ISSN 2395-1621

Injury Prediction Using Vehicle Accident Reconstruction and CAE Tools

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ABSTRACT

Every year, more than 1.2 million fatalities happen worldwide due to road accidents, which is more than fatalities caused by any disease. Throughout world, India alone accounts for 10% road accidents and corresponding economic loss in India is about 3% of its total GDP. Accident data reconstruction, analysis and injury prediction using CAE tools are vital steps in understanding the causes of accidents and preventive solutions for the same. Accident reconstruction is a powerful tool to predict impact velocities and deformations using data from real world crashes. From these inputs, detailed simulations can be performed using FEM to predict occupant kinematics and injuries which can be validated using accident data. In proposed project work, real world accident scenarios will be selected from available database. Accident reconstruction will be carried out using MBD tools and parameters like vehicle impact velocities and deformations will be correlated to accident data. These inputs will be further used for detailed FEA simulations which include vehicle and occupant dummy models. Injuries predicted will be validated by accident data. Further study will be carried out to understand the possible causes of injuries and suggest solutions to reduce the severity of injuries.

Keywords- **MBD, Injury, Occupant Kinematics.**

ARTICLE INFO

Article History

Received :18th November 2015

Received in revised form :

19th November 2015

Accepted : 21st November , 2015

Published online :

22nd November 2015

I. INTRODUCTION

The primary objective of this analysis was to create a method for comparing crash tests to real-world crash cases from the Crash Injury Research and Engineering Network (CIREN). The method may also be applicable to other crash and injury samples such as the National Automotive Sampling System- Crashworthiness Data Set (NASS-CDS) and Fatality Analysis Reporting System(FARS)Previous studies,which introduced approaches and parameters for case comparison,were examined to aid in the development of this technique. Based on the criteria included in these studies, a comparison method was developed for use with real-world crashes in comparison to crash tests. This new comparison included anthropomorphic test device (ATD) injury assessment reference value and curren tinjury criteria with associated risk curves.CIREN data was reviewed to introduce real- world crash parameters. Finally, common crash test databases and dummies were examined to identify congruous information to be used in conducting the comparisons. The main parameters used in crash research were identified to ensure each comparison parameter chosen was also available in all the databases used. It is critical to know the strengths of each database for selecting an ideal comparison case

CRASH INJURY RESEARCH AND ENGINEERING NETWORK

The CIREN investigates real-world crashes that occur across the United States. The Toyota-Wake Forest University School of Medicine (T/WFU) CIREN Center has been enrolling cases since January of 2006. For consideration as a CIREN case, the vehicle model year must be within six years of the current year and the occupant must have either an AIS 3 injury or two or more AIS 2 injuries in different body regions with clinical significance. No ejected occupants are enrolled in CIREN. There are injury severity, crash configuration, and model year exceptions for pediatric and pregnant occupant cases. Cases with greater than six quarter turns, significant rear impacts, or complicated crash scenarios are excluded from CIREN [7]. These CIREN case inclusion criteria were designed to ensure clean crashes and a database with very detailed information about occupant injuries and outcome for the study of real-world crashes. By finding a comparison crash test for each of these T/WFU CIREN cases, it was possible to study real-world crash occupant outcomes in relation to the crash test results.

NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION

NHTSA is a branch of the United States Department of Transportation. This regulatory agency was formed in 1970 to improve the safety of automobiles driven in this country. To accomplish this goal, the agency performs crash testing on new cars to enforce vehicle safety regulations. For example, NHTSA performed approximately 200 crash tests on 2007 model year vehicles [8, 9]. NHTSA also sets United States vehicle safety regulations that all car companies must pass.

The main crash tests used for these case comparison methods are frontal and side, including federal motor vehicle safety standard (FMVSS) 208, FMVSS 214, FMVSS 201 pole, and NCAP tests.

INSURANCE INSTITUTE FOR HIGHWAY SAFETY

The IIHS is a consumer agency funded by multiple insurance companies. The IIHS provides consumers with unbiased vehicle safety ratings and crash test results. IIHS performed approximately 150 crash tests on 2007 model year vehicles [10]. IIHS side impact crash tests use a barrier that is higher and larger than the NHTSA crash test barrier [11, 12]. This larger barrier better represents the front end of a sport utility vehicle (SUV), which addresses the issue of vehicle- mismatch crashes [13]. Vehicle incompatibility has shown to generate more injuries for the occupants in the smaller vehicle, especially in side impacts where the front bumper of the larger vehicle impacts above the level of the side door sill of the smaller vehicle [14]. IIHS also performs frontal crash tests using a 40% offset frontal stationary barrier instead of a full frontal configuration. The test recreates a frontal impact where a vehicle departs the travel lane to the left and impacts an oncoming vehicle [15].

CRASH TEST DUMMY INJURY CRITERIA

For each type of crash test performed by NHTSA or IIHS, ATD loads were measured for multiple body regions [16]. The loads that the ATD experienced as a result of the crash test must remain below specific thresholds. These threshold values have been determined through extensive post mortem human subject impact testing. Side impact ATDs are used for FMVSS 214,side NCAP tests, and IIHS frontal crash tests. NHTSA has begun to utilize 50th percentile male ATDs and pediatric ATDs, in addition to the standard fiftieth percentile male ATDs in many of its most recent crash tests. ATD information was extracted from the crash test report and compared to the injuries sustained by the case occupant.

There are multiple side impact ATDs currently in use, including the SID, SID-IIs, and ES-2re, and each dummy has its own set of threshold values [9, 18, 20]. These are used by both NHTSA and IIHS to assess whether a crash test passes the criteria. Common tests using these ATDs include FMVSS214, FMVSS 214 pole, side NCAP, and side IIHS crash tests. By incorporating these injury criteria with the other parameters measured during a crash test, a vehicle's crashworthiness was assessed.

Methodology

a. Selection of accident cases from database.

Selection of accident cases from database from Real World Crashes and crash injury research and engineering network for Indian accident scenario.

b. Develop the MBD Models from real world crashes.

c. Predict velocities, deformation and principle direction of force.

d. Develop Finite Element model for above cases.

e. Use this as input for Finite Element model.

f. Predict occupant Kinematics and Injuries.

g. To study possible cases of Injuries for possible solution

REAL-WORLD CRASH

The first step in comparing real-world crashes to crash tests was to extract crash information from the crash reportprepared by the T/WFU CIREN crash investigator. Importantcrash characteristics recorded for each vehicle are shown inTable 1. Each of these crash characteristics can also be foundwithin the crash test reports from NHTSA and IIHS. Many ofthese crash characteristics have been used previously toinvestigate real-world crashes, and all of these characteristicsare collected for CIREN cases.

Table 1. Important crash comparison parameters

Crash Comparison Parameters
Vehicle Year
Vehicle Make/Model
Crash Configuration (side,frontal)
Crash Type (full, narrow)
Delta V
PDOF
Maximum Crush
Object Impacted

In addition to crash and vehicle parameters, occupantcharacteristics were extracted from patient interviews andmedical records at Wake Forest University Baptist MedicalCenter, where each occupant was a patient in the traumacenter due to their involvement in the motor vehicle crash.Patient anthropomorphic measurements, gender, age, andinjuries resulting from the crash were extracted from medicalrecords and recorded with the crash and vehiclecharacteristics. Important occupant comparison parametersare listed in Table 2

Table 2. Important occupant comparison parameters

Occupant Comparison Parameters
Weight
Height
Seat Location
Restraint Status
Airbag Deployment

Each of the occupants' injuries was scored using the Abbreviated Injury Scale (AIS) and Injury Severity Score(ISS) [21]. The injuries were then ranked according to theAIS scale and body region injured for each occupant. Foreach injury, radiology images were selected from the patient'strauma scan history. Once all the CIREN real-world crash,vehicle, and occupant information was collected, thecomparison crash test was identified.

Real-World CIREN Crash Data

With the advent of sophisticated finite element (FE) vehicle models and human body models that are highly representative of human anthropometry and anatomy, it is imperative that these models can be used to assist the understanding of the mechanism of aorta injury. On the other hand, conditions in real world accidents are not well controlled and the accuracy of reconstruction could greatly be affected for lack of engineering measurements for model validation. Cases selected from the Crash Investigation Research Engineering Network (CIREN) were reconstructed in two stages as described. In Stage I reconstruction, validated FE models were scaled to match the case vehicles and actual deformation pattern matched simulation results while in Stage II, the WSHBM along with vehicle structures, which intruded into the occupant compartmental space, were used to predict the maximum principal strain and pressure in the aorta. In Stage I, vehicle models obtained from NCAC FE model archives were selected to best match the vehicle type as those of the actual case, since not all vehicle models were available. The Federal Highway Administration (FHWA) and the National Highway Traffic Safety Administration (NHTSA), through the NCAC, have put in a great deal of resources to build and validate these FE vehicle models. Further details on the validation of these models are reported on the NCAC website (http://www.ncac.gwu.edu/vml/models.html). The same vehicle type models were scaled to match with the overall dimensions, such as the wheelbase, width, and height, of the case vehicle.

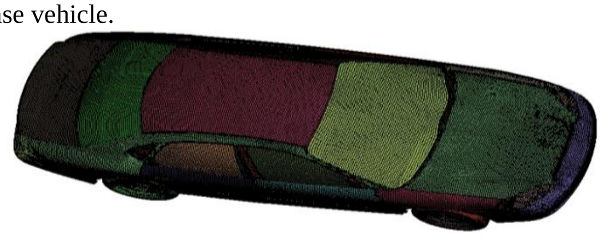

Fig.1Taurus Validated Model

Dummy Positioning

Twenty-seven QST tests of HR seats were randomly selected from a larger series and were evaluated for strength and seat deformation under occupant loading. They represented 20 different seat types from four suppliers. Averages and standard deviations in QST results were computed. In addition, eight repeat tests were conducted with one seat to determine repeatability of the QST. These data were compared to an earlier repeatability study of the 1994 W pre-HR seat, which was evaluated at two facilities. Finally, 12 QST tests were conducted where variability was introduced in the seat back angle, track position, offset and orientation, and in the seatback angle transducers.

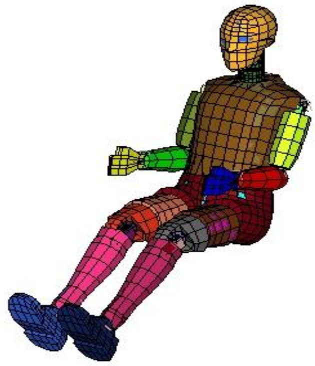

Fig.2 Hybrid-III 50th Percentile Male for Indian scenarios

COMPARISON CRASH TEST

The second step to compare real-world crashes to crash tests was to identify a comparison crash test case. Because eachvehicle model was not tested every year, a range of vehiclemake, models, and years was identified to begin a databasesearch in either the NHTSA or IIHS database. This wasachieved by using the Sisters & Clones List to identifyvehicles that did not undergo a significant change in bodystyle or safety system revision [22]. The Sisters & Clones listis a database of vehicle make and models according toproduction year for US vehicles and imports. Each vehiclehas model year ranges when significant changes were notmade to that vehicle. The Sisters & Clones list also contains areference for vehicles that were sold under different brandnames. Once the vehicle range was found, the real-worldcharacteristics were examined to determine whether to searchthe NHTSA or IIHS database. If there was more than onhorizontal crash event for the real-world vehicle, the impactassociated with the occupant's most serious injuries waschosen as the event used to search the crash test database.This excluded impacts from comparisons such as curbimpacts and ditches, because these events could not becompared using crash tests due to their minor nature. Often,the most injurious event was that with the highest Delta V.For this method, the most serious crash event for theoccupant was used for comparison.

Which specific database to search was chosen based on thecrash, vehicle, and occupant characteristics of the real worldcrash. Table 3 lists general characteristics and the crash testsbest suited for comparison. Some important databaselimitations determined which was chosen to search forcomparisons. For example, the IIHS side impact crash testincluded in the IIHS online database was introduced for 2002model year vehicles, so earlier vehicle model years involved in side impacts had to be searched in the NHTSA database only.

Table 3. Common crash characteristics and associated crash tests

Real-World Common Crash types	Crash Test
High speed full frontal impact or frontal impact with a rear seat occupant	NHTSA NCAP run at 35mph
Moderate speed full frontal impact	NHTSA FMVSS208 run at 25mph
Offset frontal impact	IIHS offset frontal run at 40mph
High speed side impact	NHTSA side NCAP, crabbed run at 39mph
Moderate speed side impact	NHTSA FMVSS 214, Crabbed, run at 33mph
Side impact with large impacting vehicle	IIHS side run at 31mph

Using Delta V, crash type, and occupant seating position, the initial database for searching was chosen and the vehicle make/model was entered. Each available comparison crash test was analyzed according to the real-world characteristics, narrowing the choices further by focusing on the occupant characteristics of seating position, restraint status, and occupant height and weight. A different crash test speed could be acceptable if the test contained the proper ATD size and position in reference to the real-world occupant. To aid in the process of selecting crash tests, it was important to know specifics about each database. NHTSA FMVSS 208 tests are run with unbelted ATDs and IIHS offset frontal impacts only have a driver dummy. Some recent NHTSA tests are run with pediatric dummies in the backseat in multiple child safety seat configurations. It was important to choose the crash test that best represented the occupant characteristics, as well as the crash and vehicle characteristics. This allowed for a more appropriate comparison between ATD resultant measurements and the real-world crash occupant's injuries. After narrowing these choices by occupant parameters, there were typically one or two choices left for possible crash tests.

In this way, a systematic methodology was used to find comparison crash tests for each T/WFU CIREN case. A summary of these comparison procedures is shown in Figure3.

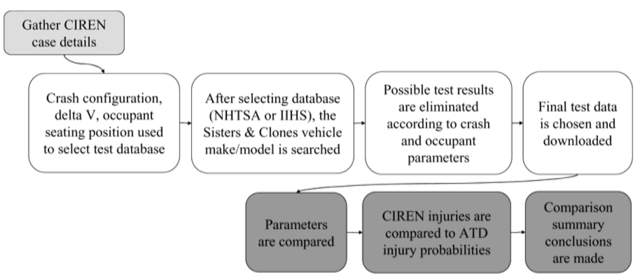

Figure 3. Steps for comparing CIREN case to crash test

Once a final comparison crash test was chosen, all files for the crash test were downloaded. This included the report documents, vehicle photographs, crash test videos, and data curves. Delta-V of the crash test was calculated by analysing the acceleration curves from the crash test data files. ATD measurements were extracted from the reports and data curves, then injury risk curves and critical values from literature were used to compare injury risk to the injuries sustained by the case occupant. Each parameter was compared between the crash test and the real-world crash inorder to investigate the similarities and differences and make conclusions about the comparison.

RESULTS

After analyzing all 120 of the cases for the T/WFU CIREN center, 100 frontal and side cases were successfully compared to crash tests. Using the detailed methods developed for these comparisons, one case is presented as an example of the developed methodology. The CIREN case vehicle was a 2005

Toyota Rav4 involved in a full frontal impact with a 1999 Plymouth Grand Voyager SE. The estimated PDOF was 350 degrees with a delta V of 34.8 mph. The case occupant was the driver, a 38 year old female who was 5′ 2″ (157 cm) and 180 lbs (82 kg). She was belted, and the driver frontal airbag deployed as a result of the crash. According to the Sisters and Clones list, the vehicle model range for the Toyota Rav4 extended from 2001 to 2005. The NHTSA NCAP database was chosen as the specific crash test database to search due to the high delta V frontal impact experienced by the case vehicle. After searching in the NHTSA database, The two cases with “Vehicle No. 1” indicated these were frontal crash tests, so the crash test marked as “Vehicle No. 2” was removed from the possible comparison tests because this is a side crash test. NHTSA 4893 was chosen because of the 2004 vehicle model year and occupant characteristics that more closely matched the CIREN case occupant. This crash test used a belted Hybrid III 50th percentile male ATD, with a weight of

172 lbs, which closely compared to the weight of the CIREN case occupant.

I. CONCLUSIONS

With so many people travelling on the roads, vehicle safety is an important issue. As shown by these comparison methods, by using the current resources provided by NHTSA and IIHS toresearchmotorvehiclecrashes,cost-effectivestudiescan be performed that reveal areas where vehicle manufacturers are succeeding in reducing injury incidence and severity as well as areas that need increased attention. The methodology developed in this study was effective for comparing real- world vehicle crashes and crash tests for frontal and side impacts, using data from the T/WFU CIREN Center. By incorporating this comparison method into current research practices, including those employed for CIREN, much more can be learned about the safety of vehicles on the roads today.

Acknowledgment

Thanks to Dr C. S. Pathak and S.R.Deshpande for his valuable contribution in developing the IJRSD article template.

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