Proceedings of IMECE'03
2003 ASME International Mechanical Engineering Congress
Washington, D.C., November 15–21, 2003

IMECE2003-43061

BIOMECHANICAL STUDY OF REAR CHILD CHEST INJURY MEASURES RELATED TO COLLAPSING FRONT SEATS IN REAR IMPACTS

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ABSTRACT

Government recommendations have been made to place children into the rear seating areas of motor vehicles in order to alleviate airbag hazards in frontal impact. In most moderate to severe rear impacts, however, the adult occupied front seats will "yield" or "collapse" into the rear seat area and thus pose another potential head and chest injury hazard to the rear seated children. Numerous factors or variables, each with a wide parameter range, influence whether or not an occupied collapsing front seat will result in engagement with the rear occupant, and whether that engagement is likely to cause injury to the rear-seated occupant. A combined experimental and analytical method, employing instrumented surrogates in a sled-buck test set-up, has been utilized to study the multi-variable potential injury problem of the rear-seated child in rear impact. A 3 year-old H-III surrogate, seated in the built-in booster seat of a minivan, was used as the rear seat passenger in this study. Five tests were utilized. The experimental surrogate data from the test method is combined into a "polynomial response function" that expresses "injury levels" (i.e. HIC and chest G) as a function of the many variables, and allows for analytical "interpolation and extrapolation" at variable combinations and ranges not tested. Actual accident cases were compared with the biomechanical injury measures. The present study presents a methodology to delineate the biomechanics of injuries using multivariate analysis.

INTRODUCTION

With a few exceptions[1, 2] experimental research studies dealing with occupant injuries induced by front seat collapse during rear impact has focused primarily on the front seat occupant. This study examines issues related to injury potential of rear seated children located behind adult occupied seats that are likely to collapse into the rear occupant area during moderate to severe rear impacts. The primary issue deals with the questions of whether or not an occupied collapsing front seat will lead to contact with the rear child and, if such contact does occur, will it cause injury. Several variables, each having a wide parameter range, tend to complicate investigation of the issue. For instance, strength of automotive front seat systems vary considerably from the weaker single sided recliner types on up to the much stronger "belt-integrated" seat types. In addition to the front seat strength, there are also several other factors or variables that influence the injury risk to rear seated occupants. These variables include factors such as the weight of the front seat occupant and the severity of the rear impact. Further complicating the issue is the fact that each of these factors also encompasses a wide parameter range. Front occupant sizes can range from as small as a 5th percentile female of about 50 kg on up to larger adult occupants weighing more than double that amount.

METHOD

A two-level (i.e. Hi (+1) and Lo (-1)) factorial method, in conjunction with a sled-buck test setup and instrumented surrogates, is presented as a means for developing "polynomial response functions" that enable test efficient examination of biomechanical injury measures covering a wide range of parameters for many variables. Five tests were run to examine rear child HIC and chest G injury levels, as they relate to rear impact severity (independent variable X1) and front occupant weight (independent variable X2), when the front occupant is seated in a typical minivan collapsing seat (i.e. single side recliner type) and the child is seated in a "built-in" OEM booster seat. A 3 year-old H-III surrogate is used to represent the rear child. During the tests the sled-buck system is towed rearward into a crushable barrier that produces a crash pulse modeled to the actual vehicle crash pulse. For all 5 tests, the front seats were placed in a nominal position at about 2/3 from full forward, with a seatback angle of 22 degrees. Table 1 lists the range of variables for each test configuration and the resultant measured child HIC and chest G level.

Table 1: 2-Level Factorial Test Configurations and Child Dummy Resultant Chest and Head Injury Measures

TEST CONFIG.	Variable X1 (kph)	Variable X2 (kg)	Resultant Child HIC	Resultant Chest G
1	32.5	80	1,903.6	92.6
2	22.5	50	47.4	15.1
3	22.5	110	2,335.2	40.0
4	42.5	50	178.3	27.7
5	42.5	110	8,515.9	141.5

Table 2 illustrates the "computation matrix" used to develop polynomial coefficients that relate the two independent variables (i.e. X1 and X2) to the biomechanical injury measures for the 3 year-old H-III child chest G levels. For a specific polynomial coefficient, simply multiply the resultant column "Child Chest G" value by the corresponding plus or minus sign of each row in a given column, and then "sum" the values in that column. Divide the "sum" by 4 and the result yields the polynomial coefficient for that column. As an example A1 would be 34.7.

Table 2: Polynomial Coefficient Calculation Matrix for Development of the Child Chest G Polynomial Function

TEST CONFIG.	A0	A1	A2	A12	Resultant Child Chest G
2	+	-	-	+	15.1
3	+	+	-	-	40.0
4	+	-	+	-	27.7
5	+	+	+	+	141.5
Σ	224.3	138.7	114.1	88.9	
Aij =Σ/4	56.1	34.7	28.5	22.2	

Thus, the 3 year-old Chest "G-Level" polynomial function is:

$$\text{CHEST "G"} = 56.1 + 34.7\,X_1 + 28.5\,X_2 + 22.2\,X_1X_2 \qquad (1)$$

The X1 and X2 parameters represent dimensionless values for the "Impact Severity (i.e. speed change) " and "front Occupant Weight", respectively. For instance, the low weight of the 50 kg female would be represented as a "–1" value of X2. Likewise, the average and high occupant weights would be represented as "0" and "+1" values. Values between or beyond the test values are extrapolated proportionately. For instance, a weight of 65 kg would be represented by a value of "-1/2", etc. In order to develop the CHEST "G" curve for a threshold level of 60 G's, as an example, all that is required is to select a given weight of front occupant (in X2 dimensionless form) and solve for the corresponding speed variable X1 (in dimensionless form) from the CHEST "G" equation set equal to a value of 60. Repeating this process for a range of weights results in a polynomial curve at the 60 G level.

RESULTS

Figure 1 illustrates a plot comparing both 50 and 60 "G" Chest injury curves based on the results of the Table 1 test data as a function of "impact severity" X1 and "occupant weight" X2. The "X" and "Y" points on the curves represent two actual cases involving fatal chest injuries to two little girls, ages 5 and 7, in different accidents. Similar data and correlations were published earlier for the 3 year-old child HIC response[1].

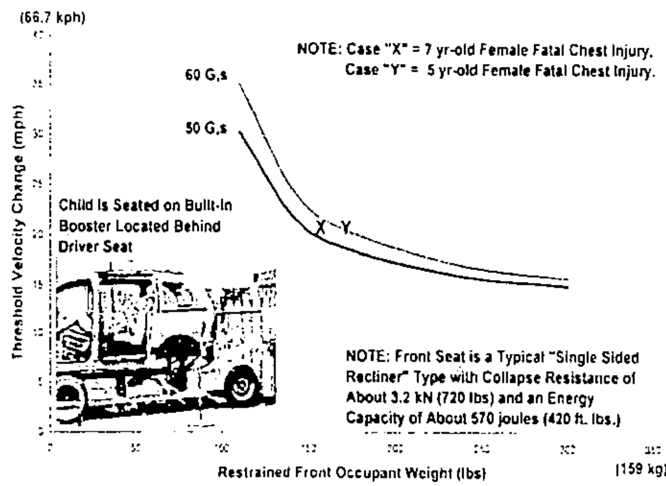

Fig. 1: Polynomial Curves for Child Chest "G" Levels

REFERENCES

1. Saczalski, K., Sances, A., Srirangam, K., Burton, J., Lewis, P., "Experimental Injury Study of Children Seated Behind Collapsing Front Seats in Rear Impacts", 40th Annual Rocky Mountain Bioengineering Symposium Proceedings, 10-13 April, 2003, ISA Vol. 437, pp 259-265.
2. Rashidy, M., Deshpande, B., Gunasekar, T., Morris, R., Munson, R., Lindberg, J., Summers, L., "Analytical Evaluation of an Advanced Integrated Safety Seat Design in Frontal, Rear, Side, and Rollover", 17th ESV, June 4-7, 2001