ISSN 2278-8808
An International Peer Reviewed
SCHOLARLY RESEARCH JOURNAL
FOR INTERDISCIPLINARY STUDIES

A REVIEW ON VEHICLE CRASHWORTHINESS AND OCCUPANT PROTECTION MECHANISMS

M.S.Rohokale, Dr. D.R .Pangavane

1-Research Scholar, NGBU, Allahabad (UP)

2- Director and Professor, Presti ge Institute of Science and Technology, Indore (MP)

Abstract

Automotive Industry demands the robustness of the designed vehicle which suits the needs or expectations of the potential customers. Characteristicssuch as costs, design appeal, cabin comfort, infotainment functionality, agility,passive safety, theft deterrence, reliability or sustainability are the main factors inthe purchasing decision. Instead of vehicle engines power and torque, the customer cares about vehicles acceleration, maximum speed, wind noise and the energy costs. Nowadays, transportation safety efforts focus on crashworthiness, crash avoidance,driver performance, and highway construction. Over the past decade automakershave added many features to help the driver avoid a crash, such as anti-lockbraking systems, traction control devices and daytime running lamps. Vehiclesalso include many crashworthiness features such as rigid steel occupant-cellssurrounded by strategically placed, energy absorbing components.In addition,vehicles are equipped with an impressive array of restraint systems such asenergy-absorbing steering columns, three-point belts, front and side air bags andhead restraints to reduce the risk of injury.

***Keywords**: Vehicle Crashworthiness, transportation safety, Automotive Industry, etc.*

Introduction: Vehicle Customers are typically not directly interested in the engines performance or fuel consumption. They actually care for fuel economy, Vehicle's acceleration and overall costs.Automotive development should focus on the need based characteristics apparent by customers. Figure 1 depicts the expected balance between customer needs and the automobile design parameters. These characteristics or customer expectation parameters can be divided into three categories like Customer domain, Functional Domain and Physical domain.Knowledge of the legal and personal requirements andtheir interdependencies, the design approaches to meet them and the methods tovalidate them is a prerequisite for successful automotive design. The first motor vehicle fatality occurred in 1889 in New York City.Arguably this event led to the birth of automotive safety as a fieldof study. Over the past century, occupant safety has become an important designobjective among all the performance criteria of ground transportation vehicles.Manufacturers realized early on the need to demonstrate occupant protectionbefore the public accepted the automobile as a viable means of transportation.There are three distinct periods in the development history of automotive safety.This early period focused on basic improvements such as reduction of tire blowoutsto avoid loss of vehicle control; introduction of the self-starter to eliminate injuriesassociated with engine cranking; incorporation of headlamps to provide for nightvisibility, installing laminated glass to reduce facial lacerations, and adopting anall-steel body structure for better occupant protection [1]. Safety engineers design and manufacture vehicle body structures to withstand static and dynamic service loads encountered during the vehicle life cycle. Exterior shapes provide low aerodynamic drag coefficient. The interior provides adequate space to comfortably accommodate its occupants. 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, some of which may be in conflict with each other. 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 including space-frame structures [2]. Vehicle crashworthiness and occupant safety remain among the most important and challenging design considerations in the automotive industry. Early in the history of vehicle structural developments, vehicle bodies were manufactured from wood, and the goal of crashworthiness was to avoid vehicle deformations as much as possible. Over the years, the body structures evolved to include progressive crush zones to absorb part of the crash kinetic energy by plastic deformations. At present, vehicle bodies are manufactured primarily of stamped steel panels and assembled using various fastening techniques. Designers create vehicles to provide occupant protection by maintaining integrity of the passenger compartment and by simultaneously controlling the crash deceleration pulse to fall below the upper limit of human tolerance. A crash deceleration pulse with an early peak in time and a gradual decay is more beneficial for protection of a restrained occupant. Therefore, the goal of crashworthiness is an optimized vehicle structure that can absorb the crash energy by controlled vehicle deformations while maintaining adequate space so that the residual crash energy can be managed by the restraint systems to minimize crash loads transfer to the vehicle occupants [3].

Figure 1- Customer Expectation Parameters for a Vehicle

Real world vehicle collisions are unique dynamic events where the vehicle maycollide with another vehicle of similar or different shape, stiffness and mass; or itmay collide with another stationary object such as a tree, utility pole or bridgeabutment. Generally, for the purpose of body development, safety experts classifyvehicle collisions as frontal, side, rear or rollover crashes. Further, the vehiclemay experience a single impact or multiple impacts. Moreover, vehicle crashesoccur over a wide range of speeds, persisting for a fraction of a second, such as when a vehicle hits a tree, or for few seconds as in rollover events. These factorsillustrate some of the complex tasks involved in the design of vehicle structuresto satisfy crashworthiness constraints for all collision scenarios [4].

State Of The Art For Vehicle Crashworthiness And Occupant Protection

Research work in [5] provides a historicalview of crashworthiness development, explaining current data collection methods for analyzing realworld crashes before presenting a new approach in real world crash data collection. The new methodologyaims to substantially improve our understanding and analysis of the cause and effect of injuries thatare seen in everyday crashes. This improved understanding is achieved by examining the behavior of the structural elements in the car body during a crash. A generic car model has been developed,consisting of beams, joints and plate areas, which is used during car inspection. The main goal is clearidentification of the load path usage during the crash. To meet ever-increasing safety demands, especially those associated with air bags,vehicle design has evolved into a complementary mix of testing and mathematicalmodeling. The expected performance and the design stage determine the type oftest and level of test complexity. Whether assessing crashworthiness by a test, bya computer simulation, or by a combination of both, the ultimate objective is todetermine the potential for human injury due to exposure to real world crash conditions.Unfortunately, each real world crash is a unique event, and thereforeattempting to duplicate all real world crash conditions is a formidable task that isboth time-consuming and expensive. Accordingly, engineers use selective laboratorycrash modes that appear to be most relevant to reducing injuries and savinghuman lives [6]. The work in [7] proposes a methodologyfor the development of multibody models of road vehicles, for passive safety analysis, whichinclude all general structural and mechanical features of real vehicles and start by exhibitingimpact dynamic responses similar to the top of line vehicles. These vehicle models, designatedas generic, do not require the knowledge of most of the particular details of the designof the real vehicle, which the manufacturers are unable to release, but can be adjusted tohave crash responses similar to those of the real vehicle. Based on an existing finite elementmodel of a car, which has all constructive features of vehicles of the chosen class, amultibody model is built applying the plastic hinge approach. By using a selected numberof crash scenarios, defined in international standards such as the EuroNCAP, selected parametersof the vehicle multibody model are adjusted to ensure a good correlation between itsimpact responses and those of the finite element model. The crash responses are measuredin terms of structural deformations, velocities and accelerations, occupant injury measuresand structural energy absorption capabilities. The authors in paper[8] presents a multiobjectiveoptimization procedure for the vehicle design, where theweight, acceleration characteristics and toe-board intrusionare considered as the design objectives. The responsesurface method with linear and quadratic basis functionsis employed to formulate these objectives, in which optimalLatin hypercube sampling and stepwise regression techniquesare implemented. In this study, a no dominatedsorting genetic algorithm is employed to search for Paretosolution to a full-scale vehicle design problem that undergoesboth the full frontal and 40% offset-frontal crashes. The goal of the work in [9] is to increase passenger safety subject to manufacturingcost constraints. The crashworthiness design process requires modeling of the complexinteractions involved in a crash event. Current approaches utilize a parameterized optimizationapproach that requires response surface approximations of the design space.This is due to the expensive nature of numerical crash simulations and the high nonlinearityand noisiness in the design space. These methodologies usually require a significanteffort to determine an initial design concept. In this paper, a heuristic approach tocontinuum-based topology optimization is developed for crashworthiness design. Themethodology utilizes the cellular automata paradigm to generate three-dimensional designconcepts. Furthermore, a constraint on maximum displacement is implemented tomaintain a desired performance of the structures synthesized. The Filadelphia law firm is investigating reports that the Santa Fe's reartrailing arm, part of the rear suspension, has no anticorrosioncoating and lacks sufficient drain holes—all ofwhich contributes to premature corrosion and deteriorationof the trailing arm and other rear suspension parts. Engineeringexperts report that, over time, the defect can causechanges in vehicle operation, including a lowering ofvehicle height, tire misalignment, steering pull, and creaking sounds from the suspension. If the corrosion isallowed to progress, the rear trailing arm may fracturewhile driving, leading to a loss of vehicle control and otherserious consequences. SaltzMongeluzzi Barrett &Bendesky, P.C. (SMBB) in [10] hasbegun a nationwide investigation into a rear trailing armdefect in model year 2001-2005 Hyundai Santa Fe vehicles.Hyundai has recently announced a recall that wouldoffer partial solutions for some car owners. The paper work in [11] presents research activities

which were carried out within SP6. The pre-crash-system combinesa sensor unit, a data processing or data fusion unit and at least onereversible high-speed actuator. As outcome of this study about the pre-crash-system, a crash load redirection to the unstruck side wasfound to be most powerful and a suitable actuator was developedwhich takes away the crash loads directly from the incoming objectat the door. This was achieved by creating a rigid connection fromthe struck door toother stiff car regions. By this, the energy absorbingprocess starts earlier and involves more structural parts. Thissystem changes the crash deformation modes completely. Both, theB-pillar as well as the door intrusions are being significantly reduced,especially in regions being most critical for the occupant. The research work in [12] is devotedto the presentation of numerical tools, based on theso-called virtual distortion method(VDM) for faststructural reanalysis and to the application of these toolsfor optimal design of adaptive structures exposed toimpact loads. The first paper deals with fast modificationsof the material distribution (coupled stiffness andmass redistribution) in dynamically loaded structures,which allows their optimal remodeling, e.g., to minimizeaverage deflections. The VDM-based approach allowsanalytical sensitivity determination, which is veryhelpful in efficient implementation of the optimizationprocedure, utilized to solve the defined remodelingproblem. The presented methodology is illustrated witha numerical example of truss–beam structure exposedto random loads. The overall behavior of the complete vehicle oscillation system, is determined bythe visco-elastic properties (stiffness and resonance frequencies) of the followingelements:

Sprung masses (body and trim, engine, drivetrain etc.)

Unsprung masses (wheels, tires, wheel carriers, brakes etc.)

Rotating and oscillating masses (shafts, pistons etc.)

Passive damping elements (upholstery, spring-damper-systems, rubber mounts,mass dampers, absorbers etc.)

Active control systems (roll stabilization, damper control systems, controllableengine mounts etc.)

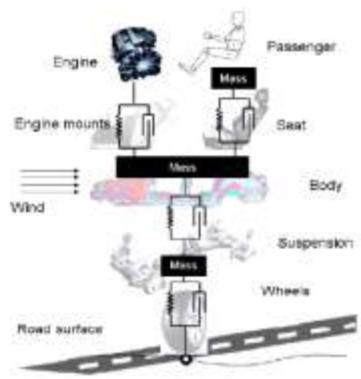

Figure 2- Visco-elastic vehicle system [13]

Figure 2 shows the visco-elastic system that determines vibration behavior ofthe complete vehicle. In addition to vertical body oscillations experienced through seat and floor,occupants are exposed to lateral and longitudinal vibrations and part specificvibration phenomena – such as torsional vibrations of the steering wheel orvibration of the gear shift lever. Figure 3 shows different customer relevantvibration phenomena and their respective areas of acceleration and frequency.Requirements for ride comfort vary greatly from market to market. Europeancustomers e.g. usually drive shorter distances at higher speed on excellent roadsand hence prefer tight suspension and upholstery in order to get a more directcontact to the road. In

the U.S., cars are usually driven at lower speed over longerdistances; drivers and passengers ence place higher importance on softsuspension, maximum damping resulting in a high level of comfort [13].

Figure 3- Customer relevant vibration phenomena (Source: BMW)

Then four designing variables and optimal range of the parameters hadbeen studied and defined. Orthogonal experimental designing method was used to get 16groups of parameters for car-truck rear impact finite element simulations. Thenvariance analysis method was applied to conduct the significance analysis offour influencing factors about two optimal objectives. Finally, whole-car rearimpact tests were carried out according to the obtained optimal design, and gotbetter deceleration curve and deformation [14]. The research work in [15] deals with thedecision fusion strategies of a multi-sensing embedded system to achieve significant enhancement in the reliability of occupant safety through the fused decisions. Multi-sensing approaches to determine weight, vision, and crash sensing aredeveloped for occupant detection, classification, position calculation, and crash detection. A rule-based decision fusionalgorithm is then developed to fuse the multi-sensing decisions. The developed sensing systems are incorporated into anembedded device. To execute the embedded system, a system interface between the software and hardware is developed usingLab Window/CVI with the C programming language. The experimental results demonstrated that the real time operation of the embedded system validate the effectiveness of the decision fusion algorithm, characterize the safety measures and monitorthe decision application. Several events were tested that prove the performance of the embedded system is robust towardsoccupant safety measures.

Conclusions, Discussions And Future Research Directions: Computer aided analysis and simulation were used to evaluate the crash and structural performance of the reduced mass CAD model. The following theoretical study indicates that a low-mass body structure has the potential to meet Federal Motor Vehicle Safety Standards (FMVSS) for light duty vehicles for front, side, and rear impacts, roof crush, occupant restraints and several Insurance Institute for Highway Safety requirements. This study also provides a discussion on the applicability of low-mass body structure engineering and manufacturing to other vehicle classes as well as a bill of material with a full cost analysis for the engineering and manufacturing of a body structure.This work can be further extended by using Finite Element Analysis (FEA) andstudy& Analysis of Biomechanics researchfortheoccupantsafety.

Reference

John D. Graham, "Technology, Behavior and Safety: An Empirical Study of Automobile Occupant Protection Regulation", Journal of Policy Sciences, Elsevier Science Publishers, Vol.17, pp. 141-151, 1984.

Winnicki, John and Eppinger, Rolf, "A Method for Estimating the Effect of Vehicle Crashworthiness Design Changes on Injuries and Fatalities", NHTSA Technical Report, pp. 1-30, 1998.

William T. Hollowell, Hampton C. Gabler, Sheldon L. Stucki, Stephen Summers and James R. Hackeney, "Updated Review of Potential Test Procedures for FMVSS No. 208", Office of Vehicle Safety Research, pp. 1-122, 1999.

D. Friedman and C E Nash, "Measuring Rollover Roof Strength for Occupant Protection", International Journal of Crash, Vol.8, Issue No. 1, pp. 97-105, 2003.

M. Lindquist, A. Hall and U. Bjornstig, "Real World Car Crash Investigations- A New Approach", International Journal of Crash, Vol.8, Issue No. 4, pp. 375-384, 2003.

Paul Du Bois, Clifford C. Chou, Bahig B. Fileta, Tawfik B. Khalil,, Albert I. King, Harold F. Mahmood and JacWismans, "Vehicle Crashworthiness and Occupant Protection", Edited by Priya Prasad and Jamel E. Belwafa, American Iron and Steel Institute, Michigan, 2004.

Luís Sousa, PauloVeríssimo, Jorge Ambrósio, "Development of generic multibody road vehicle models for crashworthiness", Journal of Multibody System Dynamics, Voḷ19, pp.133-158, 2008.

Xingtao Liao, Qing Li, Xujing Yang, Weigang Zhang and Wei Li, "Multiobjective optimization for crash safety design of vehicles using stepwise regression model", Journal of Structural Multidisc Optimization, Voḷ35, pp. 561-569, 2008.

Neal M. Patel, Byung-Soo Kang, John E. Renaud, Andres Tovar, "Crashworthiness Design Using Topology Optimization", ASME Journal of Mechanical Design, Vol.131, 2009.

Saltz, Mongeluzzi, Barrett and Bendesky, "Industry Updates- Philadelphia Law Firm Investigating Hyundai Santa Fe Defects", Journal of Failure Analysis and Prevention, Vol.9, pp.527-533, 2009.

E. Zimmerman, V. Muntean,T. Melz, Bj. Seipel, Th. Koch, "Novel Pre-Crash-Actuator-System based on SMA for Enhancing Side Impact Safety", Springer Journal of Advanced Microsystems for Automotive Applications 2009, pp 49-64, 2009.

MarcinWiklo, Jan Holnicki-Szulc, "Optimal design of adaptive structures: Part I. Remodeling for impact reception", Journal of Structural Multidisc Optimization, Vol.37, pp.305-318, 2009.

ZhonghaoBai, Qianbin Zhang, ZhengXu, and Libo Cao, "Application of Orthogonal Experiments and Variance Analysis in Optimization of Crash Compatibility",ICICA 2010, Part II, CCIS 106, Springer Verlag, pp. 142–149, 2010.

M. A. Hannan, A. Hussain, A. Mohamed, S. A. Samad And D. A. Wahab, " Decision Fusion Of A Multi-Sensing Embedded System For occupant Safety Measures", International Journal Of Automotive Technology, Vol. 11, No. 1, pp. 57−65, 2010.

Marta Carvalho, Jorge Ambrósio, "Identification of multibody vehicle models for crash

Analysis using an optimization methodology", Journal of Multibody System Dynamics Vol̩ 24, pp. 325–345, 2010.