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Crash Analysis Of Car Chassis Frame Using Finite Element Method

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ABSTRACT

Vehicle crash is a highly nonlinear transient dynamics phenomenon. The purpose of a crash analysis is to see how the car will behave in a frontal or sideways collision. Crashworthiness simulation is one typical area of application of Finite-Element Analysis (FEA). This is an area in which non-linear Finite Element simulations are particularly effective.

In this project impacts and collisions involving a car frame model are simulated and analyzed using ANSYS software. The chassis frame forms the backbone of a heavy vehicle; its principle function is to safely carry the maximum load for all the designed operating conditions. The frame should support the chassis components and the body. It must also withstand static and dynamic loads without undue deflection or distortion. The given model is tested under frontal collision conditions and the resultant deformation and stresses are determined with respect to a time of 80 Mille sec for ramp loading using ANSYS software.

The crash analysis simulation and results can be used to assess both the crashworthiness of current frame and to investigate ways to improve the design. This type of simulation is an integral part of the design cycle and can reduce the need for costly destructive testing program.

Introduction

In automobile design, crash and structural analysis are the two most important engineering processes in developing a high quality vehicle. Computer simulation technologies have greatly enhanced the safety, reliability, and comfort, environmental and manufacturing efficiency of today's automobiles. This significant achievement was realized with the advanced software and powerful computers that have been available in the last twenty years.

The primary concern for drivers and passengers is safety. Governments have responded to this key concern and expectation with an increasing number of regulations. Although the details may vary slightly from country to country, the fundamental requirements are almost similar. A vehicle is expected to provide adequate protection to drivers and passengers in a not so serious accident. To protect the occupants of a car, there are many new tangible safety features such as airbags; ABS control brakes, traction control.

A less tangible feature that cannot easily be seen by drivers and passengers is the crash response behavior. In a well designed automobile, the car body and various components are the protective layer for the occupants of the vehicle. They serve as the crumpling zone to absorb the energy of impact. The traditional approach involves multiple iterations of design, prototype and crash tests. The process is time consuming and expensive. The availability of high performance computers and crash simulation software has revolutionized the process. Instead of relying on experimental validations, the safety design process is supplemented with computer simulation to evaluate the design. Since the inception of crash simulation, the product cycle of a new automobile has been reduced by half and the resultant vehicle is safer, better and more comfortable.

Crash Simulation Evolution

Year	Regulatory Requirements	FE Model Size (elem)	Prototypes Reqd (cars)
1985	1	10000	150
1990		20000	120
1995	5	80000	100
2000		0.5M	50
2005	20	1M	20

Reduce Injuries & Fatalities
Made possible by supercomputers
Significant cost savings

In the present thesis an attempt has been made to

(i) To investigate the deflection and stresses in a chassis using static analysis

(ii) (ii) To see the transient response of a car frame under crash simulation

Frame structure

Safety engineers design and manufacture vehicle body structures to withstand static and dynamic service loads encountered during the vehicle life cycle. The vehicle body provides most of the vehicle rigidity in bending and in torsion. In addition, it provides a specifically designed occupant cell to minimize injury in the event of crash. The vehicle body together with the suspension is designed to minimize road vibrations and aerodynamic noise transfer to the occupants. In addition, the vehicle structure is designed to maintain its integrity and provide adequate protection in survivable crashes.

The automobile structure has evolved over the last ten decades to satisfy consumer needs and demands subject to many constraints. Among these constraints are materials and energy availability, safety regulations, economics, competition, engineering technology and manufacturing capabilities. Current car body structures and light trucks include two categories: body-over-frame structure or unit-body structure**.** The latter designation includes space-frame structures.

Unibody Construction: Most vehicles today are manufactured with a Unitized Body/Frame (Unibody) construction. This is a manufacturing process where sheet metal is bent and formed then spot welded together to create a box which makes up the structural frame and functional body of the car. These vehicles have "crumple Zones" to protect the passengers in case of a collision.

Body-on-Frame Construction: Most heavy duty trucks and a few premium full-size cars are still manufactured with a body-on-frame construction. This is a manufacturing process which a weight-bearing

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frame is welded together and then the, engine, driveline, suspension, and body is bolted to the frame.

In an accident, the Unibody frame is designed to "crumple" and absorb the energy of an impact better than a Body-on-Frame construction.

The chassis frame supports the engine, transmission, power train, suspension and accessories. In frontal impact, the frame and front sheet metal absorb most of the crash energy by plastic deformation. The three structural modules are bolted together to form the vehicle structure. The vehicle body is attached to the frame by shock absorbing body mounts, designed to isolate from high frequency vibrations. Unibody vehicles combine the body, frame, and front sheet metal into a single unit constructed from stamped sheet metal and assembled by spot welding or other fastening methods. The construction of the unit body structure, also known as unit-frame-and-body or frame-less body, is claimed to enhance whole vehicle rigidity and provide for weight reduction.

Materials used

Most auto bodies today use stamped sheet as structural members that are spot welded together to form a unitized body. This unitized structure is called the body-in white (BIW). BIW structural members support most of the loads designed for strength, fatigue resistance, stiffness, as well crush loads for crashworthiness.

Material properties of steel

Property	Nomenclature	Value
Young's modulus	EX	200000 N/mm^2
Density	DENS	7800 kg/mm^3
Poisson's ratio	NUXY	0.3
Ultimate strength	UT	340-2100 MPa

CRASHWORTHINESS TESTS CRITERIA AND MODEL REQUIREMENTS In the automotive industry, crashworthiness connotes a measure of the vehicle's structural ability to plastically deform and yet maintain a sufficient survival space for its occupants in crashes involving reasonable deceleration loads. Restraint systems and occupant packaging can provide additional protection to reduce severe injuries and fatalities. Crashworthiness evaluation is ascertained by a combination of tests and analytical methods.

Currently vehicle crashworthiness is evaluated in four distinct modes:

- Frontal
- Side
- Rear
- Rollover crashes

Types of crash tests**:** All cars undergo front- and side-impact testing, which includes

- 64kph (40mph) Front impact test: to assess car's performance in severe accident
- 50kph (30mph) Side impact test
- 29kph (18 mph) optional Pole impact test: to driver's head
- 40kph (25mph) child and adult pedestrian impact tests ***Crash Tests - Regulatory Rules***

The following are the requirements for the consumer rash tests conducted by

- Federal Motor Vehicle Safety Standard (FMVSS)
- Insurance Institute for Highway Safety (IIHS)

FMVSS Frontal impact requirements:

- 30 mph (48kph) into a fixed barrier
- Hybrid III in front driver and passenger seats
- Uses dummy injury measures for regulation
  - chest G's <= 60
  - HIC <=1000
  - Femur loads <= 10KN
- Protection must be automatic
- Purpose of this test is to examine the performance of the occupant restraint systems (seatbelts, airbags, etc.)

IIHS Frontal impact requirements:

- 40% offset, 40 mph (64kph) into a deformable barrier
- Male Hybrid III dummy in front driver seat
- Good, Acceptable, Marginal and poor ratings to assess vehicle's overall crashworthiness
- Rating based on:
  - dummy injury measures
  - structural performance
  - restraint/dummy kinematics
- Evaluates the structural performance of the vehicle

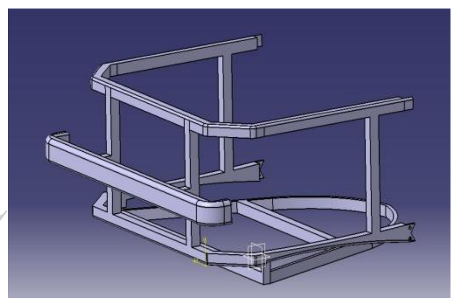
FMVSS Side impact requirements:

- 33.5 mph (54kph) crabbed impact
- Impact or mass 1367.6 kg (3015lb)
- uses SID dummy in front and rear seats
- uses dummy injury measures for regulation
- TTI(d) <= 85g for 4 door passenger cars
- TTI(d) <= 90g for 2 door passenger cars
- pelvic acceleration <= 130g
- Where TTI(d) = 0.5 x (Gr + Gs)
  - Gr = Max. Rib acceleration
  - Gs = Lower spine acceleration

IIHS Side impact requirements:

- impactor mass = 1500 Kg
- impactor shape derived from Ford F150 front profile
- 30 mph perpendicular impact
- driver and rear passenger dummies
- purpose is to represent crash type that poses greatest risk to occupants (pickups/SUV as striking vehicle)promote head protection

Modelling and meshing of chassis

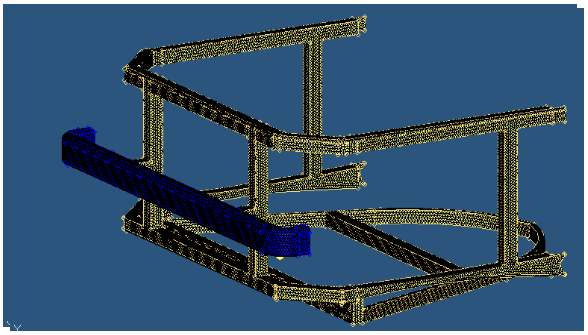


CATIA model of car front part

Element Description

Solid45 is used for the 3-D modeling of solid structures. The element is defined by eight nodes having three degrees of freedom at each node: translation in the nodal x, y, and z directions .The element has plasticity, creep, swelling, stress stiffening, large deflection, and large strain capabilities. A reduced integration option with hourglass control is available

Shell63 has both bending and membrane capabilities. Both in-plane and normal loads are permitted. The element has six degrees of freedom at each node: translations in the nodal x, y, and z directions and rotations about the nodal x, y, and z-axes.



Final mesh of a car frame

From the hyper mesh software we can observe following in our model

- The total number of elements is **133758**
- The total number of nodes is **40374**

For 3Delements

- The maximum aspect ratio is 7.29
- Minimum interior angle is 4.61
- Maximum interior angle is 156.25
- Minimum jacobian is 1

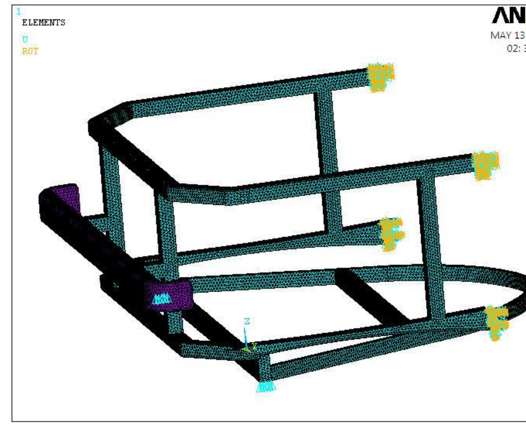
For 2Delements

- Maximum aspect ratio is 4.84
- Minimum jacobian is 1
- Minimum interior angle 13.84
- Maximum interior angle is 141.07

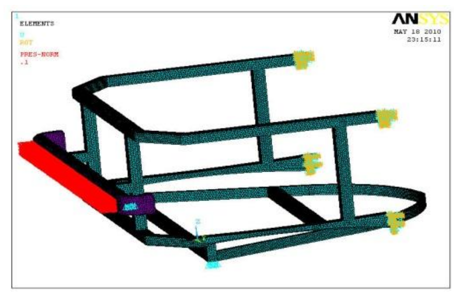
Types of Analysis Used

The following analysis has been carried out

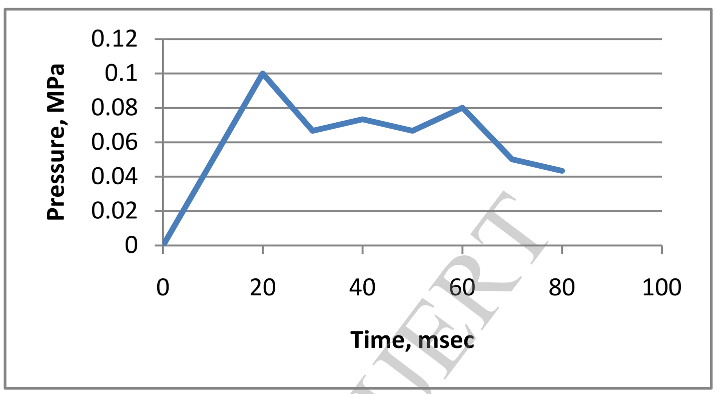
- Static
- Modal
- Transient



Car Frame with Imposed Boundary Conditions



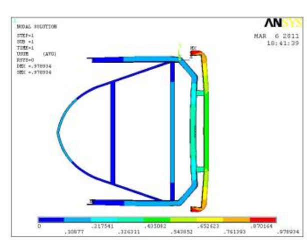
Car frame with load and imposed boundary conditions



Variation of Pressure against Time

RESULTS AND DISCUSSION

Results for Static Analysis: From the static analysis the deflections and stresses are obtained in the bumper under a load of 0.1MPa.



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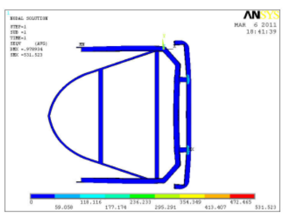
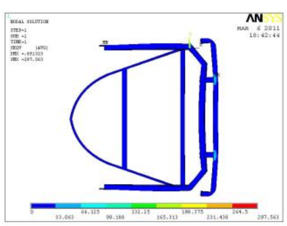
Vector plot of deformation for shell thickness 3mm under static load

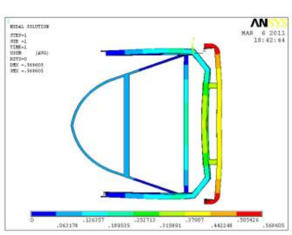
From the above figure it is observed that that the maximum deflection is 0.978934mm for the bumper made of thickness 3mm at the point which is indicated as MX which is at node 63982.The minimum deflection is obtained at the constrained points which are are indicated as MN.



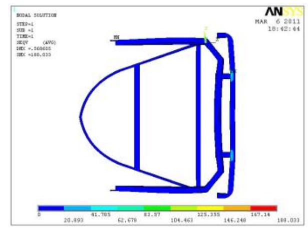
Vector plot of Von-mises stress for shell thickness 3mm under static load



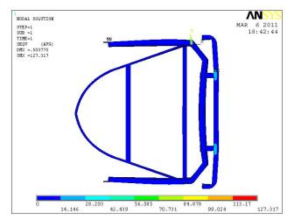
Vector plot of deformation for shell thickness 4mm under static load



Vector plot of Von-mises stress for shell thickness 4mm under static load



Vector plot of deformation for shell thickness 5mm under static load



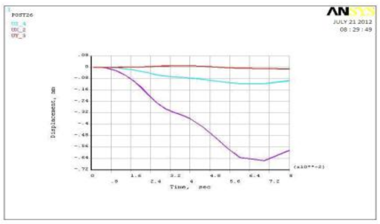
Vector plot of Von-mises stress for shell thickness 5mm under static load

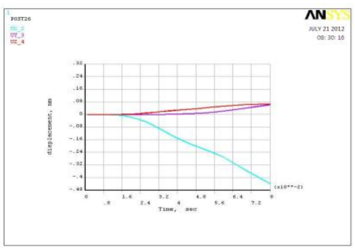
Results for Modal Analysis: The modal analysis of the car frame is carried out to estimate the natural frequencies and corresponding mode shapes for the structure of car frame. The table gives the first ten natural frequencies of the model with different thickness of the shell of the bumper of an automobile, which varied from 3mm to 6mm.

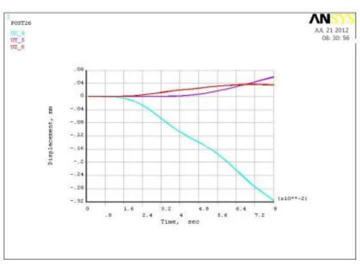
Natural Frequencies of Car Frame by Varying Thickness of the Bumper

Mode No	Natural Frequencies, Hz			
	Bumper Thickness, mm			
	3	4	5	6
1	0.531657	0.526162	0.520871	0.51576
2	0.587794	0.587785	0.587776	0.587768
3	1.236	1.232	1.228	1.224
4	1.729	1.695	1.663	1.633
5	2.144	2.141	2.137	2.132
6	2.458	2.43	2.39	2.341
7	2.502	2.48	2.472	2.466
8	2.682	2.682	2.681	2.68
9	2.929	2.925	2.92	2.914
10	3.131	3.12	3.103	3.085

Results of transient dynamic analysis:







CONCLUSIONS AND FUTURE SCOPE OF WORK : The following conclusions are drawn from the present work

1. The deflection of the bumper is varying from 0.503577mm to 0.978934mm for various thickness of bumper under applied load condition, which is rigid. Hence based on the rigidity the design is safe.
2. By increasing the bumper made of thickness the stress induced are reduced from 531.523MPa to 127.317MPa. Hence the bumper design is safe based on strength criteria.
3. The natural frequencies estimated for various thicknesses are very low as the structure is stationary.
4. When the impact takes place on the bumper, the maximum amplitude is 0.7611mm under transient loading. This value is very less than 2.8mm as per the **Ford Motor Vehicle Design Test (FMVDT)**. Hence the bumper design is safe based on dynamic conditions.

Future Work: The bumper of a car can be

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made as sandwich model or springs can be placed in the bumper in order to reduce the impact that is transferred to the passenger compartment. Analysis of these designs can be done which may yield to better safety. These designs may also reduce the weight of the bumper leading to **increase** fuel efficiency.

REFERENCES

[1] Lonny L.Thompson, et al, Clifford C. Chou, Bahig B. Fileta, Tawfik B. Khalil, Albert King, Hikmat F. Mahmood, Harold J. Mertz, Jack Wismans, Vehicle Crashworthiness and Occupant Protection, Sponsored by: Automotive Applications Committee, American Iron and Steel Institute, Southfield, Michigan. 2001.

[2] Oijier, F., "Development and Validation of High Fidelity Vehicle Crash Simulation Models,"

[3] Cicek karaoglu et al., Stress analysis using riveted joints, International Symposium on Heavy Vehicle Weights & Dimensions, Delft, NL

[4] Tso-Chien Pan et al, "Dynamic Vehicle Element Method - Present and Future Developments," The International Conference on Vehicle Structural Mechanics.

[5] Arborio.N.,et al, Future trend of automobile and the high strength sheet steel. Tetsu-to-Hagane. vol. 68, no. 9, Japan 1982.

[6]Narender "Bumper beam-longitudinal system subjected to offset impact loading"