Vehicle Chassis Analysis: Load Cases

[1]Muruganandam.D, [2]Alexander Atoney Raj
[1]Professor, [2] UG Student
[1,2]Department of Mechanical Engineering,
[1,2]Jeppiaar Institute of Technology, Tamil Nadu. India

Abstract— The current work contains the load cases & boundary conditions for the stress analysis of chassis using finite element analysis over ANSYS. Shell elements have been used for the longitudinal members & cross members of the chassis. The advantage of using shell element is that the stress details can be obtained over the subsections of the chassis as well as over the complete section of the chassis. Beam elements have been used to simulate various attachments over the chassis, like fuel tank mountings, engine mountings, etc. Spring elements have been used for suspension & wheel stiffness of the vehicle.

I. INTRODUCTION

After years of steady, predictable model changes, the automobile industry is in the midst of the most intense product changeover in its history. To accomplish the need to design a moderate car, the structural engineer will need to use imaginative concepts [1]. The demands on the automobile designer increased and changed rapidly, first to meet new safety requirements and later to reduce weight in order to satisfy fuel economy requirements.

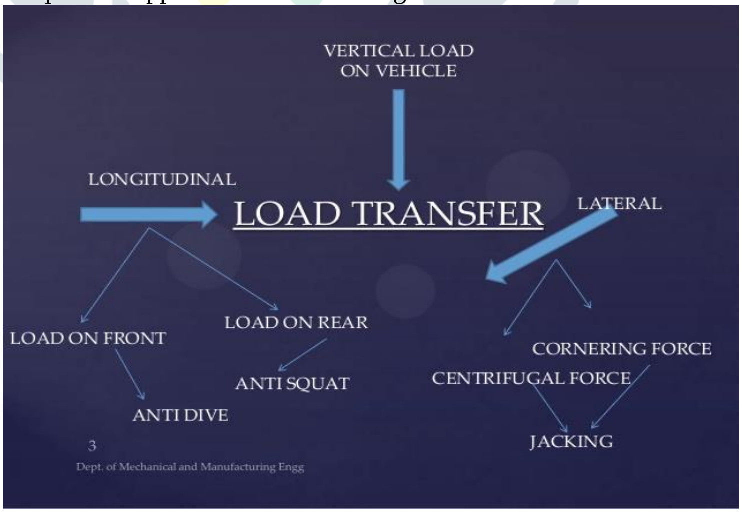
Until the 1930's every motor vehicle had a structural frame, separate from the car's body. This construction design is known as *body-on-frame* since then, all passenger cars received unibody construction, meaning their chassis and bodywork have been integrated into one another. The last UK mass-produced car with a separate chassis was the *TRIUMPH HERALD*, which was discontinued in 1971. However all trucks, busses, continue to use a separate frame as their chassis [2]. As a result, some observers argue that first true automobile was gasoline powered. Nicolas-joseph cugnot, a French military engineer who in 1769 built a steam powered tricycle for hauling artillery. Vehicle's single front wheel performed both steering and driving functions, and it could travel 2.25miles per hour with 4 passengers aboard for about 15 minutes [3]. later the two men, *KARL FRIEDRICH BENZ* and *GOTTLIEB DIAMLER* who had never met previously but filed their patents on the same day- JANUARY 29,1886-in two different German cities. Benz's three wheeled vehicle, was first drove in 1885 and while Diamler's motorized carriage was the world's first four-wheeled automobile and featured the high speech-gasoline engine.

EXPERIMENT

A chassis consist of an internal framework that supports a manmade object in its construction and use. An example of chassis is the underpart of a motor vehicle, consisting of frame.

In case of vehicles, the term rolling chassis means the frame and with addition of "running gears" like engine, transmission, drive shaft, and suspension. For commercial vehicles, a rolling chassis consists of an assembly of all the essential parts of a truck to be ready for operation on the road (without the body).[1]. Design of a pleasure car chassis will be different than one for commercial vehicle because of the heavier loads and constant work use.[4].

Mathematical modeling was therefore a logical avenue to explore. Most recently, the finite element method, a computer dependent numerical technique, has opened up a new approach to vehicle design.

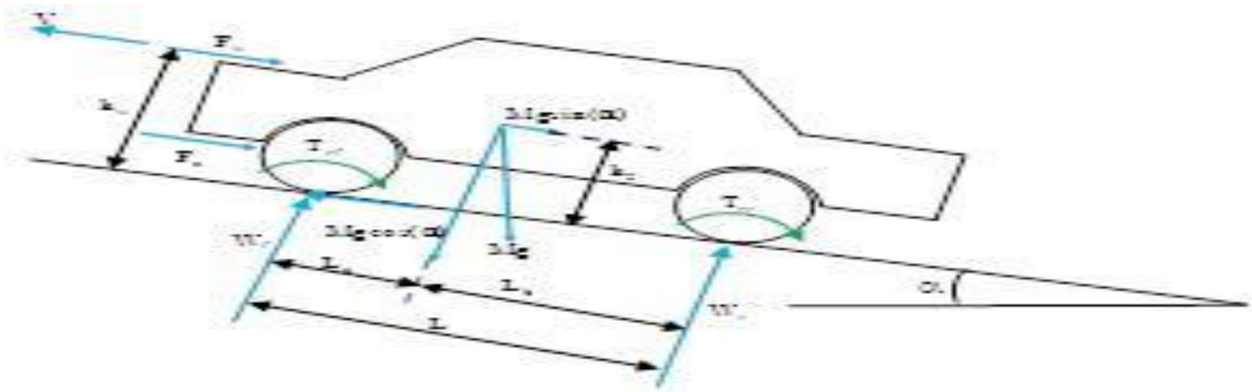


LOAD CALCULATIONS:

Adequate durability under dynamic conditions is a design requirement for the vehicle structures, the static load cases cannot be disregarded. The values for the individual load cases are taken from the expected service conditions of the particular vehicle.

The factors usually applied to the static load case, especially for those vehicles with a long overhang containing concentrated loads (e.g., rear engine buses).Such loads result in high bending moments over the rear axle. The various dynamic conditions considered here for the determination of the axle loads are considered below.

- **LOADS ON GRADES:**



The influence of the grade on the axle loads is worth considering. On primary and secondary loads, grade angle θ is as high as 6.842 deg. For the front axle, taking moment about front axle wheel at ground

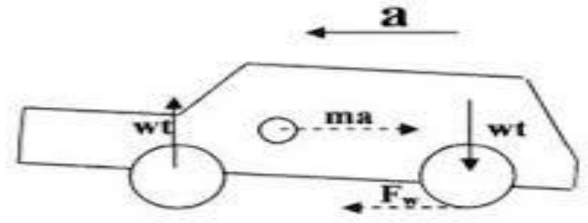
$$M_r \times L = M_t \, Cos\, \theta \times L_f \,.\, M_t \, Sin\, \theta \times H$$

The above equation gives the weight on the rear axle on grades, through which increase in weight (ΔM_g) on the rear axle due to grade can be calculated. Similarly the loads shift on negative grade can also be calculated.

In physics, when frictional forces are acting on a sloped surface such as a ramp, the angle of the ramp tilts the normal force at an angle. When you work out the frictional forces, you need to take this fact into account.

Normal force, N, is the force that pushes up against an object, perpendicular to the surface the object is resting on. The normal force isn't necessarily equal to the force due to gravity; it's the force perpendicular to the surface an object is sliding on. In other words, the normal force is the force pushing the two surfaces together, and the stronger the normal force, the stronger the force due to friction.

- **LOW SPEED ACCELERATION:**



Car under acceleration

Acceleration is typically a derived value, calculated from consecutive speed measurement data. Systems that tap into the vehicle speed sensor can monitor speed at 2-10 Hz, providing high-resolution calculations of acceleration values based upon consecutive speed readings taken faster than once per second.

GPS-based systems record satellite signal-derived speed readings once per second. Because acceleration is calculated, acceleration values can differ depending upon the acceleration calculation method used.

Assuming the vehicle is accelerating on the level ground from the low speed, then the inertia force will act against the direction of acceleration, the load on the axles are calculated by taking moments

$$M_f \times L = M_t \times L_r - (a \times M_t \times H) / g$$

Through the above equation the change in loads due to acceleration (ΔM_a) on wheels can be calculated.

- **BRAKING:**

Full braking is the greatest load to which a forward securing arrangement is exposed. Recent developments in the field of truck tires, coupled with modern brake systems and asphalt roads, permit braking deceleration values that are perfectly capable of approaching 0.8 g . Other factors, such as the distribution of axle weights, also play a role in this context.

During full braking, the following forces act forwards on the cargo in the coordinate system of the loading area (parallel to the loading area):

- inertial force component from the braking maneuver,
- downhill force (weight component) arising from the geodetic inclination of the loading area (pitching angle and gradient of road),
- inertial force arising from tangential acceleration from superimposed pitching oscillation.

The normal force acting from the cargo on the loading area is generally reduced by two causes, namely, as a result of the inclination of the loading area, by the

- upwardly directed vertical component of the inertial force,

- ❖ reduced normal component of the weight-force.

The vehicle under consideration is the N_2 category vehicle. For the N_2 category of the vehicle, under P-F type of test, mean retardation (D) ≥ 6 m/sec^2. Due to this retardation the change of the axle loads is,

$$\Delta M_{br} = (H \times M_t \times D) / (L \times g)$$

- ➢ **STEADY STATE CORNERING**:

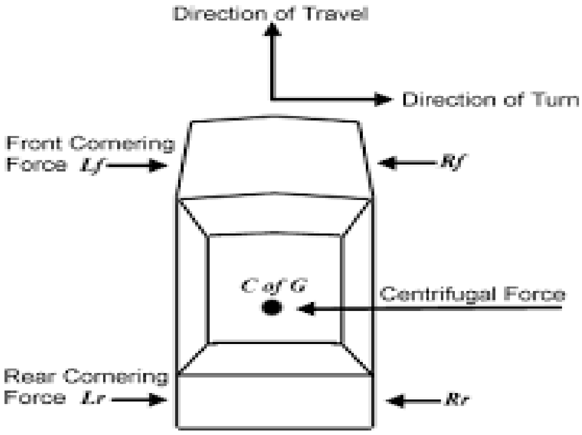
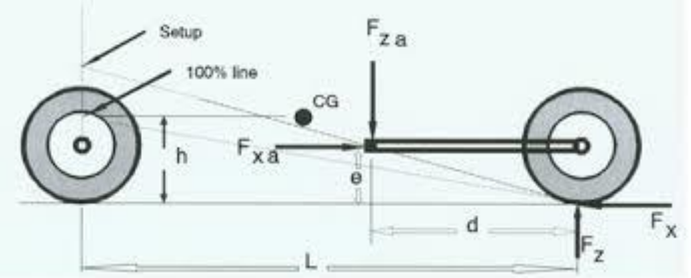


fig. 2

Roll center of a suspension system is that point, in the transverse plane axis about which the sprung mass of that end of vehicle will roll under the influence of centrifugal force.
It is sort of geometrical balance point. It is also a point through which the lateral forces transmitted from the tire's contact patches act upon the chassis.
Lateral forces act on the at the Roll Center of vehicle during cornering. A line joining the roll centers of the suspensions is roll axis. The lateral separation between the suspensions causes them to develop roll resisting moments proportional to the difference in the roll angle between the body and the axle.

$$K_\phi = 0.5 \times K_s \times s^2 \text{ Kgf mm/rad}$$

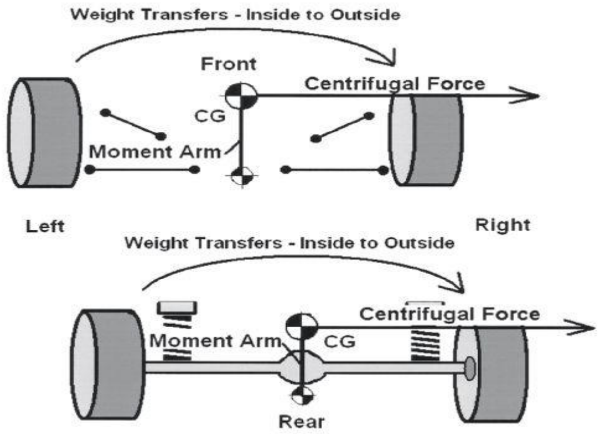
- ➢ **ANTI-DIVE AND ANTI-SQUAT GEOMETRY:**



Anti-dive and anti-lift are tricks that can be applied to a truck's front suspension geometry to control brake drive and acceleration lift

- ❖ As the wheel moves, the upright tends to move with the wheel. But since the upright is rigidly mounted, it tends to neglect the torque. As a result, when accelerating, there is a forward thrust, on lower A-arm and upper A-arm will be pulled in reverse direction.
- ❖ As the IC is in front of COG and slightly above it, the rear and end squat will be reduced and the front end will rise higher due to more weight shifted to rear part.
- ❖ Changing the upper control arm offset negates the lifting force created.
- ❖ This will result in less rise of the front end and less weight would be transferred to the rear.

- ➢ **LATERAL LOAD TRANSFER**:



- ❖ Lateral load transfer is caused by forces very similar to those which cause longitudinal transfer-with the operating axis turned ninety degrees.
- ❖ In any cornering situation, centrifugal force, acting through the vehicles., tends to throw the car out at tangent to its intended path.
- ❖ This centrifugal force is resisted by lateral forces developed by the tires.
- ❖ Hence lateral load transfer is a bad thing. The transfer of load from one tire of a pair to the other reduces total attractive capacity of pair.
- **LATERAL LOAD TRANSFER(lb)=**
  {Lateral acceleration(g)*Weight(lb)*C.G. Height(inch)}/Track Width(inch)

- **RESULT AND DISCUSSION:**

As it is clear that ,vehicle load transfer has got an expensive application in design of vehicle.
Hence study of Vehicle Load Transfer can help us to achieve optimum configuration of the suspension system, steering system and the Static Load Distribution in our Vehicle.
It is necessary to use the detailed model of the structure for analysis of the vehicle chassis. It becomes even more necessary, when the center of gravity of the vehicle is towards left or right of the central plane of the vehicle.
Loads for various load cases have been calculated, then checked with the measured loads & then loads for load combination cases have been calculated on all the wheels.

- It is impossible to cover all the conditions for the analysis of the vehicle on road conditions, however the above-mentioned boundary conditions can be used as the starting analysis for the stresses in the vehicle.
- **NOMENCLATURE:**

Sr. No.	NOTATION	DESCRIPTION	UNIT
01	A	Acceleration	m/sec
02	ΔFzfr	Load Transfer on Front Right Wheel (due to cornering)	Kgf
03	ΔFzfr	Load Transfer on Rear Right Wheel (due to cornering)	Kgf
04	G	Acceleration due to Gravity	m/sec
05	H	Height of the Center of Gravity of the Vehicle From the Ground	M
06	Hf	Height of the Roll Center at the Front Axle	M
07	Hl	Height of the CG above Roll Center of the Vehicle	M
08	Hr	Height of the Roll Center of the Rear Axle	M
09	Hu	Height of the Bump	Mm
10	Ks	Vertical Stiffness of the Suspension	Kgf/mm
11	Kϕ	Roll Stiffness of the Suspension	Kgf mm/rad
12	Kϕf	Roll Stiffness of Front Suspension	Mm/rad

13	Kϕr	Roll Stiffness of Rear Suspension	Kgf mm/rad
14	L	Wheel Base of the Vehicle	M
15	Lf	Distance of Center of Gravity of the Vehicle From Front Axle	M
16	Mf	Weight on the Front Axle of the Vehicle	Kgf
17	Mr	Weight on the Rear Axle of the Vehicle	Kgf
18	Mt	Total Weight of the Vehicle	Kgf
19	Mfl	Weight on the Front Left Wheel	Kgf
20	Mrl	Weight on the Rear Left Wheel	Kgf
21	Mrr	Weight on the Rear Right Wheel	Kgf
22	R	Radius of the turn	M
23	S	Lateral Separation Between Suspensions	Mm
24	T	Track Width of the Vehicle	M
25	V	Velocity	m/sec
26	Θ	Grade Angle	Degrees
27	A	Road Bank Angle	Degrees

- **REFERENCES:**

[1]. Ashutosh Dubey and Vivek Dwivedi., Vehicle Chassis Analysis: Load Cases and boundary conditions for stress analysis.

[2]. Starry,Donn A. vietnam studies; Department of army, washington, D.C. 1978. Association of Licensed automobile manufacturers (U.S) (1992). Official handbook of automobiles.

[3].H J Beermann, The Analysis of Commercial Vehicle Structures, Verlag TUV Rheinland GmbH Koln-1989.

[4]. Johanssan & S, Eslund, Optimization of Vehicle Dynamics in Truck by use of Full Vehicle FE Models, I.Mech.E.-C466/016/93, pp 181-193,1993

5. John Fenton, Handbook of Automotive Body Construction & Design Analysis, Professional Engineering Publishing-1998.