Numerical Simulation of Car Crash Analysis Based on Distributed Computational Environment

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Abstract: Automobile CAE Software is mainly used to assess the performance quality of vehicles. As the automobile is a product of technology-intensive complexity, its design analysis involves a broad range of CAE simulation technique. An integrate CAE solution of automobiles can include comfort analysis (vibration and noise analysis), safety analysis (car body collision analysis), process-cycle analysis, structural analysis, fatigue analysis, fluid dynamics analysis, test analysis, material data information system and system integration. We put an emphasis on simulation of a whole automobile collision process, which will bring a breakthrough to the techniques of CAE simulation based on high performance computing. In addition, we carry out simulation for a finite-element car model in a distributed computation environment and accomplish coding-and-programming of DAYN3D is accomplished. We also provide computational examples and user handbook. Our research collects almost ten numerical automobile models such as Honda, Ford and etc. Moreover, we also deal with different computational scales for the same auto model and some numerical model of air bag is included. Based on the numerical auto model, referring to different physical parameters and work conditions of auto model, we can control physical parameters for the numerical bump simulation and analyze the work condition. The result of our attempt conduces to the development of new auto models.

I. INTRODUCTION

In keeping up with international standards, the research on the collision process of car body structure is indispensable. Autos composite collision, transient and response process can be derived from highly nonlinear transient dynamics. So an explicit finite element program of nonlinear dynamical analysis can successfully solve nonlinear contact, nonlinear shock load and nonlinear material caused by high-speed collision of car body structure.

Three-dimensional DYNA3D collision analysis program derives itself from two-dimensional DYNA2D program, which has experienced those versions over the years of 1984, 1987, 1992, 1995 and so on. The latest DYNA3D now takes more factors into account, such as large deformation, non-elastic material and contact slide boundary. Developing rapidly and being increasingly powerful, it has become a general collision analysis program. Since 1995, DYNA3D has been applied to the concurrent computational program in some vector computers. DYNA3D Version 92 is an explicit nonlinear finite element program for analyzing transient dynamical response of three-dimensional solid and structures. The element units in the program include one-dimensional beam element, two-dimensional quadrilateral element and triangular element and three-dimensional solid element, altogether four categories of elements. DYNA3D program can effectively describe thirty material models' functions. It is suitable for the model which is elastic or plastic when compound substance is used, and heating effect and load rate is considered. The models are follow-up/isotropic, elastic-plastic, thermo-elastic-plastic, soil, linear viscoelastic, gum-elastic, high-energy dynamite combustion, elastic-plastic fluid or geological model, etc. In addition, there are ten state equations that can be chosen to fit some kind of material model. As we dispose all of the element units with simple methods, it is applicable to rigid material simulating rigid kinetics, and to rigid material precisely describing geometrical and mass distribution of complex substance. So the units in the program are also suitable for large strain, great rotate condition, nonlinear material condition and rigid body. In particular, the program is unique in dealing with frictional slide and uni-surface contact. It can be used to assess the force between two independent objects or between any two mechanical links in the same object. The program includes eleven unique contact-collide algorithms, six methods of attachment and shell unit node-entitative node connection. They can make up all kinds of complicated engineering structure and can be used in collided and explosion load computation, collide-contact problems and so on.

Proceedings of the Fifth International Conference on Algorithms and Architectures for Parallel Processing (ICA3PP'02)
0-7695-1512-6/02 $17.00 © 2002 **IEEE**

II. DYNA3D REVIEW

DYNA3D program consists of seven sections, the whole technological process is shown in Figure 1.

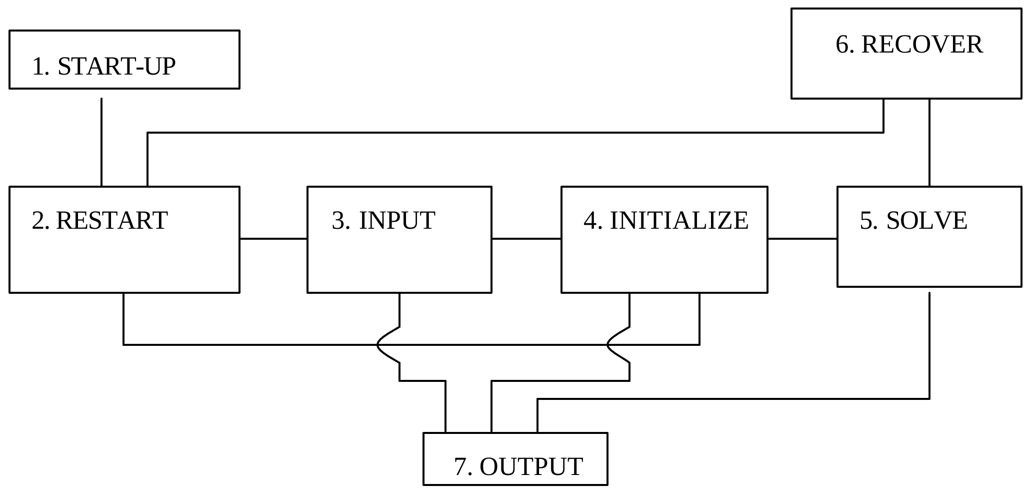

Figure 1: Brief job flow of DYNA3D.

III. DYNA3D PARALLELIZATION

As to massive parallel program, the existing solution is to use automatic area and grid division techniques so it becomes parallel explicit finite element program. Every processor needs only very little communication with other processors but can process much more work.

Generally the simulation model for the whole auto collision is very large. We have made numerical simulation of Honda model collision on single processor using Version 92 DYNA3D program. The whole model has 8112 nodes, 1440 solid elements, 91 beam elements, 6005 shell elements, and the whole simulation process lasts about the order of 10 hours. It is evident that the efficiency of single processor is relatively very low, so we work on a massive parallel computer, Dawning-2000, in National High Performance Computing Center (Shanghai) and make improvement on Version 92 DYNA3D Fortran source code.

The whole auto model mainly consists of beam elements, shell elements, solid elements and discrete elements, and most are shell element. Therefore, most of the computational quantity of numerical simulation comes from the computation of shell elements. As each shell element is independent from each other, so the computation of shell elements in DYNA3D program can be paralleled. The following shows the structured flowchart of shell-element computation subprogram in DYNA3D program.

IV. NUMERICAL RESULTS

Figures 3 and 4 show at different time ending collision simulations of Honda Model on Dawning-2000 (National High Performance Computing Center, Shanghai).

V. NUMERICAL RESULTS BY LS-DYNA3D

Figure 5 shows the comparison of time spent on Ford Model computation using different number of nodes on Dawning-2000, in National High Performance Computing Center (Shanghai). Figures 6 and 7 show simulating results of Ford Model, front collision and 50% front offset collision respectively. The results come from the output of LS-DYNA on Dawning-2000.

VI. CONCLUSION

With the help of Dawning-2000 and DYNA3D program, our research leads to the simulation results of auto collision. To establish research and to develop high performance grids which can be applied to advanced manufacturing industry in our country will help to establish a public computational environment for high performance computer-aid design and numerical simulation needed by advanced manufacturing industry in our country. Moreover, it will help resource sharing of high performance computers in a relatively large scope. Using advanced techniques can improve the scientific standard of advanced manufacturing industry in our country and so shorten the gap between industrial advanced countries.

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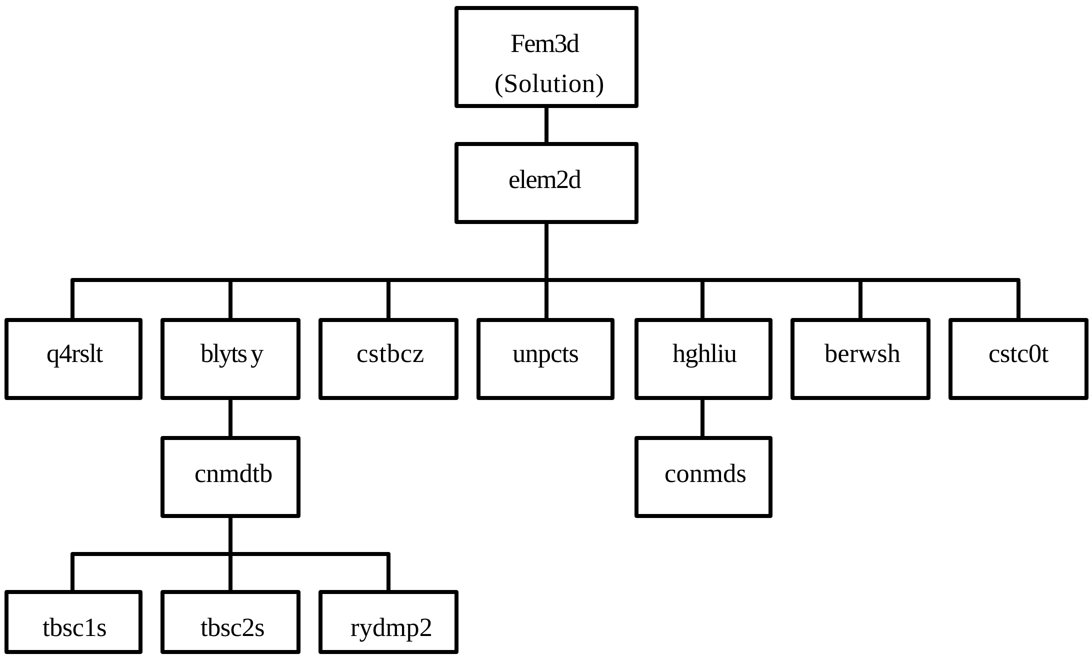

Figure. 2: The core substructure of DYNA3D solution.

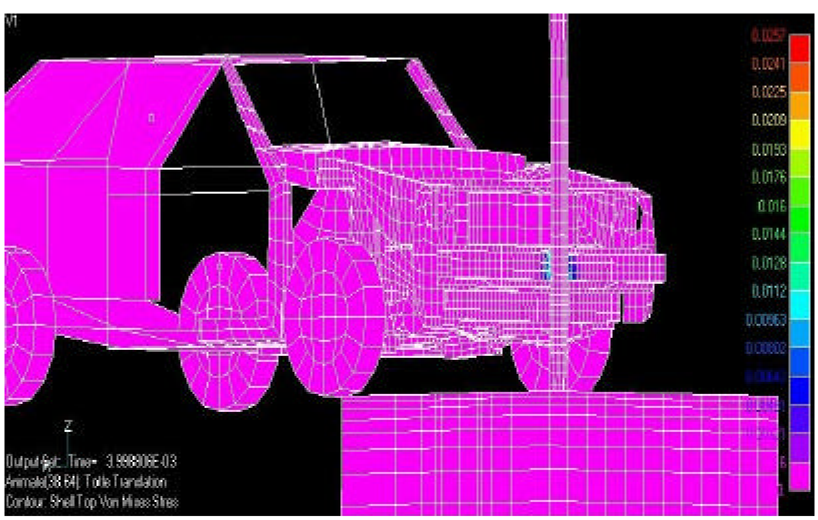

Figure 3. Honda's crash at t=0.004 second.

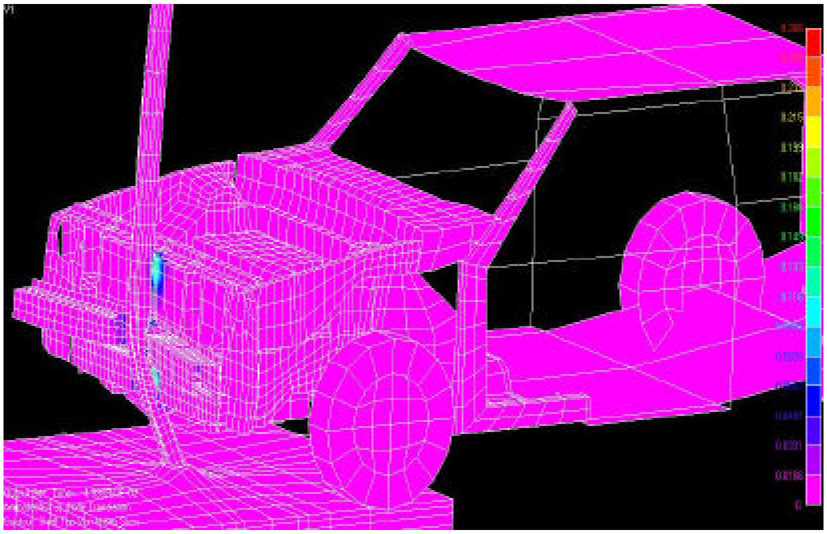

Figure 4: Another Honda's crash at t=0.05 second.

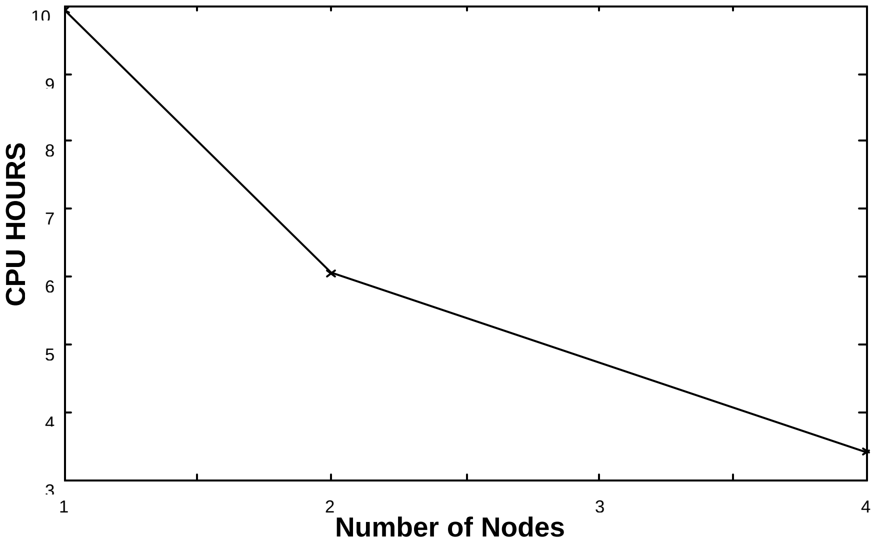

Figure 5: CPU hours of LS-DYNA simulation for different number of nodes on Dawning-2000

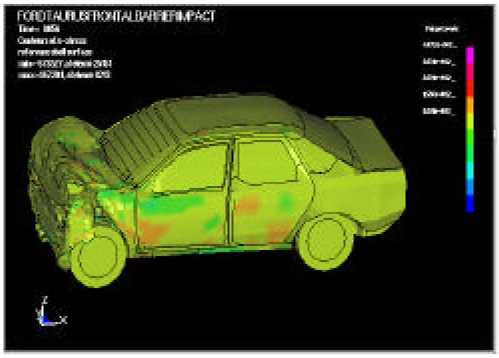

Figure 6: Front Crash.

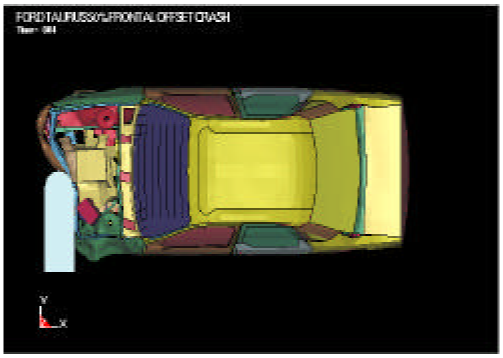

Figure 7: Offset Crash.