Integration of Finite Element Analysis (LS-DYNA) with Rigid Body Dynamics (ATB) for Crash Simulation

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ABSTRACT

This paper describes the Integration of ATB (Articulated Total Body), a rigid body dynamics program and LS-DYNA, a finite element analysis program for PC-based occupant/seat restraint modeling. The integration of ATB and LS-DYNA provides a single simulation tool with the advantages of each individual code. The results of several cases and validation are also described in detail. The output of the coupled software is found to be consistent with the output from the already validated ATB program.

INTRODUCTION

The software packages ATB (Articulated Total Body) and LS-DYNA (PC version) were coupled and integrated to provide researchers the capabilities of performing advance crash simulations in which one can include the dummy model from ATB and the seatbelt, airbag, seat and other restraint system models from LS-DYNA.

Articulated Total Body (ATB)

The ATB model has been successfully used by the Air Force Research Laboratory (AFRL) and other organizations/companies for predicting gross human body response in various dynamic environments, especially automobile crash and aircraft ejection with wind-blast exposure, and as such, has been thoroughly tested and validated over the years. It was primarily designed to evaluate the three-dimensional dynamic response of a system of bodies when subjected to a dynamic environment consisting of applied forces and interactive contact forces. The information pertaining to the dummy model, vehicle description and motion information is organized in the form of cards in the input file (.ain). GEBOD (Generator of Body Data) program is used to generate the human and dummy data sets for the ATB input file, i.e., the B cards of the input file. GEBOD computes the body segments' geometric and mass properties, and the joints' locations and mechanical properties. These data may be computed for various size of dummy.

Need for Software Integration

ATB is a robust solver with minimal computational overhead. However, ATB has limited restraint system and airbag modeling capabilities. The modeling of occupant interaction with airbag restraint systems in ATB also has limitations. LS-DYNA is a powerful finite element analysis program with many specialized restraint elements including, retractors, belts, and materials for airbag modeling. However, the occupant modeling capability of LS-DYNA does not have the same validation experience as the ATB model. With the coupled software, one can take the ATB's dummy model to LS-DYNA, design the air-bag, the seat belt and the seat system and perform a detailed analysis of the occupant with the restraint system in an automobile or aircraft. Preliminary analyses can be conducted with just ATB, with the developed model later transferred to LS-DYNA/ATB for more complex studies.

APPROACH

Modeling and Analysis Using Coupled Software

The dummy model used in the validation consisted of adult human male and female models of various heights and weight combinations. The approach used in the ATB is to consider body as being segmented into individual ellipsoids, which may be rigid or deformable. For the purpose of validation, a 15-segment (14-joints) rigid body model was chosen.

Restraint System Model Description

The restraint systems viz. seat belt and airbags were modeled using the LS-DYNA pre-processor, FEMB. The seat was modeled as a combination of planes with the plane defined in the ATB input files. Quadrilateral shell element was used to discretize the restraint system. The contact information of the dummy segment with the various restraint systems is defined in LS-DYNA input data file (. k). The information for simulation of vehicle motion is defined in the ATB input deck (C Cards). The airbag deployment information was defined in LS-DYNA input file.

Analysis

The simulation was performed on a Windows NT, Pentium III 500Mhz (Dual Xeon processors) machine. The cases involving the dummy models were run for 220 milliseconds of simulation time. The time step was set at 0.01secs.

For the purpose of analysis the dummy data file (.ain) and the restraint system data file (.k) were integrated by means of supplying the data decks as input to the coupled software. Post-processing was done using the LS-DYNA post-processor, PostGL (for simulation) and ETA-Graph (for plots). ATB and coupled software output data files were used to generate the plots of displacement, velocity and acceleration of the dummy's upper torso and head segment. Upper torso was chosen, as it is the most critical part of the body and X component was chosen, as it has the largest magnitude in most cases. The relative accuracy plots of X component of acceleration from output data files of ATB and coupled software are shown in the results.

Software Validation

Initially, five separate cases were modeled and analyzed to compare the results and validate the integration of the two codes. The cases are as mentioned below. The corresponding figures are at the end of the text.

Case 1. ATB ball, plane and motion (simple Problem) **-** Figure 1
Case 2. ATB dummy, seat and motion with no seatbelt **-** Figure 2
Case 3. ATB dummy, seat and motion with LS-DYNA seatbelt **-**Figure 3
Case 4. ATB dummy, seat and motion with LS-DYNA airbag **-** Figure 4
Case 5. ATB dummy, seat and motion with LS-DYNA seatbelt and airbag – Figure 5

DISCUSSION OF RESULTS

The fidelity and accuracy of the coupled software were evaluated quantitatively. The quantitative evaluation consisted of comparing the displacement, velocity and acceleration data of the various dummy segments generated by the coupled software (rigid body output file) with the corresponding data sets generated by the ATB program (.aou file).

Figure 1a shows the simple ball and plane problem where both ball and plane were modeled in ATB and the simulation is run in the coupled code using ATB input file (.ain). The results showing Z acceleration of the ball, when the simulation is run using ATB and also using the Coupled Code is plotted (Figure 1b). The plot shows that results from ATB and Coupled software match almost exactly.

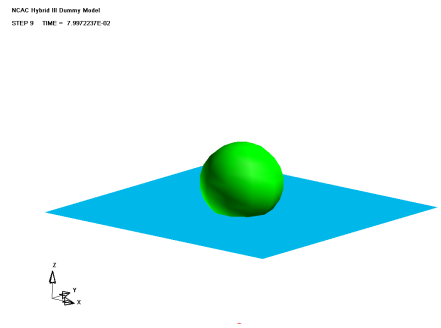

Figure 1a. ATB ball, plane and motion (Simple Problem) - Time step 80 msec.

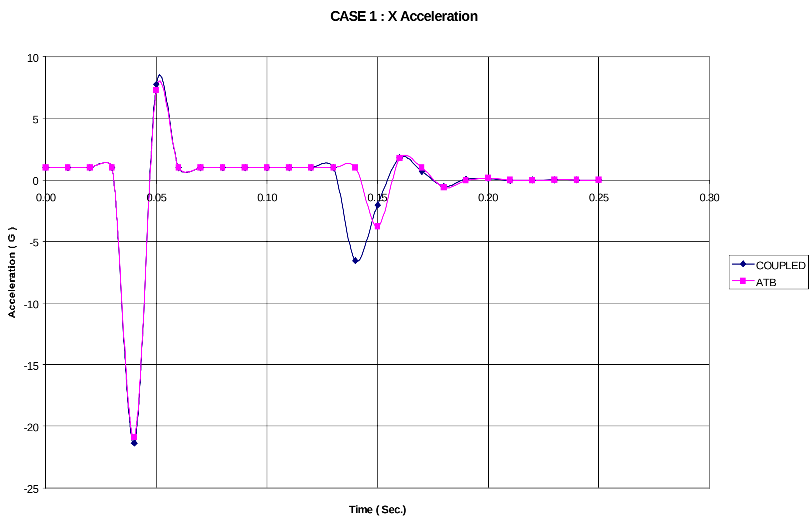

Figure 1b. Comparison of Z acceleration of the ball in ATB and the Coupled software.

Figure 2a shows the human dummy and seat modeled in ATB while the simulation is run using the coupled code with ATB input file. Figure 2b shows the same model run in ATB at the same time step (220 msec.). Figure 2c shows the comparison of X acceleration of Upper Torso of dummy in ATB alone and coupled code. The results match almost exactly.

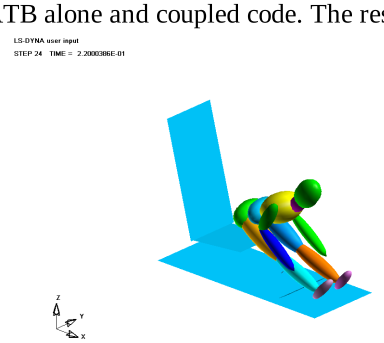

Figure 2a. ATB dummy, seat and motion with no seatbelt – Time step 220 msec.

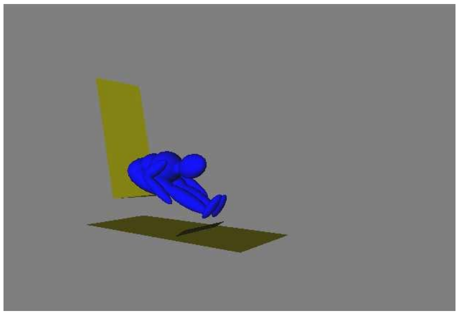

Figure 2b. ATB dummy and seat model simulated in ATB – Time Step 220 msec.

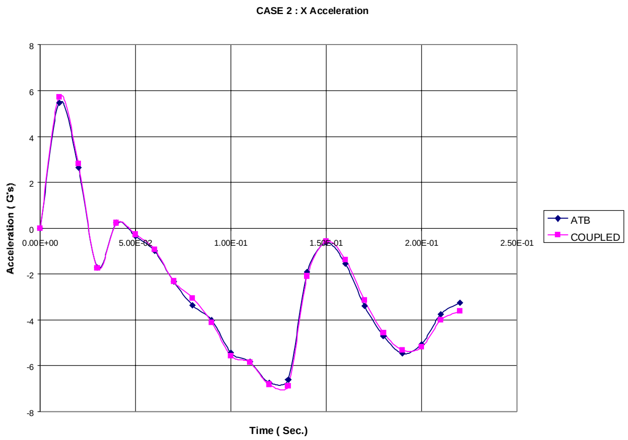

Figure 2c. Comparison of X acceleration of dummy's upper torso in ATB and Coupled software

Figure 3a shows ATB dummy, seat with LS-DYNA seatbelt when the simulation is run in coupled code. Figure 3b shows all dummy, seat and seatbelt modeled in ATB and run in ATB. The results of both the cases were compared by plotting X acceleration of Upper Torso of the dummy which is shown in figure 3c. Here the results show some difference, as seatbelts modeled in coupled code and ATB are not same, but the results show similar trend.

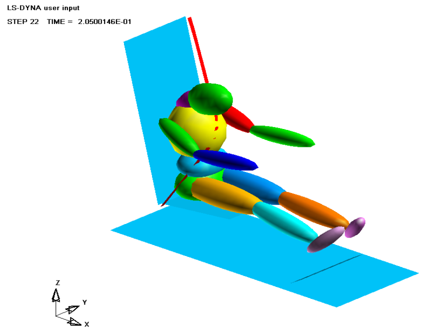

Figure 3a. ATB dummy, seat and motion with LS-DYNA seatbelt – Time step 200 msec.

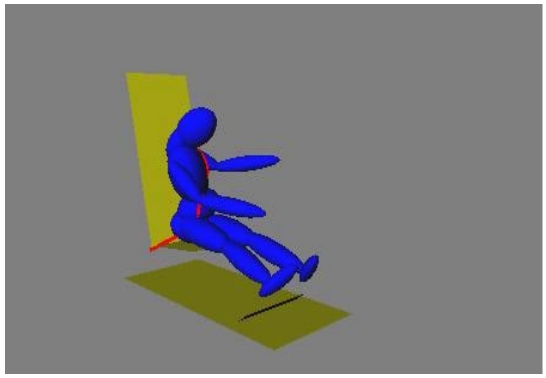

Figure 3b. ATB dummy, seat and seatbelt simulated in ATB program – Time step 200 msec.

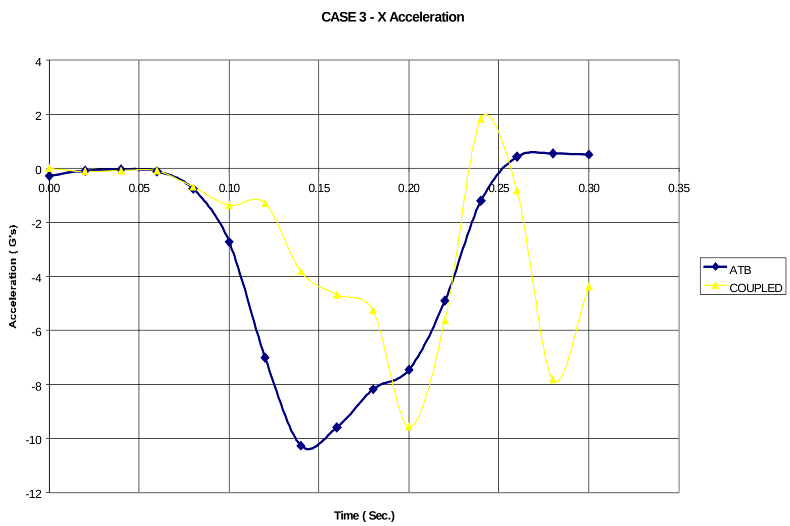

Figure 3c Comparison of X acceleration of dummy's upper torso in ATB and Coupled Software

Figure 4a shows the dummy and seat modeled in ATB and airbag modeled in LS-DYNA. As airbag-modeling capability is not available in ATB, the comparison of the data cannot be made. Figure 4b shows X acceleration of Upper Torso of the dummy only in coupled software.

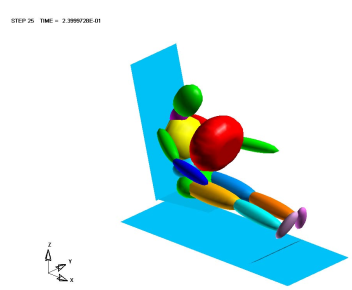

Figure 4a. ATB dummy, seat and motion with LS-DYNA airbag – Time Step 240 msec.

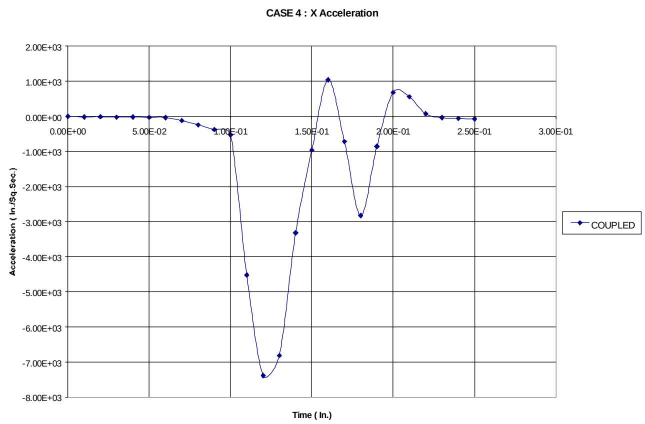

Figure 4b. Plot of X acceleration of dummy's upper torso in Coupled Software

Figure 5a shows the most complex model analyzed. It consists of the ATB dummy and seat with LS-DYNA seatbelt and airbag. In this case also, only ATB simulation cannot be run. Figure 5b shows X acceleration of Upper Torso of the dummy.

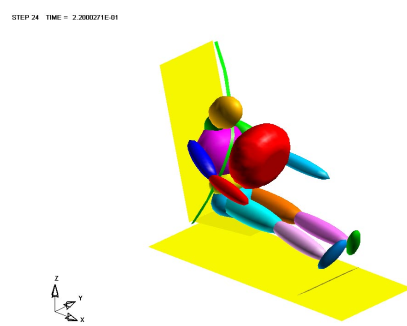

Figure 5a. ATB dummy, seat and motion with LS-DYNA seatbelt and airbag – Time step 22 msec.

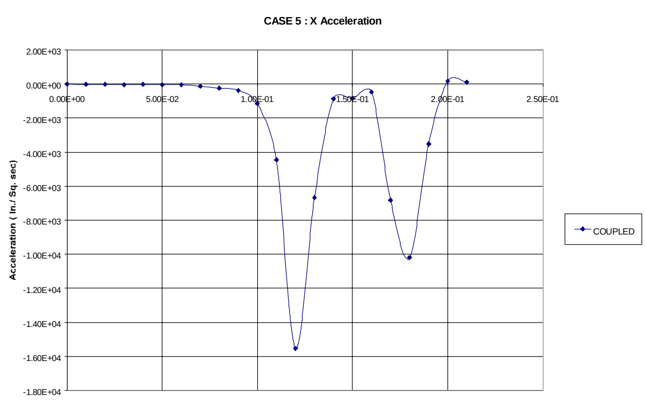

Figure 5b. Comparison of X acceleration of dummy's upper torso in ATB and Coupled Software

CONCLUSION

Initially, five separate cases were analyzed to compare the results and validate the integration of the two codes. For the validation, both the ATB and coupled code were used. The results were compared and were found to be within acceptable limits (first three cases). The results from the last two cases have to be compared with experimental data to validate the accuracy of the coupled code, since ATB cannot analyze models with airbags.

Currently, Ohio University is developing advanced models to demonstrate the capabilities of the coupled code and creating a database for airbags, seat systems, seatbelts and other restraints. A model database will be developed for the coupled code that will enable the user to choose a combination of objects from a range of seatbelts, seats and airbag models to carry out the analysis. This will help the user to optimize the selection of restraint systems and in turn develop safer automobile and aircraft interiors faster.

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