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REVIEW ON FE ANALYSIS FOR CRASHWORTHINESS OF FORD F250 FOR FRONTAL IMPACT

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ABSTRACT

The objective of this paper is to enhance crashworthiness characteristic involved in frontal crash of an automobile according to FMVSS 208. Crashworthiness analysis involves highly non linear transient dynamic problem with large deformation of thin shell structure, elastic plasticity, surface contacts etc. It is an important issue to ensure passenger safety and reduce vehicle costs in the early design stage of vehicle design.

This report also shows materials and material properties of the components which are used in crash tests. Finite-element computer models were used to test crash characteristics of vehicle. The model was based on a 2006, 4-door, Ford F250 Pick-up truck was developed at FHWA/NHTSA National Crash Analysis Centre.

The software used for the analysis is LS-DYNA. It is widely used by the automotive industry to analyze crash behavior of vehicle in a collision.

Keywords: ***Crashworthiness, Collapse mode, FMVSS 208, Frontal Impact, FE model details, Materials Properties.***

1. INTRODUCTION

Finite element models of vehicles have been increasingly used in preliminary design analysis, component design, and vehicle crashworthiness evaluation, as well as roadside hardware design. As these vehicle models are becoming more sophisticated over the few years in terms of their accuracy, robustness, fidelity, and size, the need for developing multipurpose models that can be used to address safety issues for a wide class of impact scenarios becomes more apparent. The crash event is a severe and complicated phenomenon due to the complex interactions between structural and internal behavior. Crashed structures usually experience buckling deformation high strain rate effects, fractures, and rapid structural unloading. This leads to highly transient response arising from non-linear stiffness and viscous characteristics of the crushed materials. One of the most important engineering parameters that engineers employ in crashworthiness is the energy absorption. This energy is used as a quantified measure to assure that the high impacts are sustained and absorbed by the structure without affecting passenger compartment.

The finite element method is comprised of three major phases: (1) *pre-processing*, in which the analyst develops a finite element mesh to divide the subject geometry into sub-domains for mathematical analysis, and applies material properties and boundary conditions, (2)*solution*, during which the program derives the governing matrix equations from the model and solves for the primary quantities, and (3) *post-processing*, in which the analyst checks the validity of the solution, examines the values of primary quantities (such as displacements and stresses), and derives and examines additional quantities (such as specialized stresses and error indicators).

2. FEDERAL MOTOR VEHICLE SAFETY STANDARD (FMVSS) NO. 208

The National Highway Traffic Safety Administration (NHTSA) strives to establish test procedures in regulatory requirements that lead to improvements in real world safety, often in connection with performance standards. In Federal Motor Vehicle Safety Standard (FMVSS) No. 208, “Occupant Crash Protection,” a rigid barrier crash test was applied. Historically, this test has applied to both belted and unbelted 50th percentile male anthropomorphic dummies for impact conditions from 0 to 48 kmph and impact angles from 0 to 30 degrees. As a result of problems of injuries and fatalities associated with air bags and out-of-position child passengers, out-of-position adult drivers (usually unbelted), and infants in rear-facing child safety seats, NHTSA published a final rule on March 19, 1997, that temporarily amended FMVSS No. 208 to facilitate the rapid redesign of air bags so that they inflate less aggressively.

3. FRONTAL IMPACT

Frontal impact can be realized in two stages: In the first stage, the vehicle strikes a barrier or another vehicle which causes front to end crush and the kinetic energy is dissipated into deformation of the structure. In the second stage, the occupant continues to move freely against the interior if not restrained, or interacts with restraint system, if restrained. The kinetic energy is then transformed into interior deformation of the structure and injuries to the occupant's body. Finally, the remaining kinetic energy is dissipated as the occupant decelerates with the vehicle. Injuries may occur during the second stage in case the impact loading is high enough beyond the safety limits. A good design should ensure that the kinetic energy is dissipated gradually to minimize injuries. Safety measures, such as using energy absorbing materials to cover the interior parts, seat belts, and air bags are important in reducing injuries due to interaction between the occupant and the interior.

To provide the minimum level of safety, automobile manufacturers are obliged by law to ensure that their designs comply with governmental regulations. Automobile manufacturers must demonstrate that their vehicles are in compliance with safety standards before they are sold. For frontal collisions, vehicle designs are regulated by FMVSS 208 in the U.S., by CMVSS 208 in Canada, and by ECE R-12 in Europe

4.CRASHWORTHINESS

First used in the aerospace industry in the early 1950's, the term "crashworthiness" provided a measure of the ability of a structure and any of its components to 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.

4.1 Achieving Crashworthiness

The task of the structural crashworthiness engineer is indeed unique when compared with that of the traditional structural analyst. Designers typically engineer structures using elastic analysis to withstand service loads without yielding or collapsing. Automotive structures, however, must meet all previously mentioned service load requirement, plus it must deform plastically in a short period of time (milliseconds) to absorb the crash energy in a controllable manner. It must be light, and able to be economically mass-produced. Further, the structural stiffness must be tuned for ride and handling, NVH and must be compatible with other vehicles on the road, so it is not too soft or too aggressive. In addition, the automotive safety engineer is responsible for packaging the occupants, so whatever decelerations transmitted to the occupants are manageable by the interior restraints to fall within the range of human tolerance.

The ultimate goal of the safety engineer is to reduce occupant harm. Typically, designers accomplish this goal using a combination of crash avoidance and crashworthiness measures. Available analytical tools were limited to strength of material calculations for idealized components. Engineers could not assess the overall vehicle crashworthiness until a vehicle prototype was built and tested.

4.2 Crashworthiness Requirements

The vehicle structure should be sufficiently stiff in bending and torsion for proper ride and handling. It should minimize high frequency, vibrations that give rise to harshness. In addition, the structure should yield a deceleration pulse that satisfies the following requirements for a range of occupant sizes, ages, and crash speeds for both genders:

a) Deformable, yet stiff, front structure with crumple zones to absorb the crash kinetic energy resulting from frontal collisions by plastic deformation and prevents intrusion into the occupant compartment.

b) Deformable rear structure to maintain integrity of the rear passenger compartment and protect the fuel tank. Accommodate various chassis designs for different power train locations and drive.

c) Properly designed restraint systems that work in harmony with the vehicle structure to provide the occupant with optimal ride down and protection in different interior spaces and trims.

5. COLLAPSE MODES

In order to achieve these goals, a good understanding of the structural deformation process and its mechanism should be maintained. Generally, the deformation (collapse) modes of the structure can be divided in two modes:

1. Axial collapse mode characterized by regular accordion type folding or irregular crumpling of the walls of the structure.

2. Bending collapse mode where discrete plastic hinges are formed and the structure collapses around them in a linkage type fashion.

Pure axial collapse as shown in Figure 5.1 is the most desirable collapse form, as it includes the absorption of the maximum amount of energy. An axial collapse, also called progressive buckling, involves formation of complete folds along the beam/tube. However, it is the most difficult to achieve and it can be realized only during a head on collision, direct front-rear accidents, or slightly off-angle (5^o to 10^o) impacts.

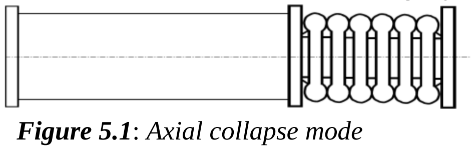

Figure 5.1: *Axial collapse mode*

On the other hand, the bending collapse mode is the most frequent to occur as it has the least energy path during an impact, and the structure will follow this path unless it is well designed to be forced into the axial collapse mode. As shown in Figure 5.2, this mode involves a global bending initiated by building up of stress concentration at a weak point until yield is exceeded and the structure bends around this point. Therefore, the design must not allow this building up of stress concentration and maintains a uniform deformation along the component length, which leads to the issue of the stability of the axial collapse.

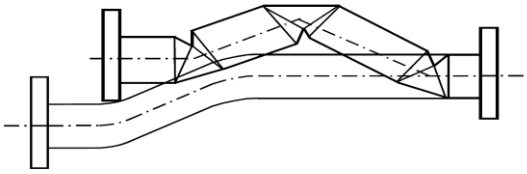

Figure 5.2: *Bending collapse mode.*

5.1 Thin wall box column

Thin-Walled box columns, composed of plate elements and subjected to axial compression, will buckle locally when critical stress is reached. Local buckling initiates the processes that lead to the eventual collapse of the section and a subsequent folding of the column. The collapse strength of the section is related to its thickness/width (*t/b*) ratio and material properties. For very small *t/b* ratios (*t/b=0.0085-0.016*), representing the so called "non-compact" sections, the mode of collapse of a section will be influenced predominantly by the geometry, since its local buckling strength is considerably below the material yield strength. As shown in Figure 5.1.1 the mode of collapse of "non-compact" sections is characterized by large irregular folds reminiscent of crumpling, which give rise to a bending type (global buckling) instability that is induced by fold irregularities. For larger *t/b* ratios, typifying the "compact" sections in which the elastic buckling strength exceeds material yield strength, the material strength properties are expected to govern the mode of collapse and, consequently, the post-buckling stability. The collapse mode in this case, as shown in Figure 5.1.2, will appear very stable even in the presence of considerable geometry or loading imperfections. Since the "compactness" of an axially compressed column affects the stability of collapse.

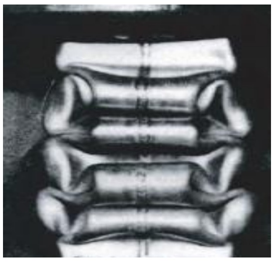

Fig 5.1.1 *Thin-walled box with small t/b ratios.* ***Fig 5.1.2*** *Thin-walled box with large t/b ratios*

6. MODEL DESCRIPTION

6.1 Detailed Truck Model--

The finite element model of a 2006 Ford F250 pick-up truck was developed at the NCAC for the Federal Highway Administration (FHWA) and the National Highway Traffic Safety Administration (NHTSA). The Ford F250 pick-up truck is a multi-purpose pickup truck. The vehicle obtained by the NCAC is anExtended-Cab, with a total wheelbase of 3610 mm (142.13) inches. The engine is a 5.4 liter Inline V8 with Electronic Fuel Injection coupled to a manual transmission with a four wheel drive configuration. However, several other models exist, such as higher engine capacity and automatic transmission with no change in the general geometry.

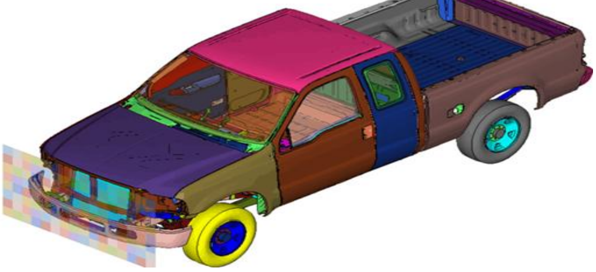

Figure 6.1- *FE model of Ford F250 pick-up truck.*

The truck was first disassembled and grouped into seven main groups, the frame, front inner, front outer, cabin, doors, bed and miscellaneous. The three dimensional geometric data of each component was then obtained by using a passive digitizing arm connected to a desktop computer. The surface patches generated from specified digitized data were stored in AutoCAD in IGES format. These IGES files were then imported into HYPERMESH for mesh generation and model assembly. The model was then translated from HYPERMESH, which outputs a neutral file, into an LS-DYNA input file which is developed at the NCAC. Since this model is used for multi-purpose crash applications, considerable detail was included in the rail frame, and front structures including bumper, radiator, radiator assembly,suspension, engine, side door and cabin of the vehicle. These parts were digitized as detailed as possible, minimizing any loss in the part's geometry.

6. MATERIAL PROPERTIES

As mentioned earlier, four LS-DYNA material models are used in the truck model. Table 1 lists the material model used along with the number of components. The first column corresponds to the material type number as used by LS-DYNA.

No	Material Type
1	Elastic
7	Blatz-Ko Rubber
20	Rigid
24	Piecewise Linear Isotropic Plastic

***Table 1:** LS-DYNA material models* used for the detailed model

Elastic	
Density	7.85E-09 mm3
Young's modulus	210,000 N/mm2
Poisson's ratio	0.3

***Table 2:** Elastic material model*

Blatz-Ko Rubber	
Density	0.95 mm3
Young's modulus	28 N/mm2

***Table 3:** Blatz-Ko material model*

Linear Isotropic Plasticity	
Density	7.85E-09 mm3
Young's Modulus	210,000 N/mm2
Poisson's Ratio	0.3
Yield Stress	215 N/mm2
Plastic Strain at failure	(no failure)

***Table 4:** Linear isotropic plasticity material model*

The elastic material model (material type 1, table 2) was used in components such as the engine, transmission, mounts and radiator. The Blatz-Ko material model (material type 7, table 3) was used in several mounts such as between the cabin and rails, engine and rails, etc. As seen from table 1, material type 24, the rate-dependent tabular isotropic elastic-plastic Material model is the most commonly used material type. Table 4 includes the values used for this material model in the truck simulation.

In addition, to increase the accuracy of the model, each component is weighed and compared to the simulation weight. This comparison was limited to the accessible parts only.

CONCLUSION

This paper presents a detailed truck model and uses this model for crash simulation. Unlike traditional materials, fundamental concepts of collapse mechanics and basic of crashworthiness are studied in this research.

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