buckling of items in compression or shear, or

(c) by failure of joints

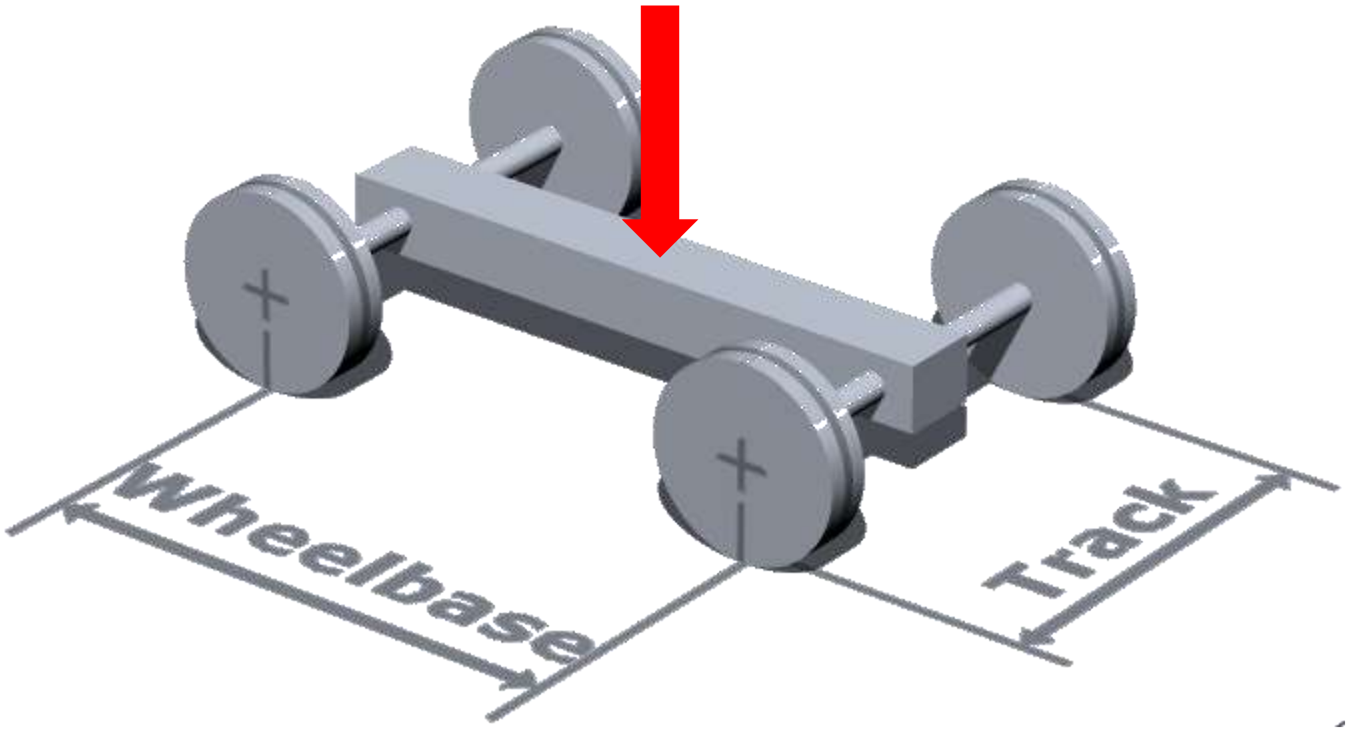
Frame

- Stiffness - The stiffness K of the structure relates the deflection Δ produced when load P is applied, i.e. P = K Δ. It applies only to structures in the elastic range and is the slope of the load vs deflection graph



Frame

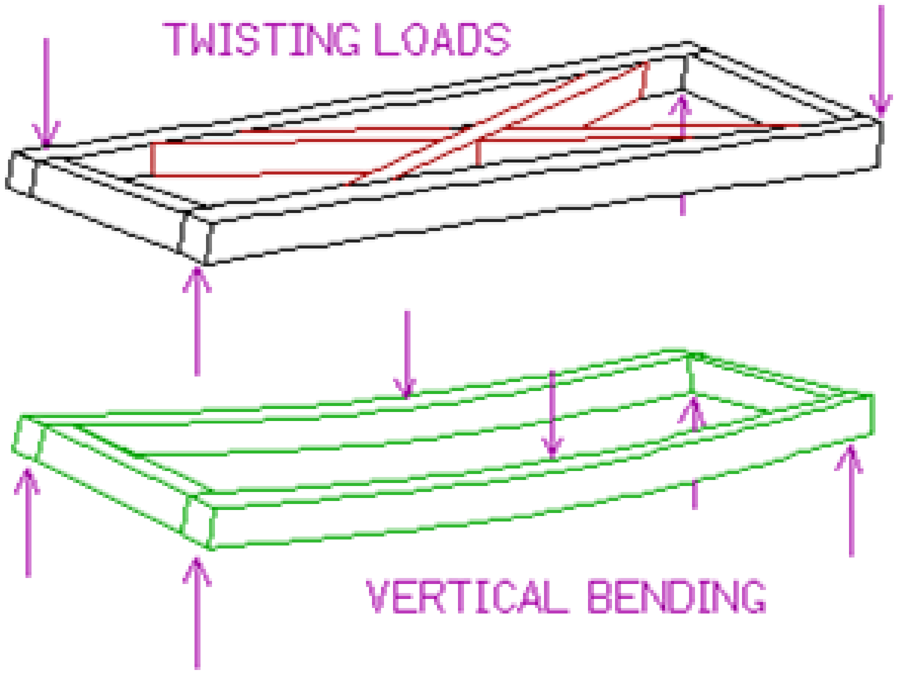
- Bending Stiffness - K_B of the structure relates symmetrical vertical deflection of a point near the centre of the wheelbase to multiples of the total static loads on the vehicle



Frame

- Torsion Stiffness - K_T of the structure relates the torsional deflection $\theta$of the structure to an applied pure torque T about the longitudinal axis of the vehicle.

Torsion case is most difficult to design and hence torsion stiffness is often used as a ‘benchmark’ to indicate the effectiveness of the vehicle structure.



Loads on a Frame

Loads in normal running conditions:

- – Vehicle transverse on uneven ground.
- – Maneuver performed by driver.

Five basic load cases:

- – Bending case
- – Torsion case
- – Combined bending and torsion
- – Lateral loading
- – Fore and aft loading

Loads on a Frame

Bending Load

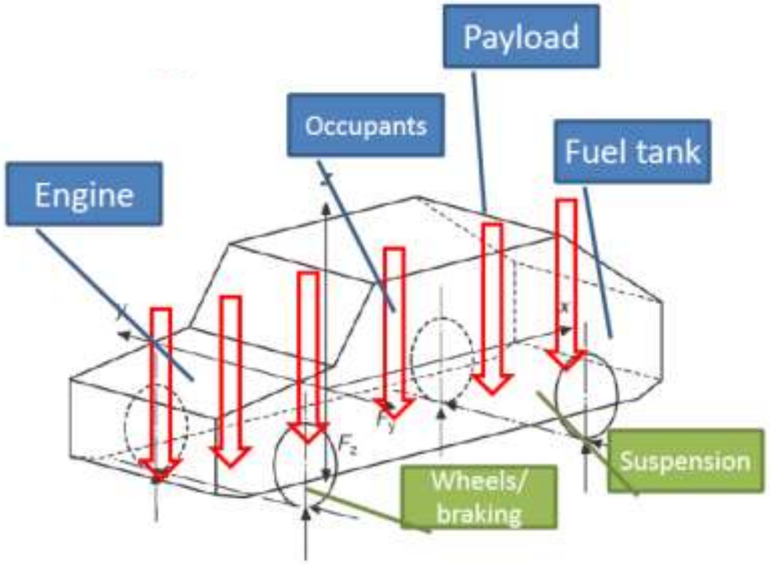
- Loading in vertical plane, due to weight of components along the vehicle frame.

Static loads

- Vehicle at rest .
- Moving at constant velocity on an even road.

Dynamic loads

- Vehicle moving on a bumpy road even at constant velocity.
- Road vehicles: 2.5 to 3 times static loads
- Off road vehicles: 4 times static loads



Loads on a Frame

Torsion Load

- When vehicle traverse on an uneven road front and rear axles experiences a moment.
- Pure simple torsion:

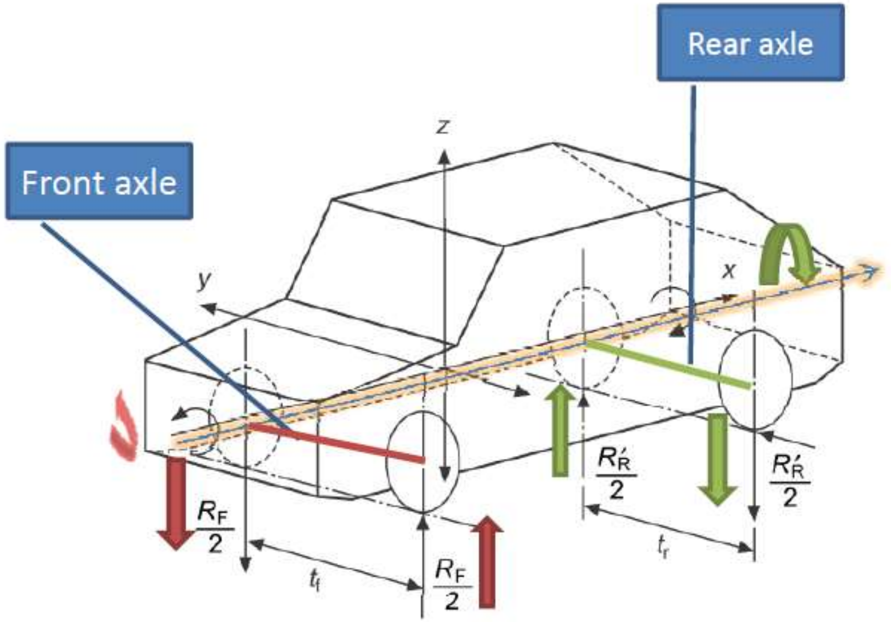
– Torque is applied to one axle and reacted by other axle.

– Front axle: anti clockwise torque (front view)

– Rear axle: balances with clockwise torque

– Results in a torsion moment about x- axis.

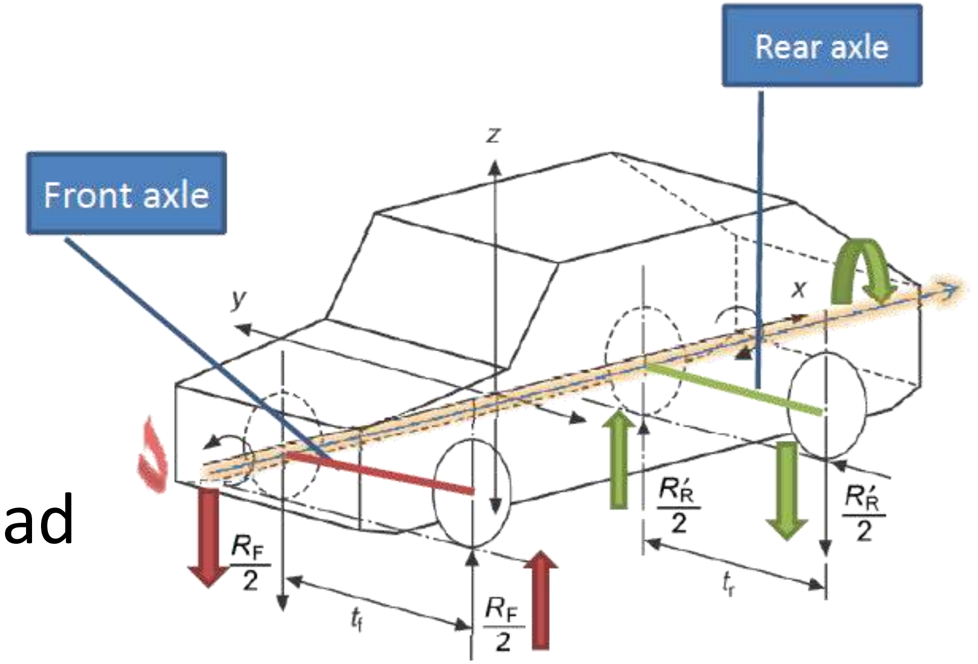
- In reality torsion is always accompanied by bending due to gravity.



Loads on a Frame

Torsion Load

- Maximum torsion load is based on the torque at the lighter loaded axle.
- In a generic passenger car the rear axle load R_R is smaller than the front axle load R_F
- The modified reaction force R'_R that will balance R_F is given by the moment balance
- $\frac{R'_R}{2} \times t_r = \frac{R_F}{2} \times t_f$
- $R'_R = R_F$ when the front and rear wheel tracks are the same



Loads on a Frame

Combined Bending and Torsion Load

- Bending and torsional loads are super imposed- loadings are assumed to be linear
- One wheel of the lightly loaded axle is raised on a bump result in the other wheel go off ground.
- All loads of lighter axle is applied to one wheel.
- Due to nature of resulting loads, loading symmetry wrt x-z plane is lost.
- R'_R can be determined from moment balance
- R'_R stabilizes the structure by increasing the reaction force on the side where the wheel is off ground .

Loads on a Frame

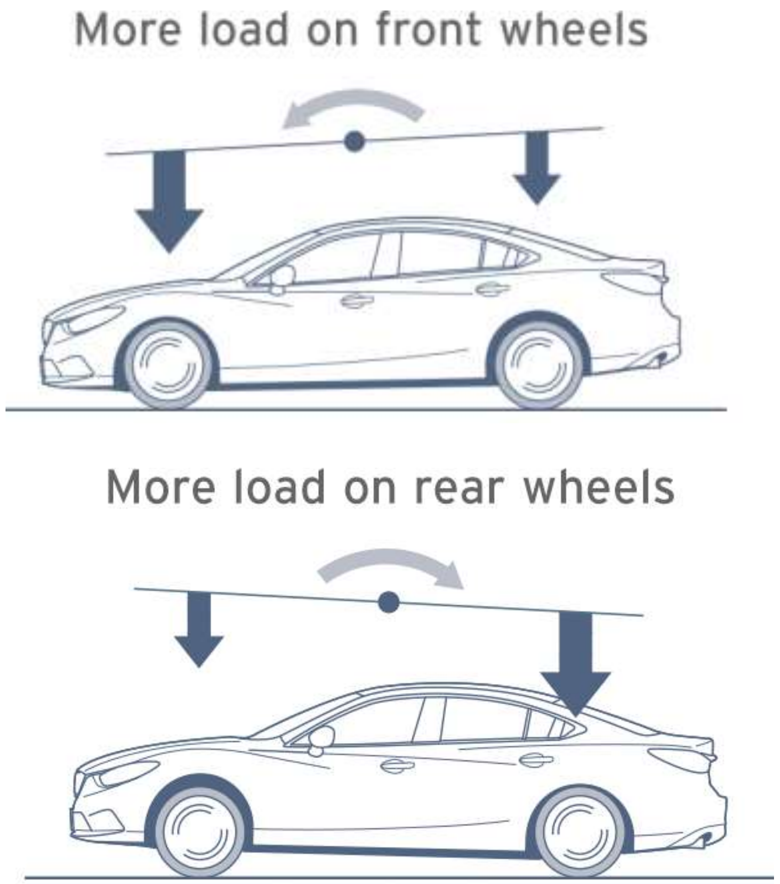
Lateral Load

- Due to cornering, generated at the tire to ground contact patch
- Balanced by centrifugal forces
- When the inside wheel reaction becomes zero, the vehicle rolls over
- Vehicle is subjected to bending in the x-y plane (top view)
- Width of car and reinforcements provides sufficient bending stiffness to withstand lateral forces.
- Lateral shock loads assumed to be twice the static vertical loads on wheels.

Loads on a Frame

Longitudinal Load

- When vehicle accelerates and decelerates inertia forces generate.
- Acceleration –Weight transferred from front to back.
- Deceleration –Weight transferred from back to front.
- **Tractive** and **braking** forces adds bending through suspension.
- Inertia forces adds additional bending.



Allowable Stress

Vehicle structure is not fully rigid

- Internal resistance or stress is induced to balance external forces
- Stress should be kept to acceptable limits
- Stress due to static load X dynamic factor ≤ yield stress of the material

– Should not exceed 67% of yield stress.

- Safety factor against yield is 1.5
- Fatigue analysis is needed

– At places of stress concentration

– Eg. Suspension mounting points, seat mounting points.

Bending Stiffness

Important in structural stiffness

• Sometimes stiffness is more important than strength

• Determined by acceptable limits of deflection of the side frame door mechanisms.

– Excessive deflection will not shut door properly

• Local stiffness of floor is important

– Stiffened by swages pressed into panels

– area moment of inertia should be increased

Bending Stiffness

Thin panels separated by honeycomb structure reduce vibration

- Local stiffness has to be increased at:

– Door

– Bonnet

– Suspension attach points

– Seating mounting points

– Achieved by reinforcement plates and brackets.

Torsional Stiffness

Allowable torsion for a medium sized car: 8000 to 10000 Nm/deg

- Measured over the wheel base
- When torsion stiffness is low:

– Structure move up and down and/or whip

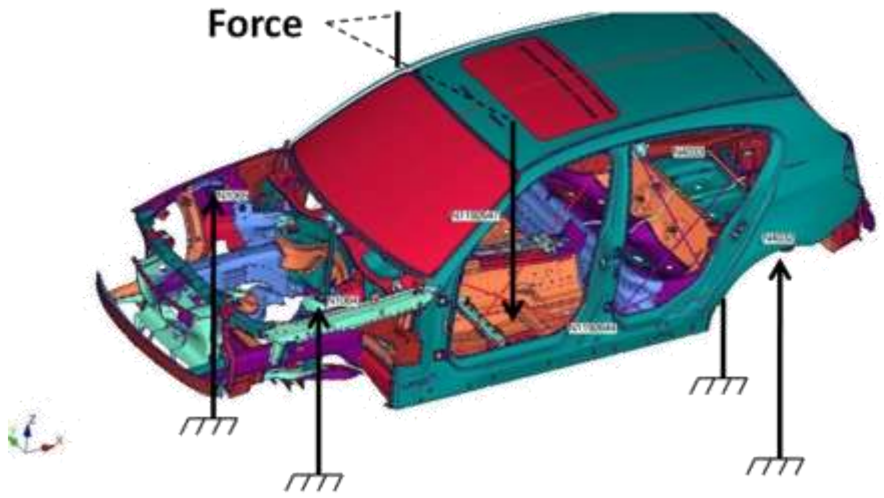
– When parked on uneven ground doors fail to close

– Doors fail to close while jacking if jack points are at a corner

- Torsion stiffness is influenced by windscreens
- TS reduces by 40% when windscreens removed
- Open top cars have poor torsional stiffness
- Handling becomes very difficult when torsional stiffness is low.

Global static bending stiffness

The ratio of the applied load, applied at the front seat locations, while the body is constrained at front and rear shock towers, as shown in figure below, to the maximum deflection along the rocker panel **[Ref1]**

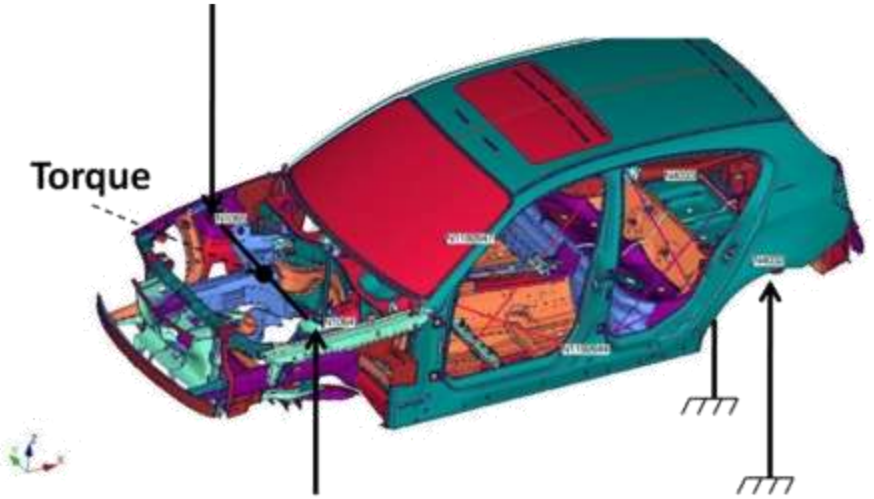


[Ref1: J. Helsen ,L. Cremers ,P. Mas , P. Sas, "Global static and dynamic car body stiffness based on a single experimental modal analysis test", PROCEEDINGS OF ISMA2010 INCLUDING USD2010]

Global static torsional stiffness

For global static torsion stiffness, a static moment is applied to the body-in-white at the front shock towers, whereas the rear shock towers are constrained, as shown in figure. The torsion angle is defined as the resulting deformation angle between the front and rear shock towers.

The corresponding torsion stiffness can be calculated as the ratio of applied static moment to the torsion angle.**[Ref1]**



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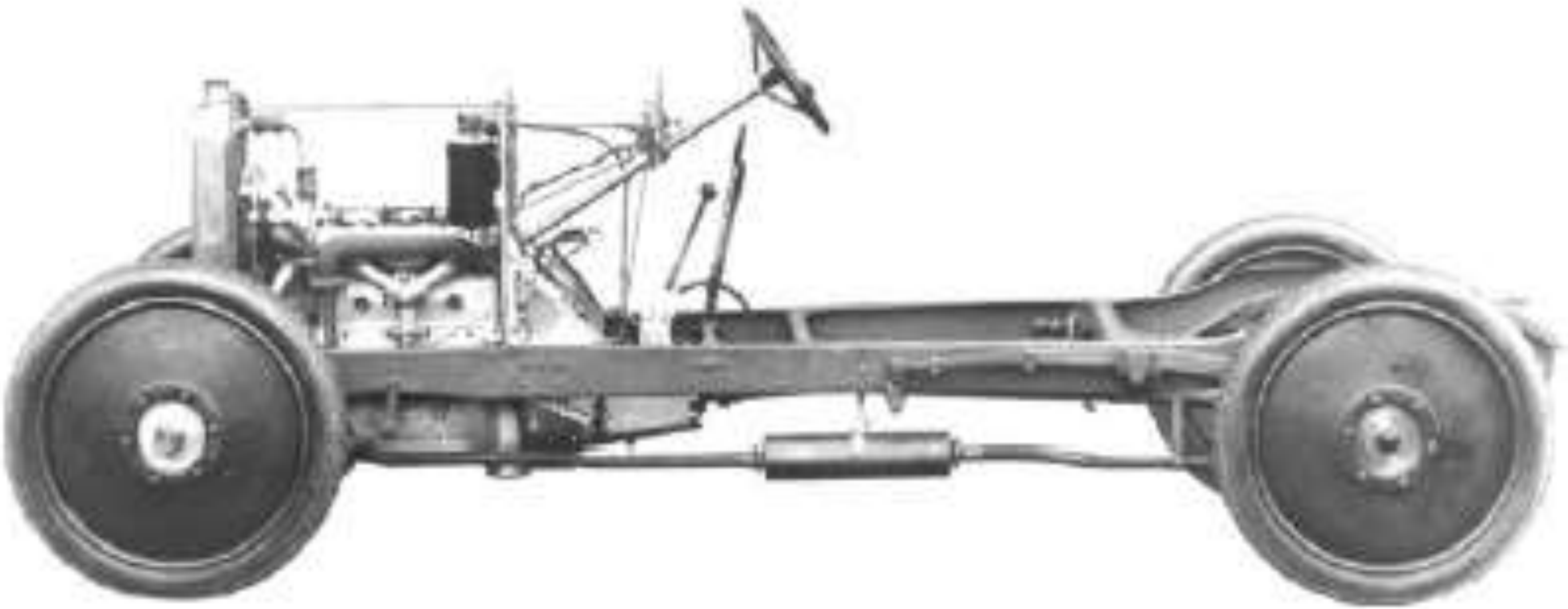
Ladder frame chassis

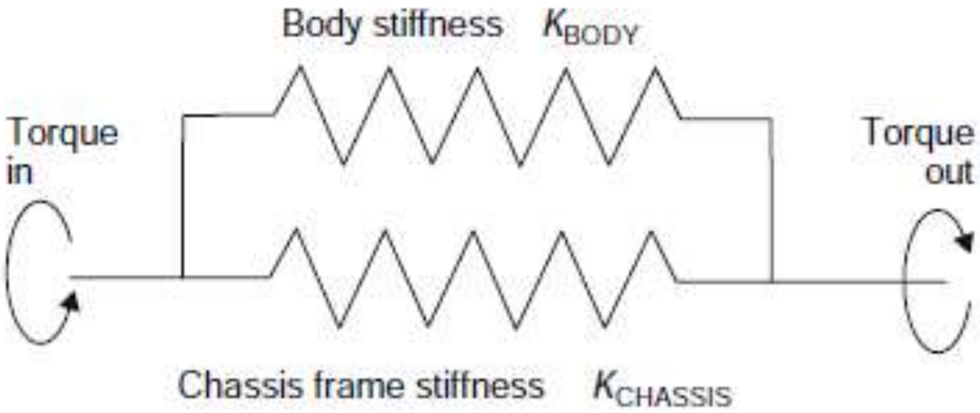


Body-on-Chassis

‘Body-on-chassis’ arrangement consists, in essence, of two structures (the body and the chassis) acting as torsion springs in parallel.

Body-on-Chassis

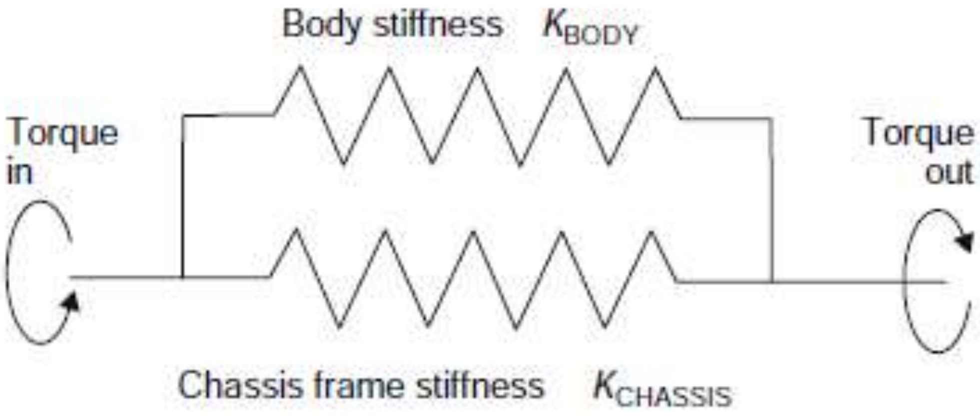
- In the simplified case where the body and chassis are connected only at their ends
- $T_{TOTAL} = T_{BODY} + T_{CHASSIS}$
- $K_{TOTAL} = K_{BODY} + K_{CHASSIS}$
- $T_{BODY}/T_{CHASSIS} = K_{BODY}/K_{CHASSIS}$
- where T = torque and K = torsional stiffness.



Body-on-Chassis

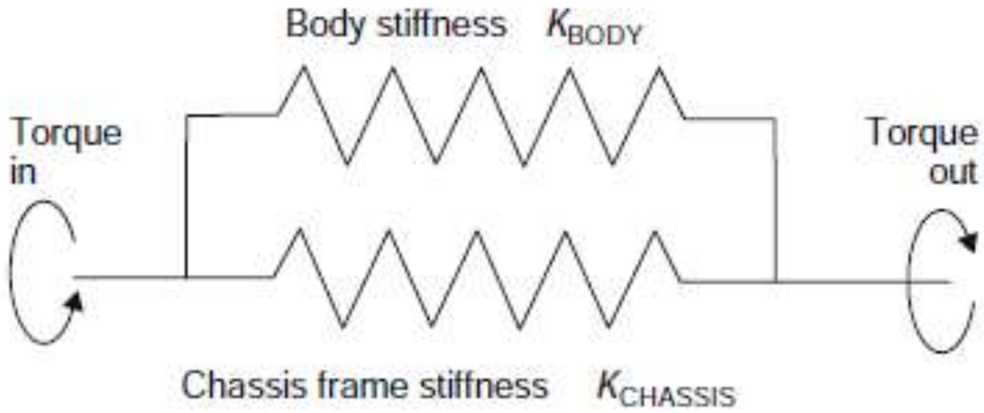
- Thus, in the case of a flexible body on a (relatively) stiff chassis frame, most of the torsion load would pass through the chassis.

- Conversely, if the body were stiff and the chassis flexible, then the body would carry a larger proportion of the torsion load.



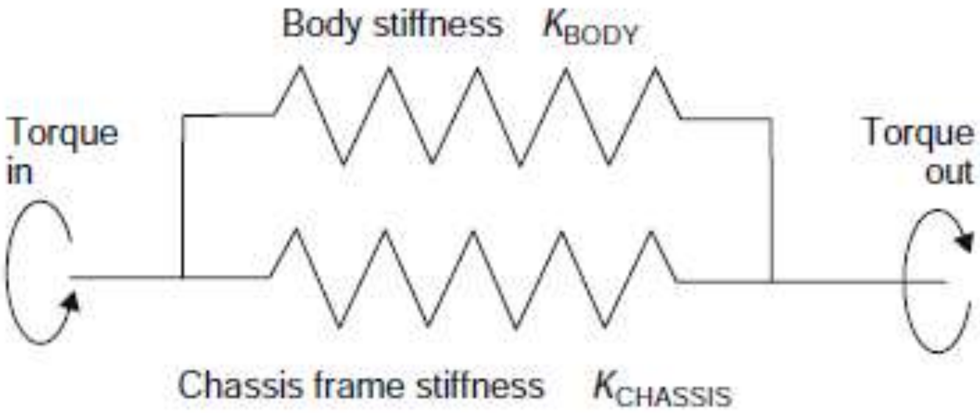
Body-on-Chassis

- Conventionally, bodies were deliberately made flexible by use of flexible material for the outer skin of the vehicle body (Eg. Wood, Fabric, thin metal sheets with discontinuities etc.)



Body-on-Chassis

- High volume production in 1930s led to the widespread use of pressed steel car body technology.
- Much greater proportion of the load was now taken through the body, owing to its greater stiffness.
- This led to problems of 'fighting' between the body and the chassis frame (i.e. rattling, or damage to body mounts caused by undesired load transfer between the body and the chassis).

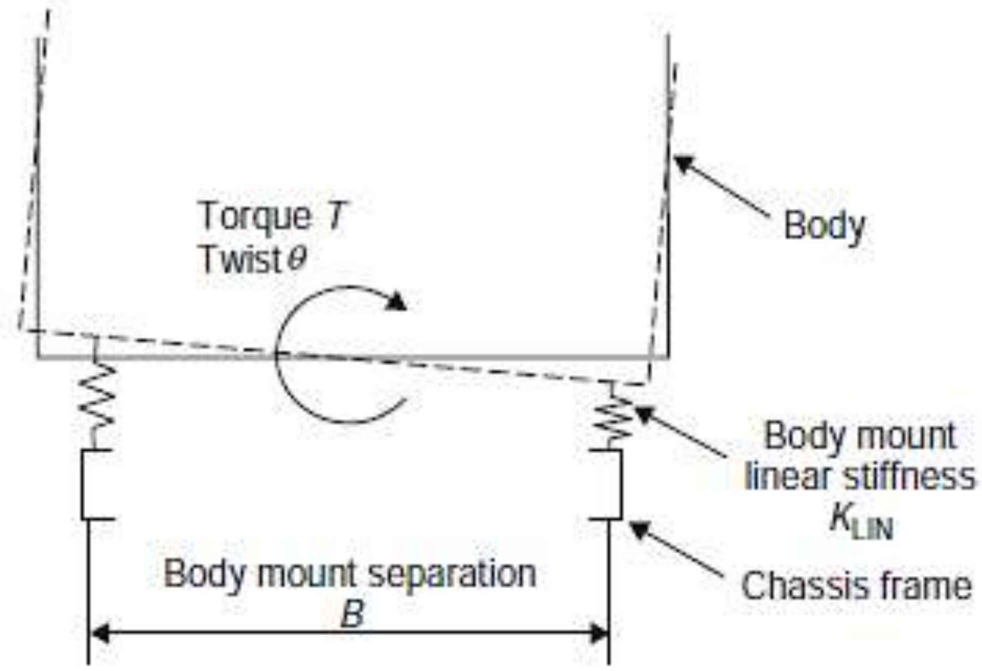


Body-on-Chassis

Solution

a. Use of flexible mountings between chassis and body

- Laterally spaced pairs of these mountings act as torsion springs about the longitudinal axis of the vehicle between the chassis and the body.



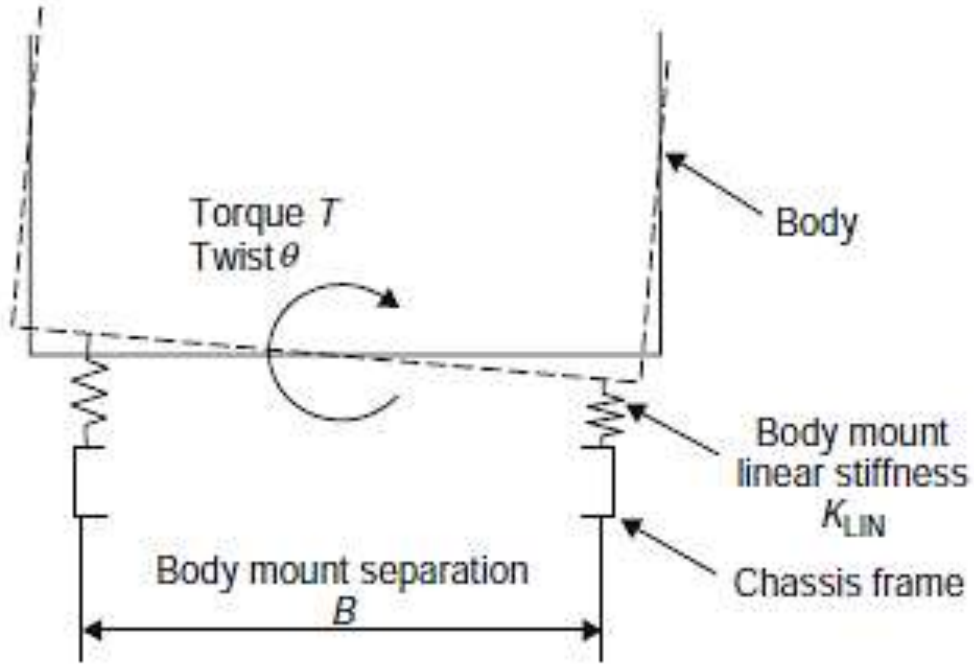
Body-on-Chassis

Solution

a. Use of flexible mountings between chassis and body

- If the linear stiffness of the individual elastomer body mounts is K_{LIN}, and they are separated laterally by body width B (see Fig), then the torsional stiffness K_{MOUNT} of the pair of mounts about the vehicle longitudinal axis is:

$$K_{MOUNT} = K_{LIN}B^2/2$$

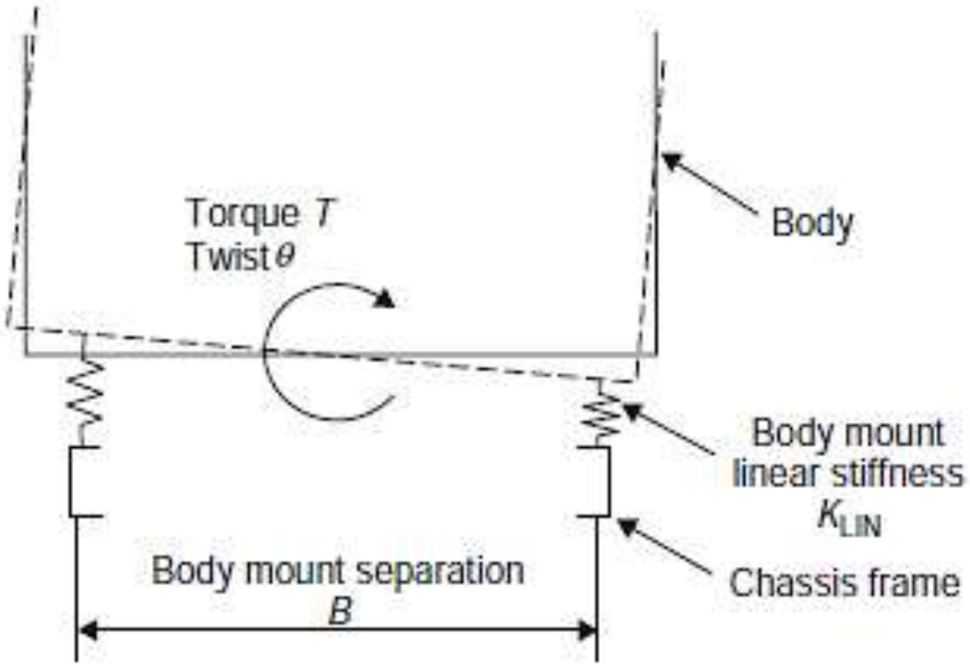


Body-on-Chassis

Solution

a. Use of flexible mountings between chassis and body

- Made the ‘load path’ through the body more flexible
- Soft elastomer mounts and the body formed a chain of ‘springs in series’



Body-on-Chassis

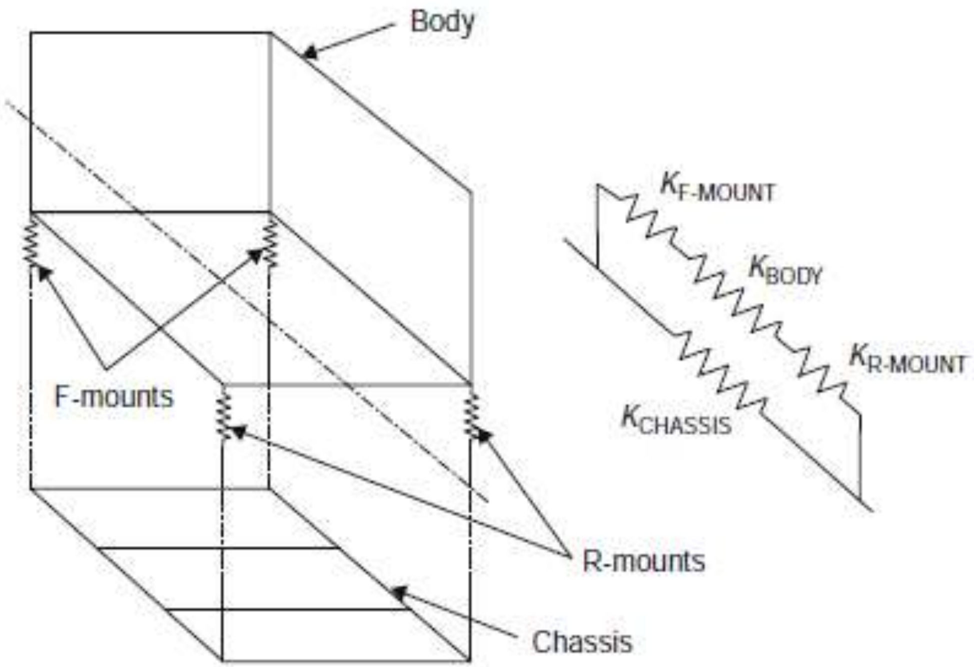
Solution

a. Use of flexible mountings between chassis and body

- For such a system the total flexibility (reciprocal of stiffness) is given by

$$1/K_{TOTAL} = 1/K_{F\text{-}MOUNT} + 1/K_{BODY} + 1/K_{R\text{-}MOUNT}$$

- As a result, the overall stiffness is lower than that of the individual elements in the series. This reduces the proportion of the torsion load carried by the body.

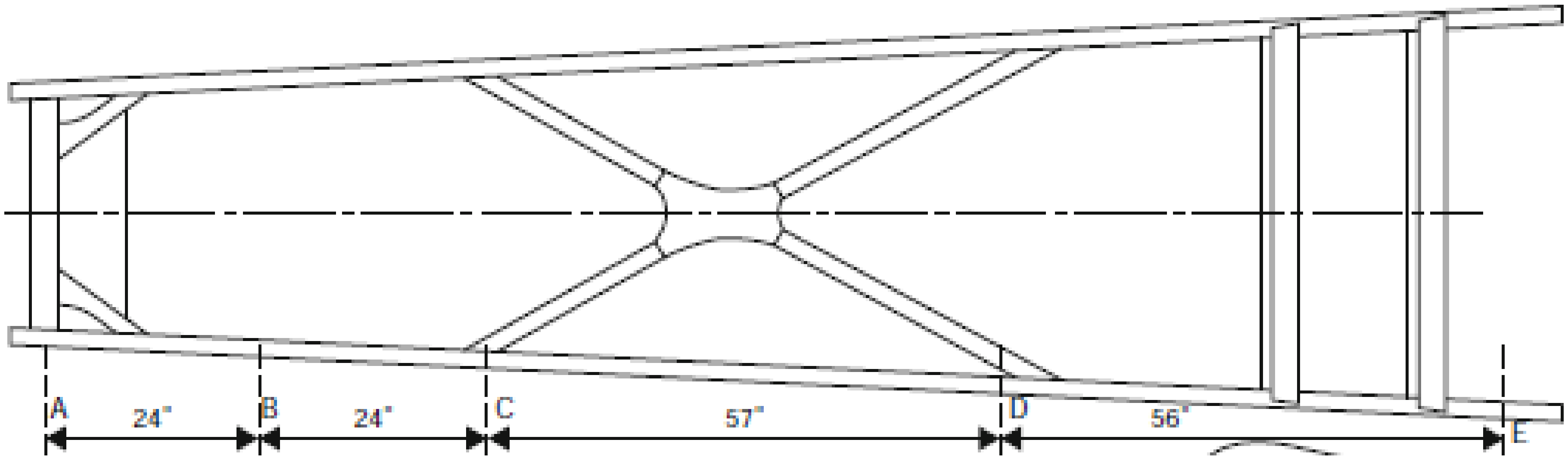


Body-on-Chassis

Solution

b. Converse of (a) – stiffen the chassis frame, thus encouraging it to carry more of the load

Cruciform bracing - a cross-shaped brace, made usually of open channel section members, was incorporated into the chassis frame as shown in Fig.

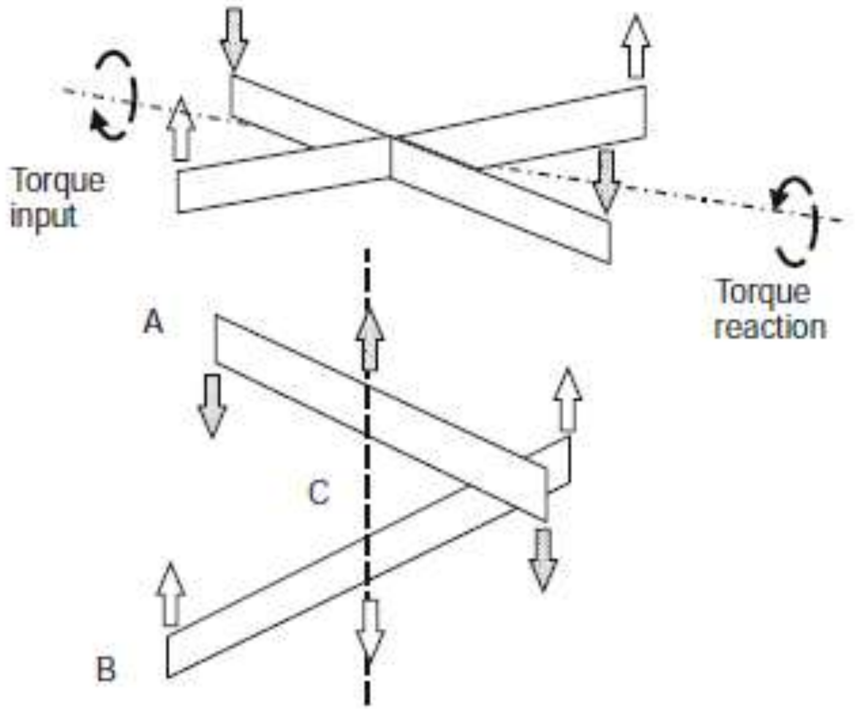


Body-on-Chassis

Solution

b. Converse of (a) – stiffen the chassis frame, thus encouraging it to carry more of the load

On the left, the ‘input torque’ is fed in as a couple consisting of two equal and opposite forces. This couple, or torque, is reacted by the couple composed of the equal and opposite forces on the right-hand side of the diagram.

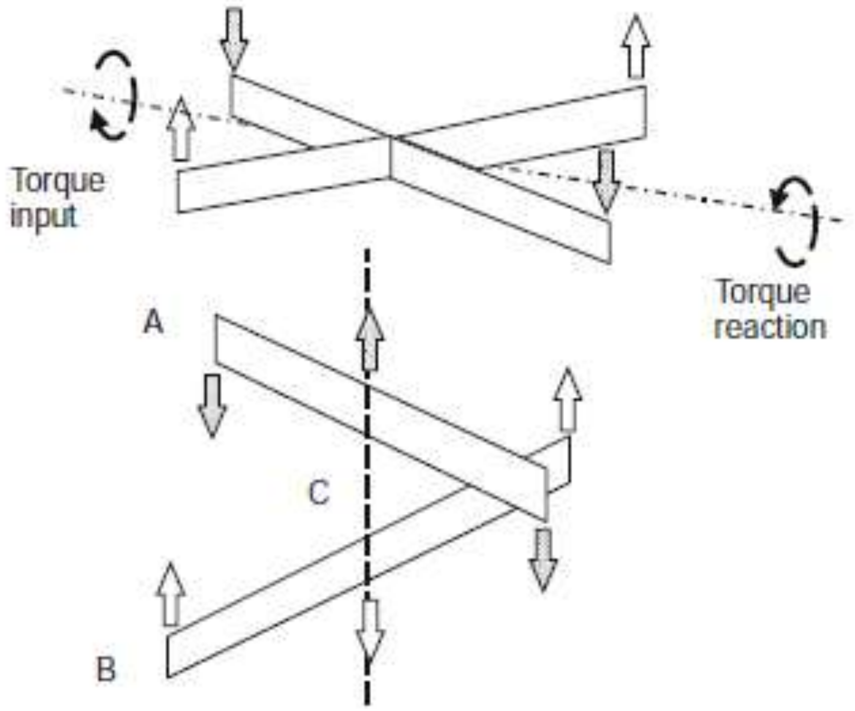


Body-on-Chassis

Solution

b. Converse of (a) – stiffen the chassis frame, thus encouraging it to carry more of the load

Although the overall effect is a torsion carrying structure, the individual members (A and B) are subject only to bending and shear forces. Hence it was possible to use open sections. It is essential that there is a good, continuous, bending load path in both members A and B at point C (point of maximum bending moment)

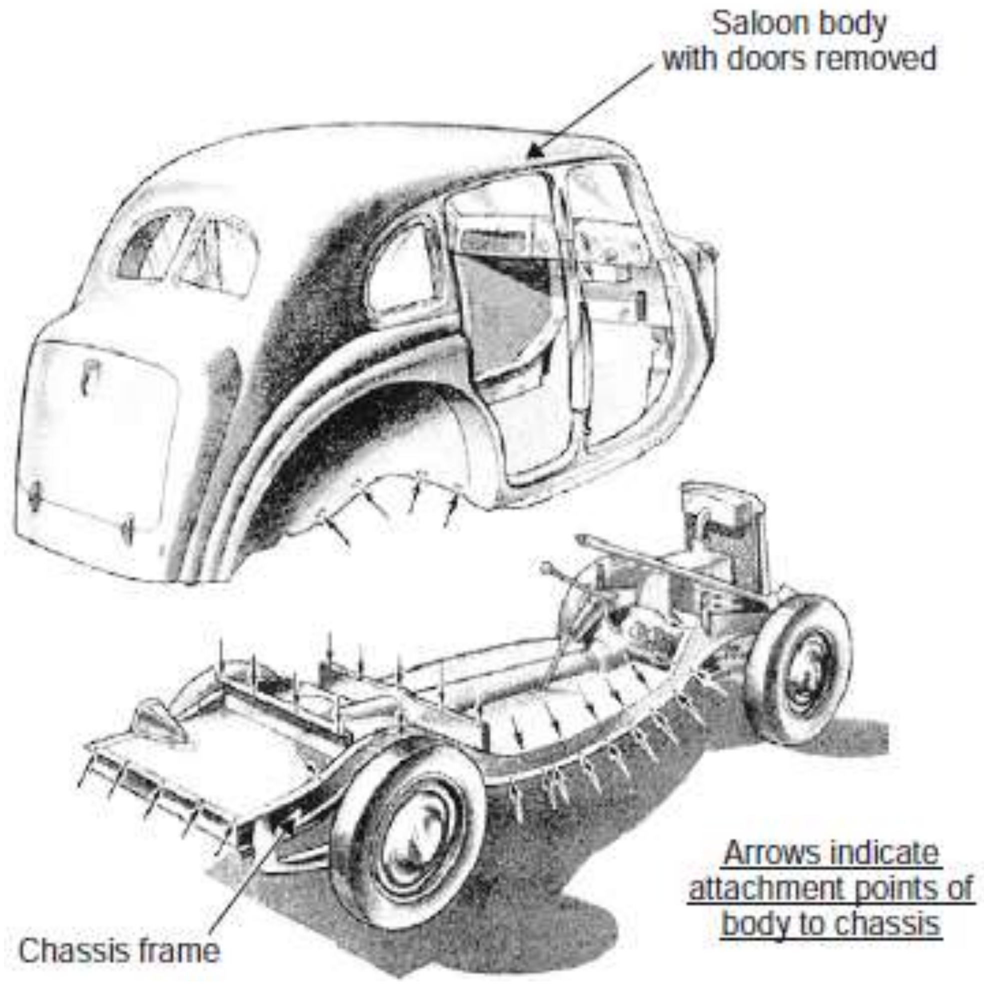


Body-on-Chassis

Solution

c. Greater ‘integration’ of the body with the chassis frame

- A body attached to the chassis frame by a large number of screws, thus using some of the high torsion stiffness of the body, is shown in Fig.
- This approach led eventually to the modern ‘integral body’



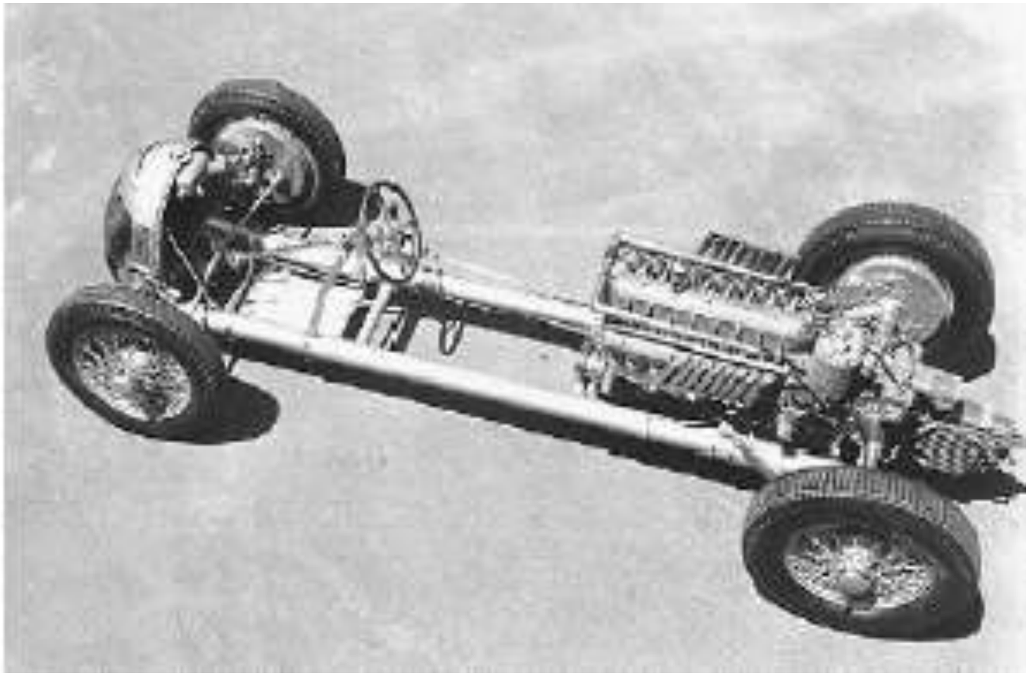
Body-on-Chassis

Solution

d. ‘twin tube’ or ‘multi tube’ frame.

-used closed section members that had several times higher stiffness than open channel members as used earlier

-used welded joints over earlier used riveted joints



Modern structure types

- The closed tube (or closed box) torsion structure has been used to greater effect by using larger section, but thinner walled members
- The torsion constant J for a thin-walled closed section member is

  $J = 4A_E^2 t/S$, for a closed section with constant thickness walls

A_E – cross section area or enclosed area

t- wall thickness

S- section perimeter

- Hence there is a great advantage in increasing the breadth and depth of the member.

Modern structure types

The torsion stiffness K of the closed section backbone member is

$K = GJ/L$

where G - material shear modulus and L - length of member, and

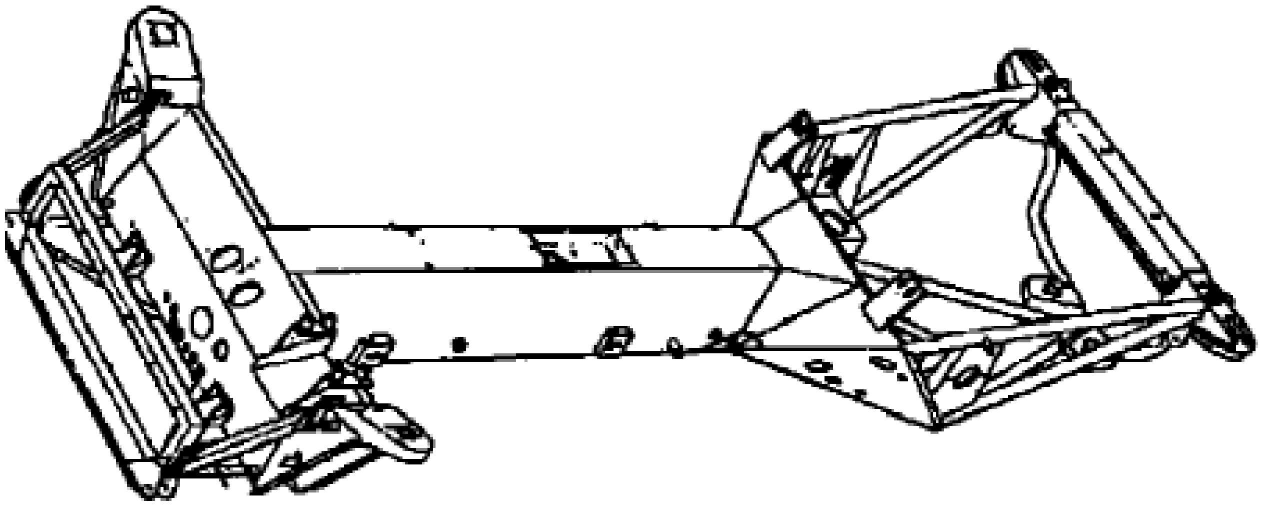
$T = K\theta$

where T - applied torque and θ- torsional deflection (twist).

Modern structure types

1. Backbone structure

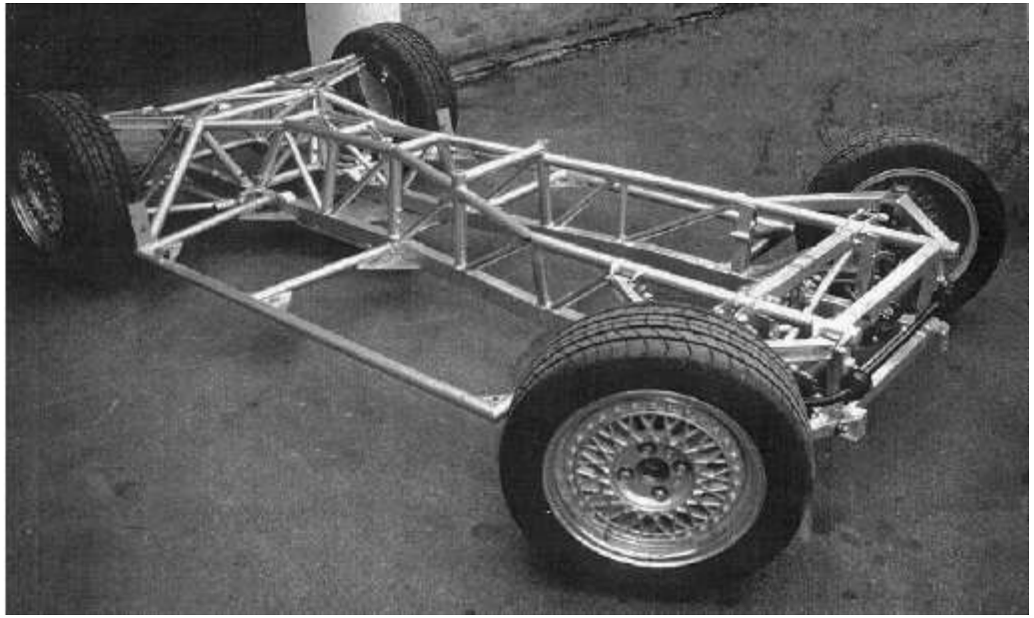
The backbone chassis derives its stiffness from the large cross-sectional enclosed area of the ‘backbone’ member. A typical size might be around 200mm by 150 mm. In tubular structures in torsion, the walls of the tube are in shear. Thus the tube consist of shear panels.



Modern structure types

1. Backbone structure

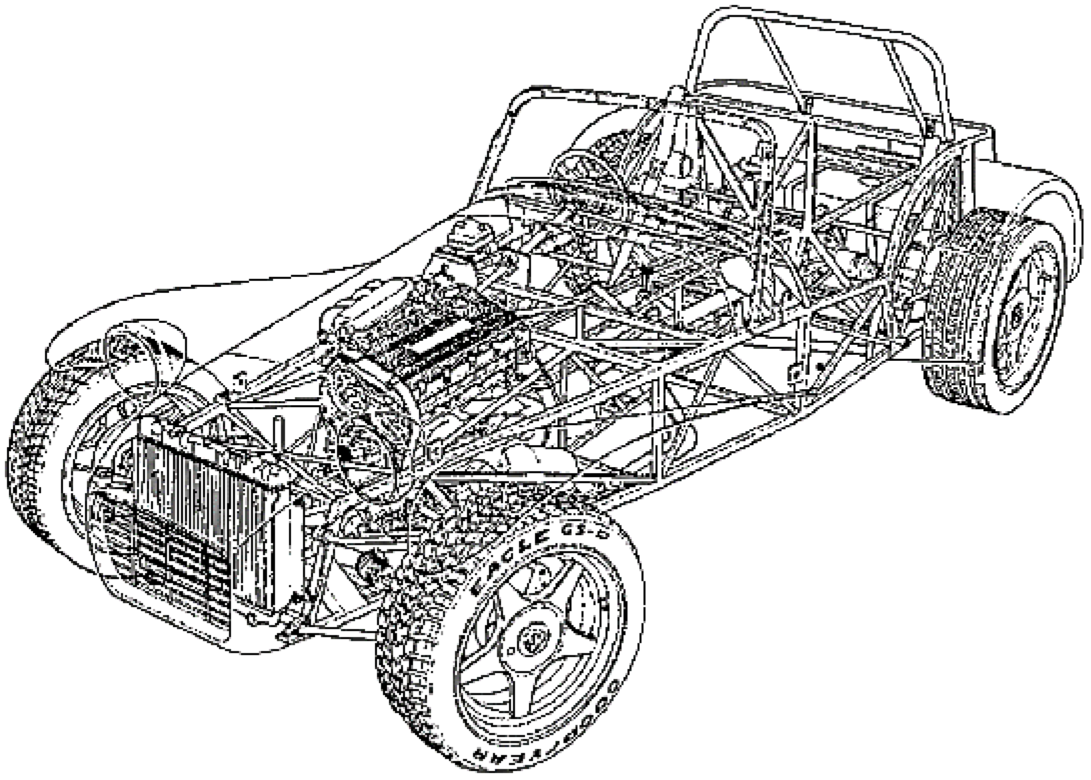
A triangulated ‘bay’ of welded or brazed small tubes can also form a very effective and weight efficient shear carrying structure. It is possible to build an analogue of the ‘backbone’ chassis frame using triangulated small section tubes as shown in the fig.



Modern structure types

2. Triangulated tube structure

The triangulated tube arrangement is not limited to backbone structures. A more common approach using this principle is the ‘bathtub’ layout, in which the triangulated structure surrounds the outside of the body as shown in fig.

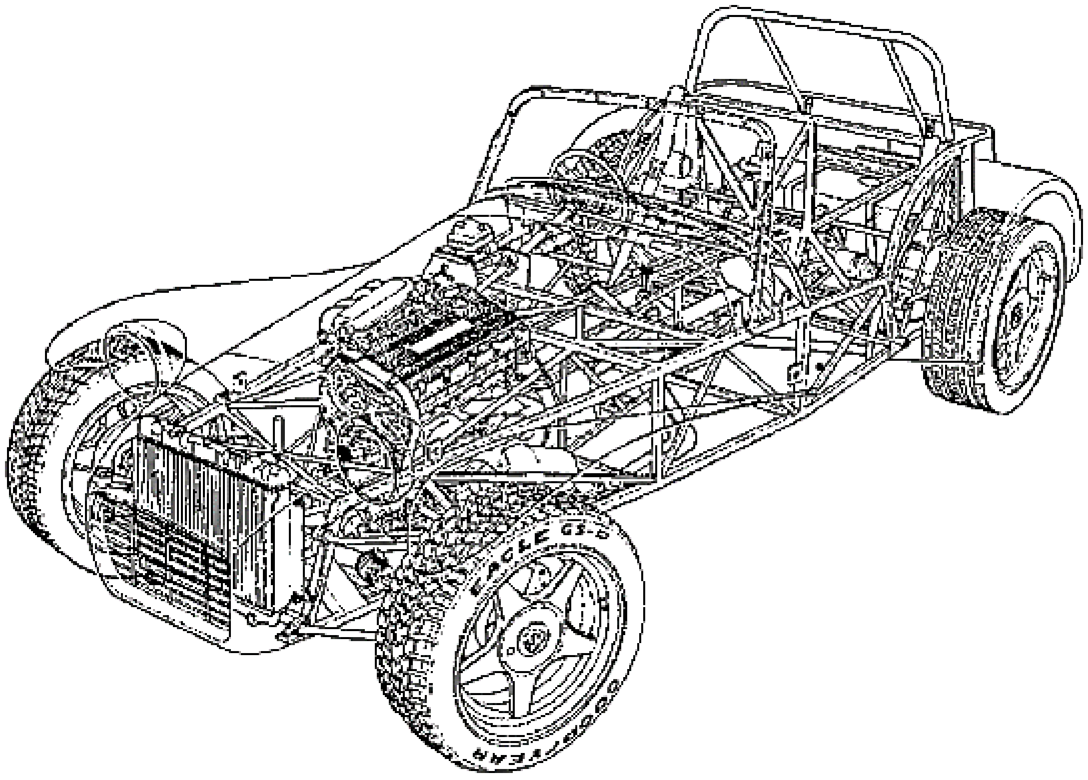


Modern structure types

2. Triangulated tube structure

This method of construction is best suited to low volume production because of low tooling costs.

It is not well suited to mass production due to complication and labour-intensive manufacture.



Modern structure types

3. Incorporation of roll cage into structure

The triangulated ‘roll cage’ now extends around the passenger compartment as shown in the fig. The enclosed cross-sectional area of the body is thus very large, and hence the torsion constant is large also.

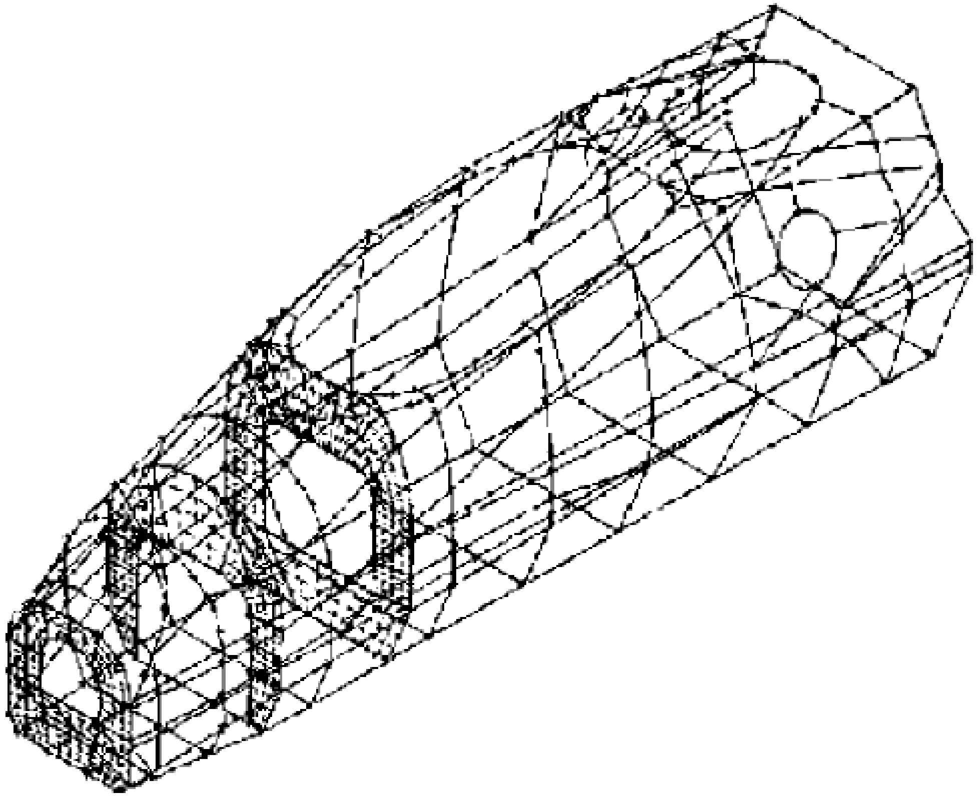
Modern structure types

4. Pure monocoque

The outer skin performs the dual role of the body surface and structure.

This is the automotive version of aircraft 'stressed skin' construction. It is very weight efficient.

The pure monocoque car structure is relatively rare. Its widespread use is restricted to racing cars as it requires a closed tube which is impractical for passenger cars.

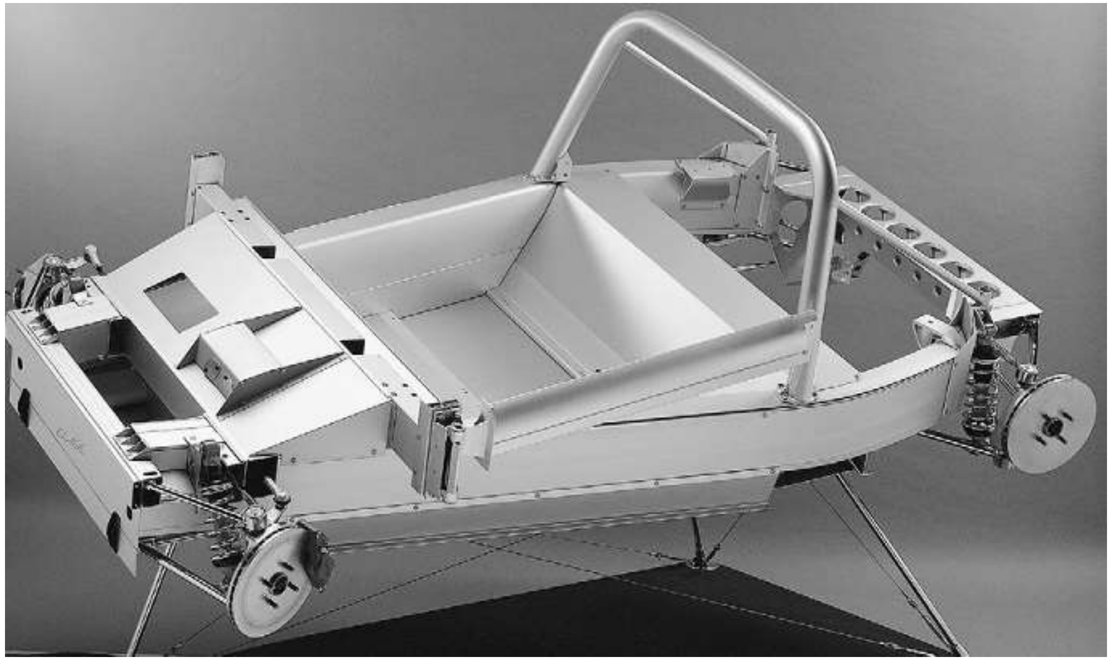


Modern structure types

5. Punt or platform structure

This is usually of sheet metal construction, in which the floor members (rocker, cross-members, etc.) are of large closed section, with good joints between members.

It is thus a grillage structure of members with high torsion and bending properties locally.

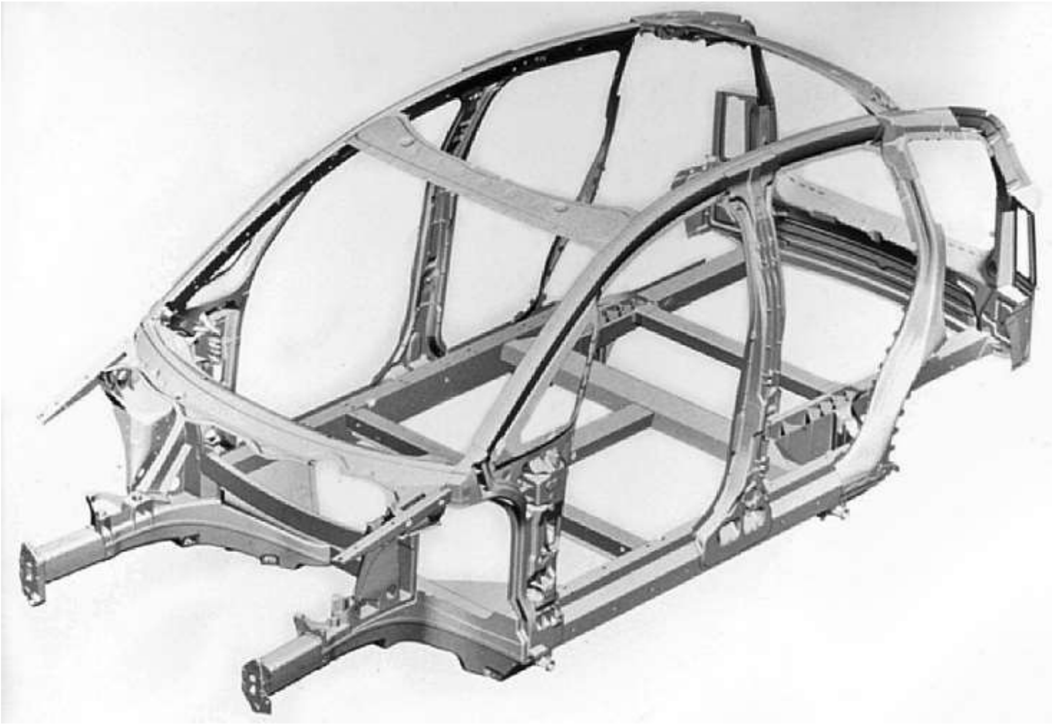


Modern structure types

6. Perimeter space frame or ‘birdcage’ frame

In this type of structure, relatively small section tubular members are built into stiff jointed ‘ring-beam’ bays, welded together at joints or ‘nodes’.

Ring beams are moderately effective at carrying local in-plane shear. For this, the edge members of each ring frame, and especially the corners, must be stiff locally in bending.

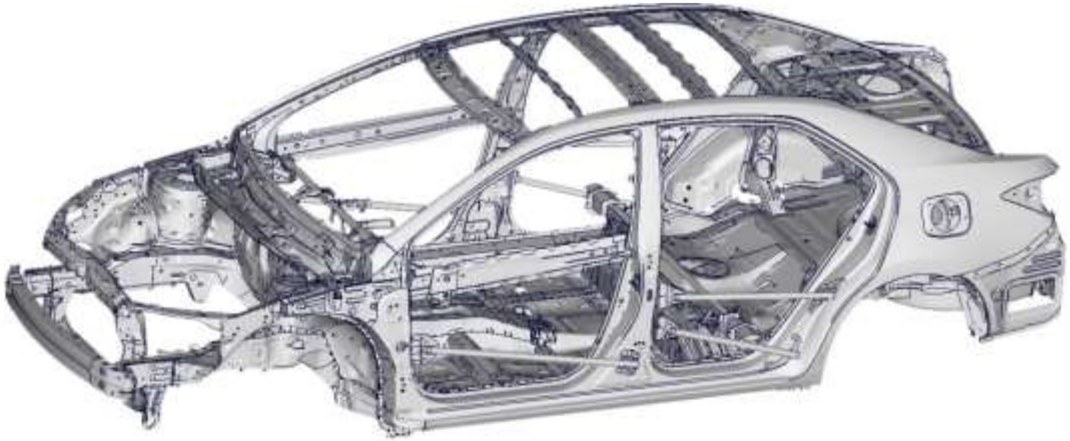


Modern structure types

7. Integral or unitary body structure

The most widely used modern car structure type, is the ‘integral’ (or ‘unitary’), spot welded, pressed steel sheet metal body.

It is well suited to mass production methods. The body is self-supporting, so that the separate ‘chassis’ is omitted, with a saving in weight.



Bumper

Outer body component attached to the front and rear end of the vehicle for aesthetic enrichment and protecting the car body against small impacts. It also helps adjust the front body height for pedestrian safety.

Design requirements for safety

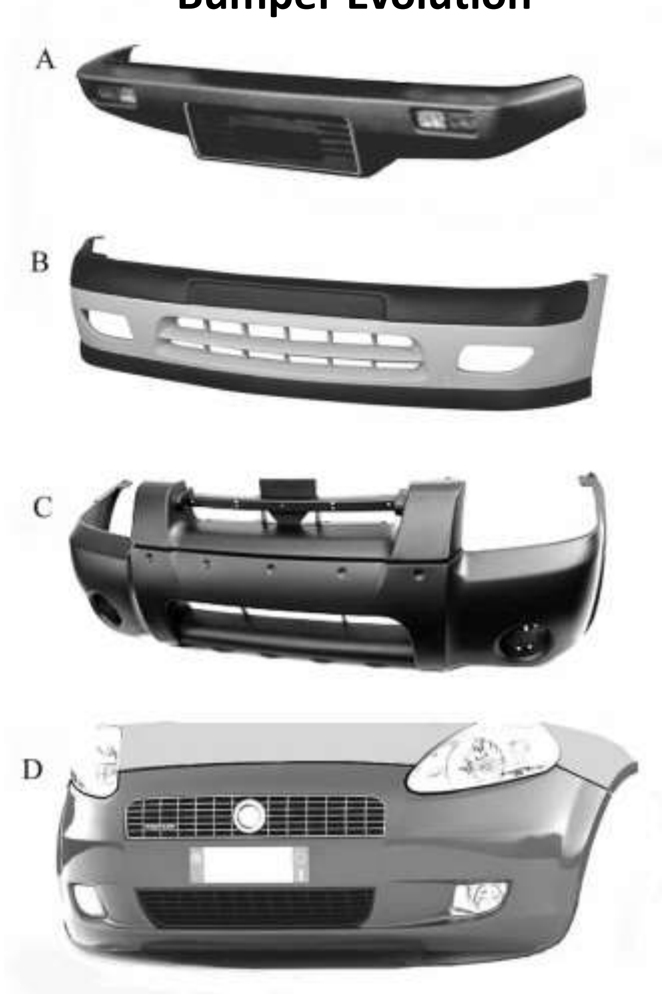
- Front and rear end of vehicles should be able to **absorb energy**.
- The **stiffness** of body parts committed to energy absorption **should increase as the passenger cabin is neared**.

Current design practice is for the bumper structure on modern automobiles to consist of a plastic cover over a reinforcement bar made of steel, aluminium, fiberglass composite, or plastic.

Bumper

- Bumpers are increasingly being designed to mitigate injury to pedestrians struck by cars, such as through the use of bumper covers made of flexible materials.
- Front bumpers, especially, have been lowered and made of softer materials, such as foams and crushable plastics, to reduce the severity of impact on legs.
- The bumper of today is really an integrated body part (even made of a different material, despite being body coloured).

Bumper Evolution



Tp – Thermoplastic
Ti – Thermosetting plastic

STEP	Years	plastic type	absorption insert	color: mass	color: painted	Fig.
1	70	Tp/Ti	no	x	specif	A
2	80-90	Tp>Ti	yes/no	x	grey	B
3	90-2000	Tp>>Ti	yes	x	as body	C
4	>2000	Tp	yes		as body	D

Bumper

The main bumper tasks include the following:

- aesthetics;
- overall body protection in parking impact (up to a speed of 4 km/h) or according to individual State safety rules;
- energy absorption and controlled transfer of stress to body frame, when impacted at 15 km/h (*insurance impact test*);
- aerodynamics;
- friendly contact (or absence of injury) in case of pedestrian's impact;
- support of winches or tow hooks for off-road vehicles

Bumper

Aesthetics

- Bumper shape, gaps with respect to adjacent parts (lamps, fenders, radiator grille, bonnet), color, roughness (skin grain) are properties relevant to the aesthetics of the vehicle
- Skin radius must comply with the regulation limit of > 2.5 mm (in some areas > 5 mm) for all surface points that can be contacted by a 100 mm sphere.
- Most zones with high risk of contact such as bumper fascia are left grey or black (mass color) in order to keep any abrasion or surface marking less evident.

Bumper

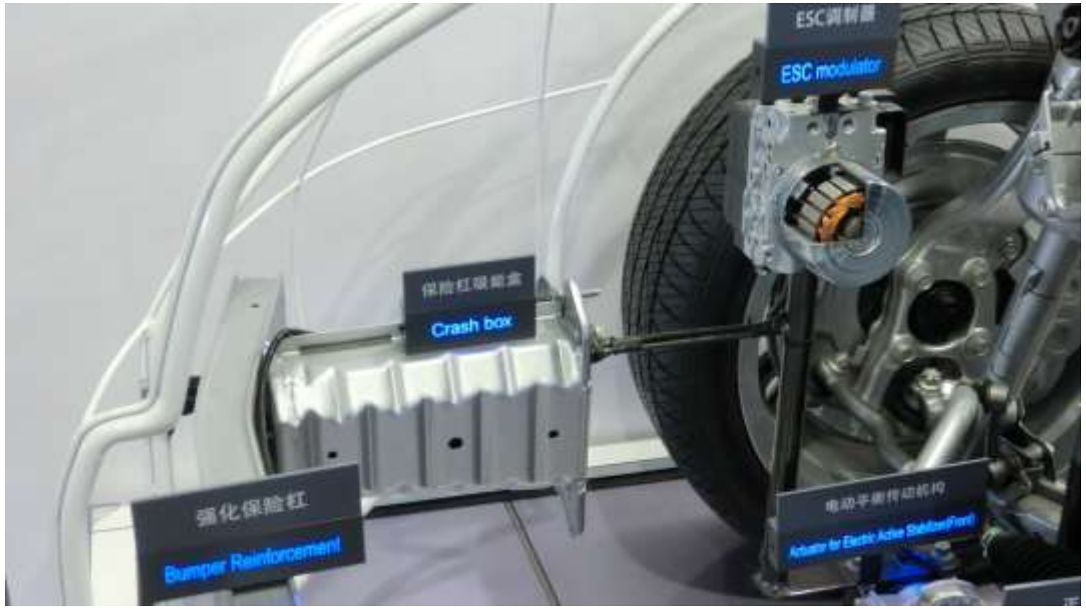
Protection in low speed crash

- Bumpers, both front and rear, must avoid permanent functional damage to the vehicle when impacted by a pendulum of mass equal to the vehicle curb weight, in three different transverse position and at a height of 445 mm from the ground.
- Front car behavior must be tested also in a barrier crash at 4 km/h speed: in such conditions some minor damage is allowed, but the vehicle must still be able to operate.

Bumper

Repair Cost Reduction

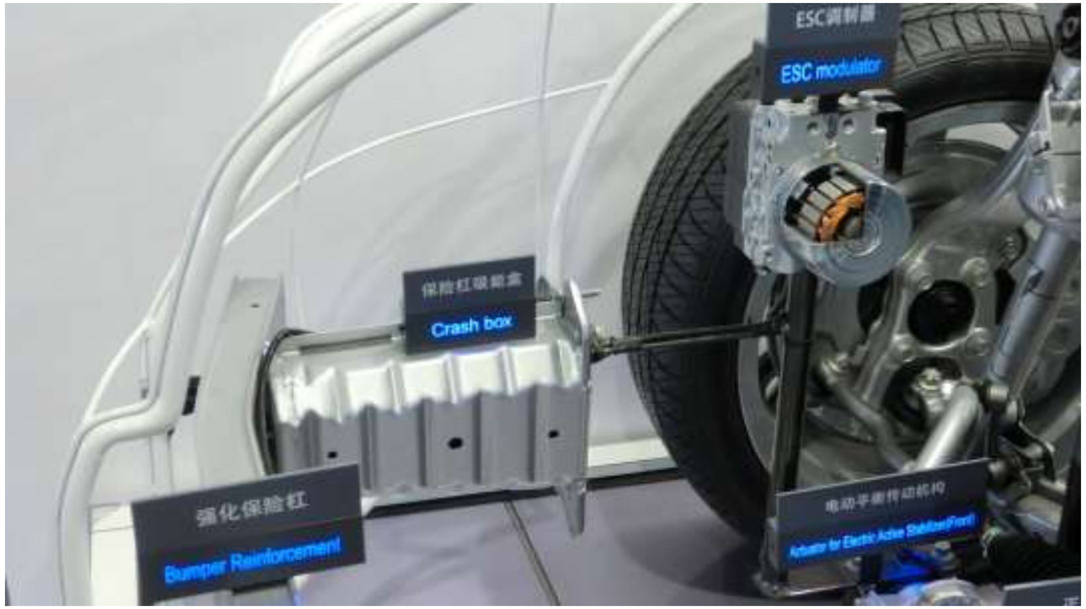
- Repair requires not only replacement of the part, but even the complete removal of the power train and accessories in order to reshape or replace the deformed body frames.
- It must be remembered that parts reshaped by stretching, hammering and welding no longer exhibit their original strength.
- To solve this issue either a metal or composite bar between the bumper and the body is provided, called as crash boxes.



Bumper

Repair Cost Reduction

- This member provides support and reaction to the bumper over a wide surface (through a plastic, high-density foam insert, dimensioned for a 4 km/h impact).
- On the other side, the same member is screwed or welded to high efficiency absorbing devices (offering a high mean collapse load to maximum load ratio), located between the bumper bar and the body rails.

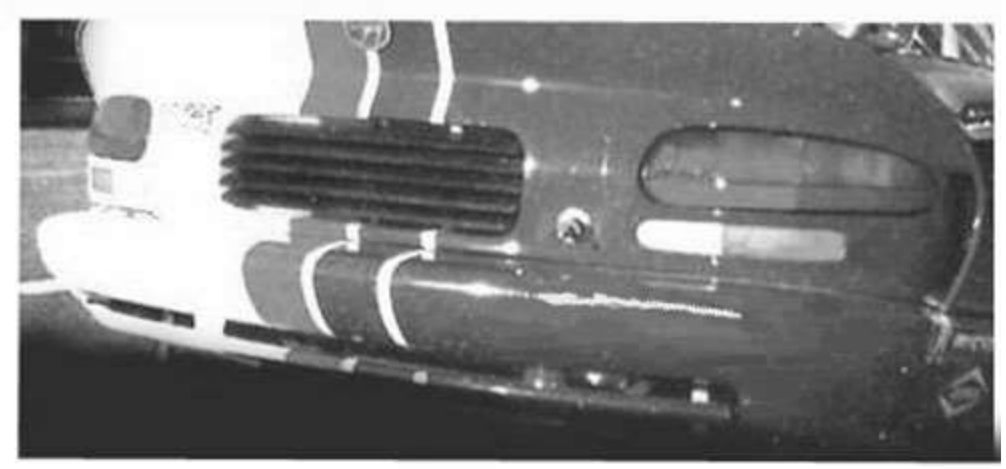


Bumper

Aerodynamics

Bumpers influence

- Lift and drag
- Air extraction for engine and underbody
- Features an air dam to accelerate the air flow in the underbody
- Sometimes, the rear bumper features air extraction from the underbody area to both control the wake and induce a reduction in rear pressure and consequently rear lift .



Bumper

Common processes and materials

- High pressure injected thermoplastic material used
- High flexibility implies less damage to vehicle as well as pedestrians in case of low speed impacts
- Good moldability facilitates manufacture of all shapes for aesthetics and aerodynamics.
- High flexibility makes mold extraction from the die easier

Bumper

Common processes and materials

- Polyolefin are used for most applications - lower cost and substantially adequate properties in each of the salient tests (impact, chemical and aging resistance, moldability, paintability)
- A persistant problem for all thermoplastics is the presence of unevenness or waviness on flat surfaces, due to cooling after moulding and aging under load (*creep*).
- Reduced by using ribs which must be very thin (otherwise sink marks can arise) or support metal blades can be snapped on to the bumper.
- Regarding energy absorbers for low speed crash, foam inserts (polyurethane or polypropylene or polystyrene) are used.