Finite Element Model Conversion from PAM-CRASH into LS-DYNA and Validation

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Abstract – This paper converts a passenger car's finite element model from PAM-CRASH model into LS-DYNA model using the HYPERMESH translator, and discusses the conversion method about PAM-CRASH and LS-DYNA finite element model. Since these two codes have different spot-weld, material, rigid body and beam format, this paper puts forward corresponding solutions and compares the simulation results of these two types of finite element model in the same impact condition in order to validate the conversion method. At present, PAM-CRASH and LS-DYNA are major finite element software in vehicle crash simulation worldwide, so the conversion method in this paper can be applied directly in converting other finite element model from PAM-CRASH model into LS-DYNA model systemically.

Keywords: LS-DYNA, PAM-CRASH, HYPERMESH, Finite element model, Model conversion

1 Introduction

Finite element analysis has proven to be a more powerful tool in analyzing various physical phenomenons. Finite element model of vehicle has increasingly played an important role in vehicle component design and vehicle crashworthiness evaluation in the design process. The different commercial finite element codes such as LS-DYNA and PAM-CRASH have widely taken part in the evaluation of full vehicle crashworthiness and component structural performance. Both of these two codes contain nonlinear, three dimension finite element codes for analyzing the large deformation dynamic response of elastic and inelastic structures using explicit time integration scheme[1]. The need to compare these different FEA codes has become more obvious.

Computer simulations of vehicle crash have developed significantly over recent years. With advances in computer technology and nonlinear finite element codes, full-scale models and simulations of such complicated phenomena are becoming possible. Finite element vehicle collision simulations have been primarily focused on the vehicle structure and their crash characteristics. Recently, refined finite element models of airbags and dummies have been incorporated in the simulations. Consequently, this allows direct evaluation of vehicle occupant risks and injuries using simulation results[2].

LS-DYNA is originated at the Lawrence Livermore National Laboratory. It is a general-purpose transient dynamic finite element program capable of simulating complex real world problems. The early applications were primarily for the stress analysis of structures subjected to a variety impact loading. LS-DYNA is widely used by the automotive industry to analyze vehicle designs. LS-DYNA accurately predicts a car's behavior in a collision and the effects of the collision upon the car's occupants. With LS-DYNA, automotive companies and their suppliers can test car designs without having to tool or experimentally test a prototype, thus saving time and expense[3].

PAM-CRASH is a software product of ESI group. The finite element program PAM-CRASH is an application-specific industrial software used to perform realistic and predictive virtual

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crashworthiness simulations in the transportation industry[4].

This paper describes the conversion method of FE models from PAM-CRASH code into LS-DYNA code, which is based on converting a finite element model of a popular passenger car in China from PAM-CRASH model into LS-DYNA model. The different spot weld, material, rigid body and beam models of FE codes, LS-DYNA and PAM-CRASH, were discussed in this paper. The simulation results in terms of the vehicle impact deformation, velocity and acceleration with different FE codes were compared in order to validate the conversion method[5]. The comparisons show good correlation with little discrepancy. The proposals for further application of the conversion method in this paper are also suggested at the end.

2 Finite Element Model Description

The vehicle finite element model used for this simulation and research was a popular passenger car in China. This FE model was developed for pole side impact. Consequently, the frontal and rear portion of the vehicle model will not undergo large deformation in such an impact condition. Some components were omitted to reduce the calculation time with the mass compensation, which did not affect the accuracy of the simulation results. On the other hand, the side structure of the vehicle was modeled in detail and included a refined mesh.

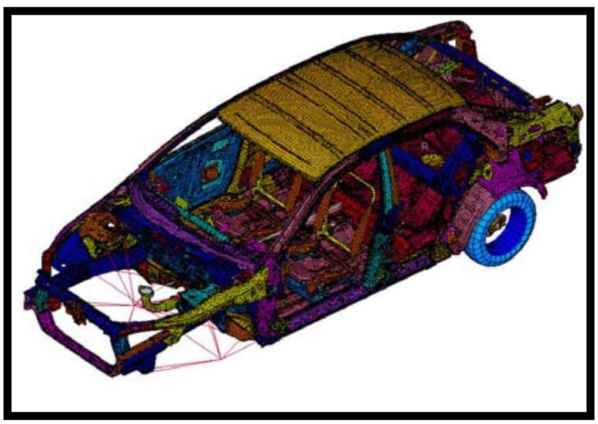

Fig.1 FE model of a popular passenger car in China

The vehicle FE model consisted of 557 parts and contains 329863 nodal points and 329788 elements. Most of the vehicle model was composed of Belyschko-Tray shell element, and other parts were made of Hughes-Liu with cross section integration beam element. 553 components in this model were made of general isotropic elasto-plastic materials, 1 component was made of isotropic elastic material. Spot welds and rigid body constraint formulations were used to connect the various vehicle components. There were no boundary conditions in this vehicle FE model.

Table 1 Vehicle FE model description of PAM-CRASH code

PAM-CRASH				
NODE	ELEMENT	MATERIAL	PROPERTY	CONSTRAIN
Nodal point Number: 329863	Shell Element Number:323795	MATERIAL TYPE 102 (Elastic-Plastic for Shell Elements)Number: 553	Shell thickness Number: 553	Rigid bodys Number: 369
Nodal mass Number: 5891	Spotweld Element	MATERIAL TYPE 201 (Elastic for Beam and	Cross sectional area	Sliding interfaces Number: 896

	Number: 5967	Bar Elements)Number: 1	Number: 1	
N/A	Bar element Number: 26	N/A	N/A	N/A

3 General FE Model Conversion Methodology From PAM-CRASH into LS-DYNA

HYPERMESH is a software product of Altair Corporation in USA. It is a high-performance finite element pre- and postprocessor for popular finite element solvers - allowing engineers to analyze product design performance in a highly interactive and visual environment.

HYPERMESH provides a convert environment from PAM-CRASH FE model into LS-DYNA FE model. In this research, HYPERMESH plays a connector role between PAM-CRASH codes and LS-DYNA codes. There is no doubt that HYPERMESH is not the only conversion software for these two FE codes. Whilst, there are also some flaws of HYPERMESH as a convert environment which deserve further research.

3.1 Proper conversion of the FE model from PAM-CRASH to LS-DYNA

3.1.1 The automatic conversion of FE model from PAM-CRASH into LS-DYNA

(1) Importing the PC file of PAM-CRASH FE model into HYPERMESH directly.

(2) Changing the solver from PAM-CRASH to LS-DYNA in HYPERMESH environment, and then export the FE model of LS-DYNA format with K file.

Automatic conversion of FE model was accomplished through above two steps. This was the first and easiest step.

3.1.2 The model issues of PAM-CRASH and LS-DYNA two FE codes in automatic conversion

There were some model issues in automatic conversion because of different formats in these two FE codes as following:

(1) The spot welds in the FE model were completely failed in automatic conversion

(2) Part of the materials in the FE model were failed in automatic conversion

(3) The rigid bodies in the FE model were completely failed in automatic conversion

(4) The beam format in these two FE code was incompatible in automatic conversion

3.1.3 The conversion of spot welds from PAM-CRASH into LS-DYNA

(1) The spot welds information should be extracted from PC file of the PAM-CRASH model and translated to MCF file. The MCF file is a kind of ASCII file which contains spot welds ID, the component connected by the spot welds number and ID and three coordinates of the spot welds.

(2) Import the MCF file into HYPERMESH in terms of CONNECTOR format, and then realize the connectors into spot welds in the HYPERMESH environment using the REALIZE function in HYPERMESH.

(3) All the spot welds connecting more than two components in PAM-CRASH FE model were failed in above two steps, these spot welds should be manually added into FE model correspondingly.

(4) All spot welds connecting two components automatic converted in HYPERMESH by importing and realizing adopted the mode of SPOTWELD&PLOTEL. The PLOTEL of element is defined as a null beam for visualization and no practical sense[3]. AS a result, the mode of spot welds should be changed from SPOTWELD&PLOTEL to only SPOTWELD.

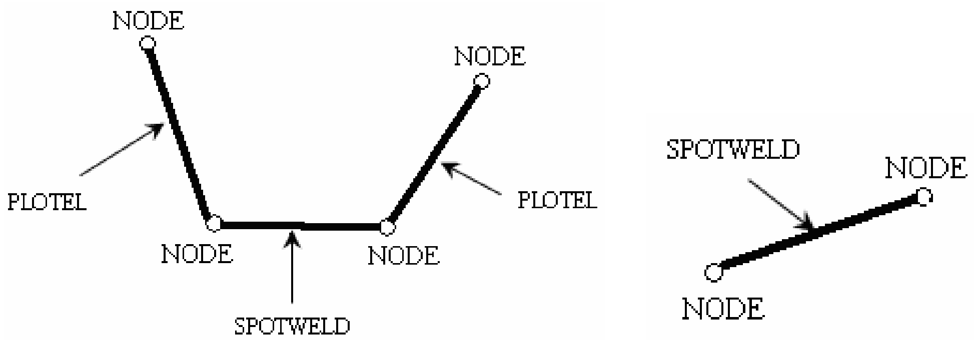

Fig. 2 The spotweld mode of SPOTWELD&PLOTEL and only SPOTWELD

(5) The spot welds connecting two components automatic and translated in HYPERMESH automatically by importing and realizing the CONNECTOR maybe occupy the same node which is not allowed in LS-DYNA algorithm. Consequently, the spot welds occupying a common node should be manually spitted.

3.1.4 The conversion of materials from PAM-CRASH into LS-DYNA

In the K file of LS-DYNA FE model automatic converted from PAM-CRASH model directly, only part of information about materials such as materials ID, mass density, Yong's modulus and Poisson's ratio were reserved. Nevertheless, other part of materials information of the FE model was failed in the automatic conversion.

(1) The materials information should be extracted from the PC file of PAM-CRASH FE model, including materials ID, mass density, Yong's modulus, Poisson's ratio, the first and the second strain rate parameter and the parameters for defining effective stress versus effective plastic strain.

(2) The different FE codes of PAM-CRASH and LS-DYNA have different manners to define the stress versus strain curve. In PAM-CRASH codes, the stress versus strain curve is defined by the type of the materials function and corresponding parameters[4]. In LS-DYNA codes, the stress versus strain curve is defined by a array of stress versus strain value[3]. As a result, the appropriate array of stress versus strain should be added into K file directly.

3.1.5 The conversion of rigid bodies from PAM-CRASH into LS-DYNA

There are two formats of rigid body in PAM-CRASH FE model as "RIGBO" and "RBODY"[4]. In LS-DYNA FE model, rigid body is defined in terms of constrains in most occasions, whose keyword is "CONSTRAINED_NODAL_RIGID_BODY"[3]. The nodes connected by one rigid body comprise a node set.

3.1.6 The conversion of beam elements from PAM-CRASH into LS-DYNA

After importing the PC file of PAM-CRASH FE model into HYPERMESH, changing the solver and exporting the K file of LS-DYNA FE model, the elements of BAR in the PC file were changed to the elements of SEATBELT in the K file. As a result, the format of SEATBELT elements should be manually modified in the K file.

(1) The BAR ID, the component ID which the BAR belongs to and the node ID connected by the BAR should be extracted from the PAM-CRASH FE model and manually added into K file of LS-DYNA model.

(2) The K point should be defined for the element of beam in LS-DYNA FE model. The K point should be not on the element of beam itself. The K point of beam is a special parameter in LS-DYNA code, which is always no use for tubular beam simulation[3]. Consequently, it is reasonable to define the K point in the border of the vehicle model such as the top of the A pillar of the vehicle FE model in this paper.

3.2 The manual correction of LS-DYNA FE model

After completing the conversion of the FE model as above steps, it was necessary to correct some minor and specific errors for the uniqueness of LS-DYNA code algorithm in order to make successful pass of the FE model in LS-DYNA solver.

3.3 Normal execution of FE model in LS-DYNA solver

The LS-DYNA FE model was able to be normally computed with LS-DYNA MPP (Massively Parallel Processors) 970 version code in multi-nodes MPP computing environment through the appropriate conversion and correction of the FE model.

4 Summary

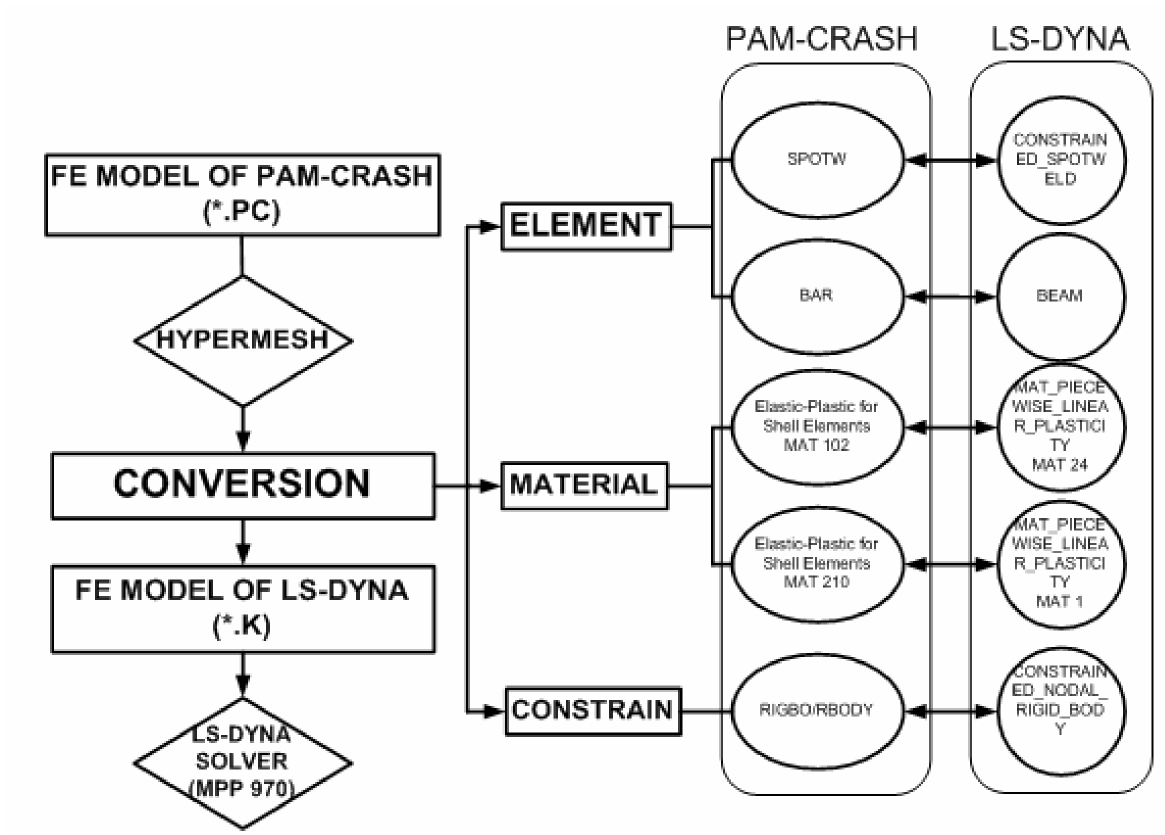

Fig.3. The flow chart of the FE model conversion from PAM-CRASH to LS-DYNA

5 Results and Disscusion

5.1 The comparison of the different FE codes simulation results with test

To perform pole side impact simulations, the boundary conditions of the simulations were as following:

(1) A cylinder rigid wall acting a fixed rigid pole with 0.3 friction coefficient
(2) Single surface contacts enveloping every component of the vehicle with 0.3 friction coefficient
(3) Initial velocity of 29 Km/h for all the nodes of vehicle[6]
(4) Other global constant parameters for two explicit codes were checked to be consistent.

In this research, the version of PAM-CRASH code was PAM-CRASH 2G; and the version of LS-DYNA code was LS-DYNA MPP 970 which was provided by ANSYS China.

Both the test and simulations were conducted according to EUROPEAN NEW CAR ASSESSMENT PROGRAMME POLE SIDE IMPACT TESTING PROTOCOL (VERSION 4.1).There was an accelerometer on the unstruck B-post of the vehicle in the pole side impact experimental test and simulations, and the accelerometer is to be fitted in the lateral direction[6]. Besides, the velocity was derived from the acceleration integration and the maximum intrusion of the side structure of the test vehicle was also compared with the simulation results.

The results of FE model simulations and vehicle experimental test were as following:

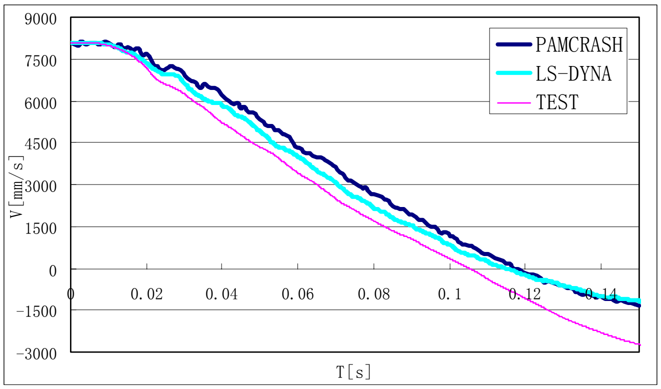

Fig. 4 Vehicle velocity comparison

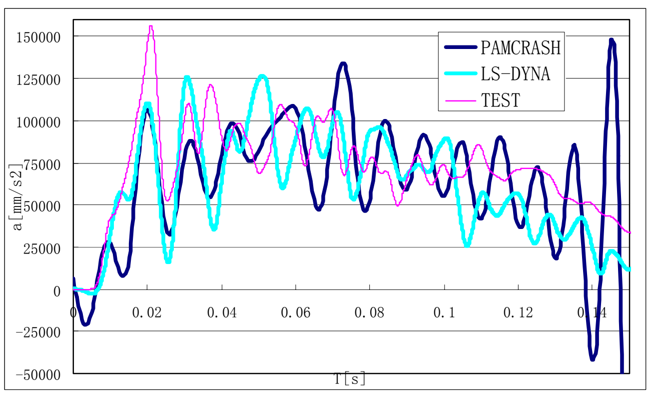

Fig. 5 Vehicle acceleration comparison

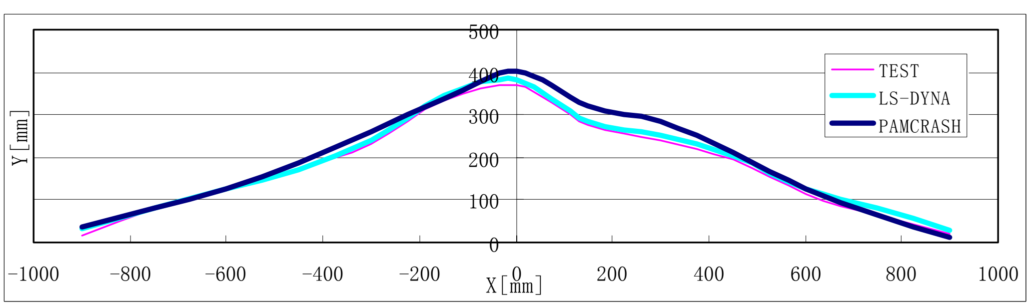

Fig. 6 Vehicle maximum deformation of side structure comparison

5.2 Discussion

From the PAM-CRASH and LS-DYNA FE models simulations and test results, the results of these two FE codes show good correlation with each other and the vehicle experimental test. The good agreement of the two FE codes simulation confirms that the conversion method proposed in this paper ensures the consistence of the FE model of PAM-CRASH and LS-DYNA format. Consequently, the conversion method in this paper is validated through the comparison of the simulations and vehicle test results, so the corresponding conversion method can be applied directly in converting other finite element models from PAM-CRASH model into LS-DYNA model systemically.

6 Conclusions

The pole side impact simulations of FE model of a popular passenger car in China were performed using LS-DYNA and PAM-CRASH of MPP version. The vehicle dynamic responses of the simulation results, including velocity, acceleration of certain point of the vehicle and the maximum deformation of the vehicle side structure, were compared with the test. The conclusions are drawn as following:

1. General conversion methodology of FE model from PAM-CRASH into LS-DYNA can be briefed as following:
   1) Getting initial FE model which is PAM-CRASH format
   2) Converting the FE model completely including the elements, materials, properties, constrains and boundary conditions
   3) Correcting the LS-DYNA FE model errors converted from PAM-CRASH model
   4) Executing the LS-DYNA FE model successfully with LS-DYNA solver in MPP computing environment
   5) Comparing the simulation results of two codes with experimental test results to validate the conversion method if necessary
2. In the conversion of FE model from PAM-CRASH to LS-DYNA, most work can be done automatically in HYPERMESH. Nevertheless, an extent of manual modification and conversion is necessary because of the incompatibility of these FE codes.
3. The suitable conversion method is able to assure good consistence of the FE model in PAM-CRASH and LS-DYNA format.
4. Vehicle dynamic responses from simulation of PAM-CRASH and LS-DYNA, such as vehicle velocity, acceleration and deformation, show good correlation with experimental data

7 REFERENCES

1. Kiran Solanki, D. L. Oglesby, G. L. Burton, H. Fang and M. F. Horstemeye. “Crashworthiness Simulations Comparing PAM-CRASH and LS-DYNA”. CAE Method for Vehicle Crashworthiness and Occupant Safety, and Safety-Critical Systems. SP-1870. Page 11~19. 2004
2. Honglu Zhang, Srini Raman, Madana Gopal and Taeyoung Han. “Evaluation and Comparison of CFD Integrated Airbag Models in LS-DYNA, MADYMO, PAM-CRASH”. CAE Method for Vehicle Crashworthiness and Occupant Safety, and Safety-Critical Systems. SP-1870. Page 91~101. 2004
3. LS-DYNA Version 970 Keyword User’s Manual. Livermore Software Technology Corporation. 2876 Waverley Way, Livermore, California, USA. April 2003
4. PAM-CRASH PAM–SAFE Reference Manual Version 2000. Pam System International. 20, rue Saarinen, Silic 303, 94588 Rungis-Cedex, France. 2000
5. C.C.Chou, P.Chen, and J.Le. “A Benchmark Study of CAE Sensor Modeling Using LS-DYNA”. 8th International LS-DYNA Users Conference. 2004
6. EuroNCAP POLE SIDE IMPACT TESTING PROTOCOL Version 4.1, March 2004