Evaluation of Performance, Reliability, and Consistency of MPP Version of LS-DYNA

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Abstract

This paper reports the on-going evaluation of the current distributed memory (MPP) versions of LS-DYNA by using set of large size vehicle finite element models with number of elements ranging from 200,000 to 380,000. The evaluation focuses on the scaling performance, reliability, and consistency of the MPP code.

Introduction

The performance of the massive parallel processing (MPP) version of LS-DYNA, which is based on message-passing and domain-decomposition programming, and its comparison with symmetric multi-processing (SMP) version of LS-DYNA have been reported in the LS-DYNA user community [1-7]. Over the past few years, the major issues relating the performance of MPP version of LS-DYNA center on the issues of scalability, reliability, and repeatability of the code. At the same time, the performance of the symmetric multi-processing (SMP) version of LS-DYNA, which is based on shared-memory and multi-threaded programming, has produced consistent and reliable results as well as reasonable speedup on up to 8 processors [5-7]. However, for larger size and more sophisticated models, MPP version of LS-DYNA offers better speedup and turnaround run time [5-7].

This paper evaluates the performance of current MPP version (version 940) of LS-DYNA code on a high-performance computer system using a large-size finite element vehicle models. Two simulation case studies with finite element models of 380,000 elements are carried out. The MPP version of LS-DYNA is used to simulation of vehicle-to-vehicle and vehicle-to-roadside hardware crash/impact events up to 150 and 50 milliseconds, respectively.

Simulation Cases and Finite Element Models

Simulation Cases – Two simulation cases are used for the evaluation of the performance of MPP version of LS-DYNA code. The first case involves the simulation of vehicle-to-vehicle offset impact with each vehicle traveling at 35 mph impact speed in the opposing direction. The second is the simulation of vehicle-to-roadside hardware impact at 60 mph impact speed.

Finite Element Models – The finite element models used in the first simulation case is the Chevy C-1500 pickup truck and Dodge Neon compact passenger car. Both models were developed at the FHWA/NTSA National Crash Analysis Center at the George Washington University [8,9]. Since these models, particularly the Neon model were developed for multiple impact application purposes, greater efforts were devoted to include all the geometric detail of the vehicle into the finite element models. The model information of these finite element models is summarized in Tables 1 and 2 for Chevy C-1500 and Dodge Neon, respectively. Figure 1 shows the isometric views of these vehicle models individually while Figure 2 shows both vehicle models in the offset frontal impact configuration.

Table 1. FEM Information of C-1500 Pickup

Parts	217
Nodes	61,304
Solid Element	3,358
Beam Element	184
Shell Element	50,428

Table 2. FEM Information of Neon

Part	323
Nodes	285,634
Shell Element	267,847
Beam Element	67
Solid Element	2,860

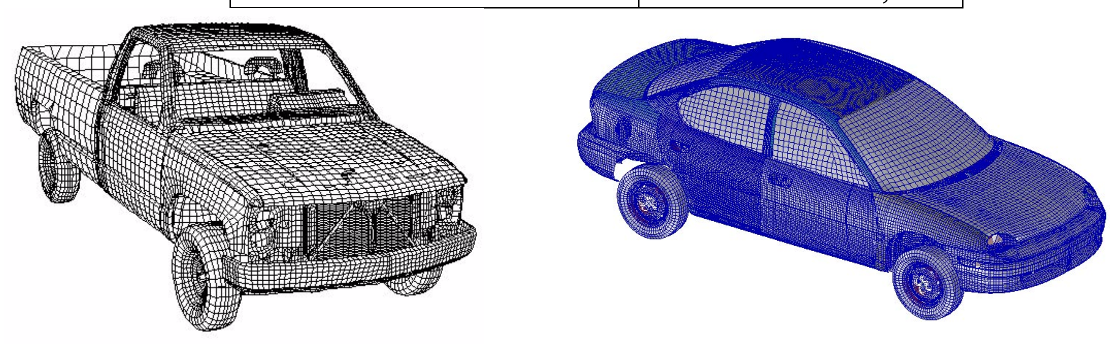

Figure 1. Isometric View of the Chevy C-1500 and Neon Finite Element Models

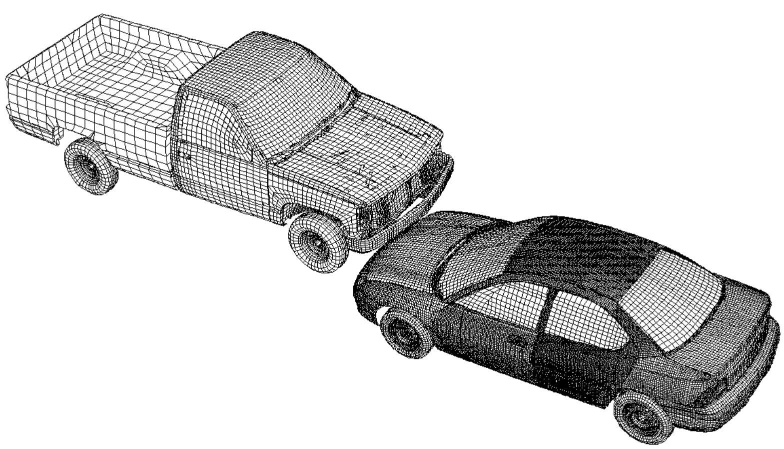

Figure 2. Chevy-to-Neon Frontal Offset Impact Model

The second simulation case involves the vehicle impacting to a roadside hardware, a seven-foot height breakaway sigh support. The vehicle model used in this case is the Dodge Caravan. The finite element model of the vehicle was also developed at NCAC for the purpose of multiple impact applications [10]. The finite element mesh sizes were kept uniform throughout the entire vehicle. The average mesh size in this model was maintained at about 12 – 15mm. The finite element model information is summarized in Table 3 whereas Figure 3 shows the Dodge Caravan vehicle model.

Table31. FEM Information of Caravan

Parts	539
Nodes	381835
Number of shells elements	330,582
Number of beam elements	130
Number of solid elements	6,253

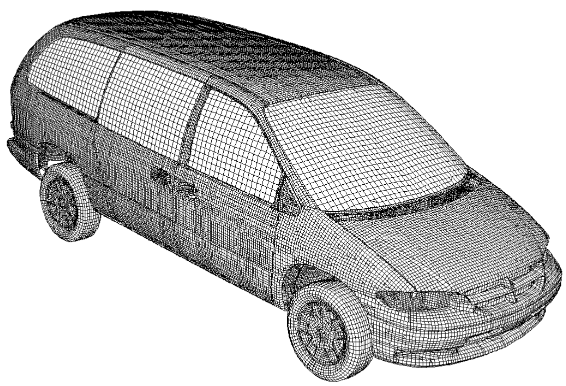

Figure 3. Isometric view of the Neon finite Element Model

Simulation

Current production version of MPP LS-DYNA is used to carry out these two cases simulation on a Hewlett-Packard V class (V2500) computer system. Figures 4 and 5 illustrate the initial and deformed states of the simulation. The first case was simulated for 150 milliseconds of impact event while the second case for 50 milliseconds. Figures 4 and 5 illustrated the vehicle models in the two simulation cases at their initial and deformed states, respectively.

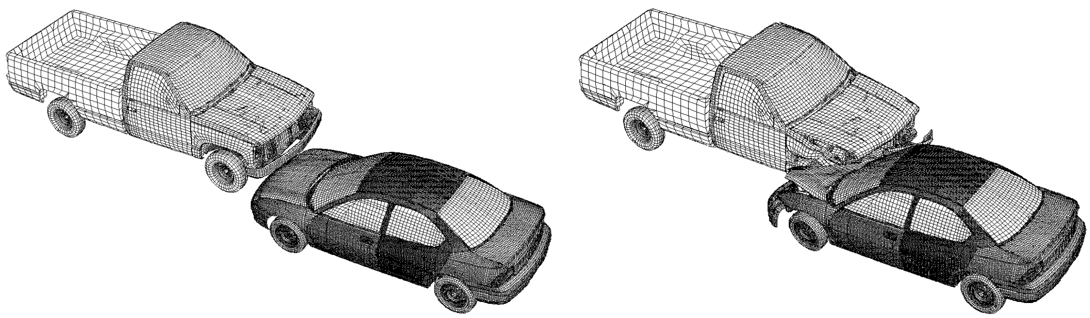

Figure 4. Initial and Deformed States for Case 1 Simulation

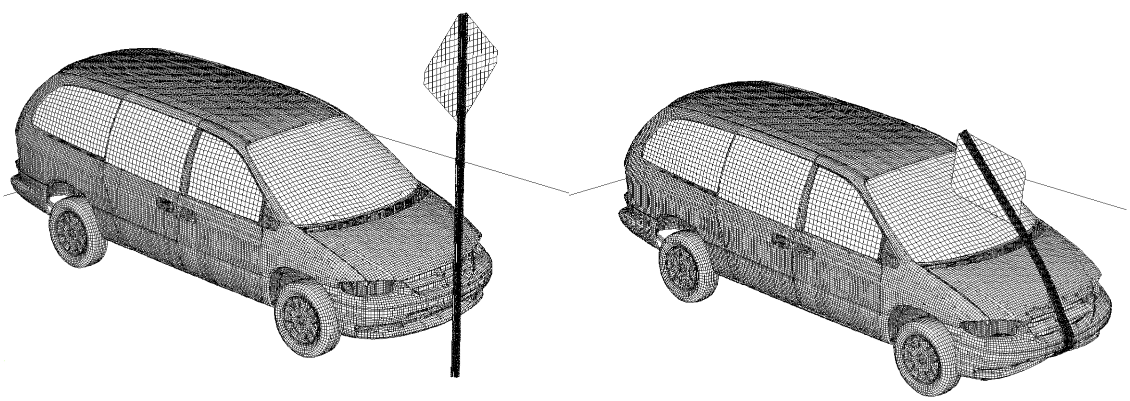

Figure 5. Initial and Deformed States for Case 2 Simulation

Discussion of Simulation Results

<u>*Performance of MPP*</u> – Simulation runs using MPP versions with 1, 2, 3, 4, 5, 6, 7, and 8 CPUs were carried out on the 8-CPU HP V2500. Figures 6 and 7 shows the comparison of CPU timings of using different number of CPUs, respectively. The scaling of using different number of CPUs is plotted in Figure 8 and 9 for these two cases, respectively. In both simulation cases, it can be observed that the scalability of the CPU timing improves as number of CPU is increased. It is also interesting to note that for second case, the scalability was rather flat between two to five CPUs but started to improve as the number of CPU exceeds five.

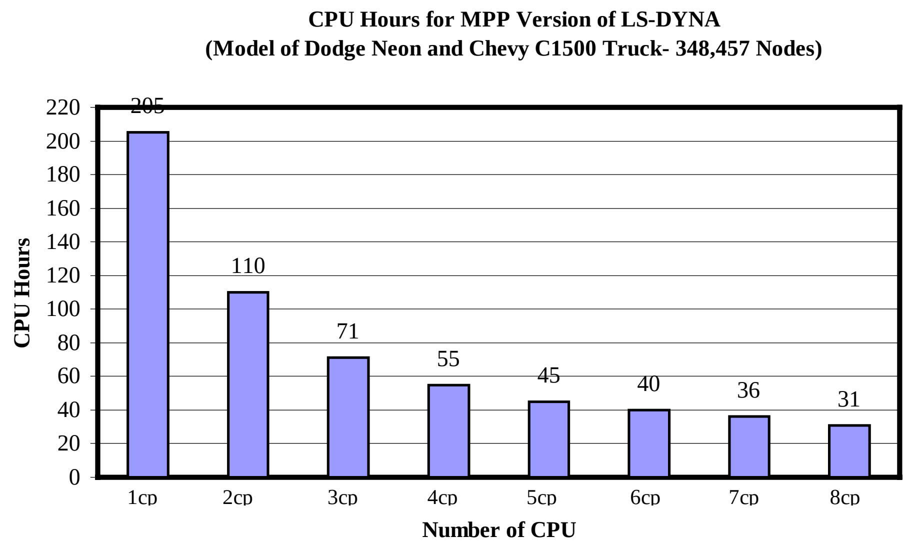

Figure 6 Comparison of CPU Timing for Case 1

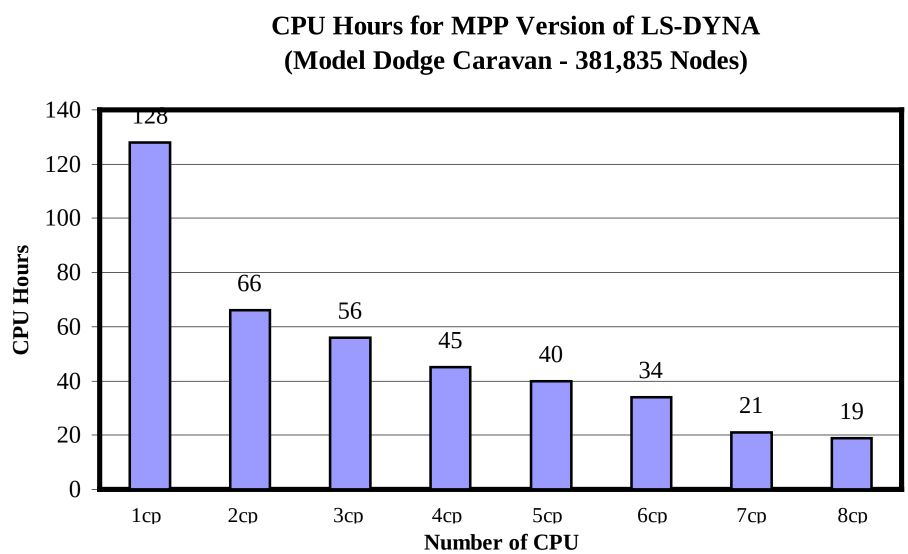

Figure 7 Comparison of CPU Timing for Case 2

While the maximum number of CPU used in this study is limited to eight it is expected that the scalability will further improve with larger number of CPUs based on our previous findings [7]. Compared with previous studies, it is observed that the performance in terms scalability improved with the models used in this study. This is expected since MPP version should scale better for larger size models used in this study

(380,000 elements) versus previous study (270,000 and 52,000 elements). It should be interesting to ascertain the speedup of MPP version beyond eight CPUs, which is not available at the time this paper is prepared.

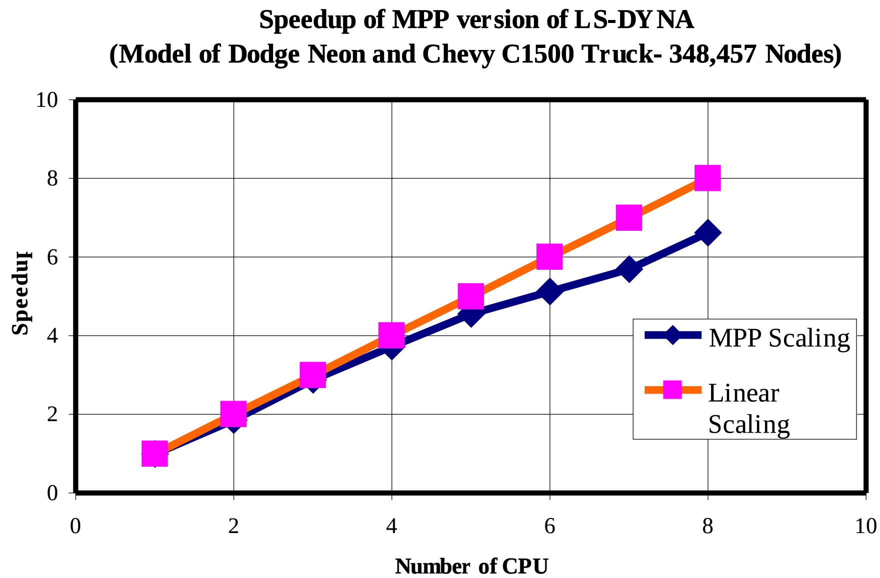

Figure 8. Scaling of MPP 940 for Case 1

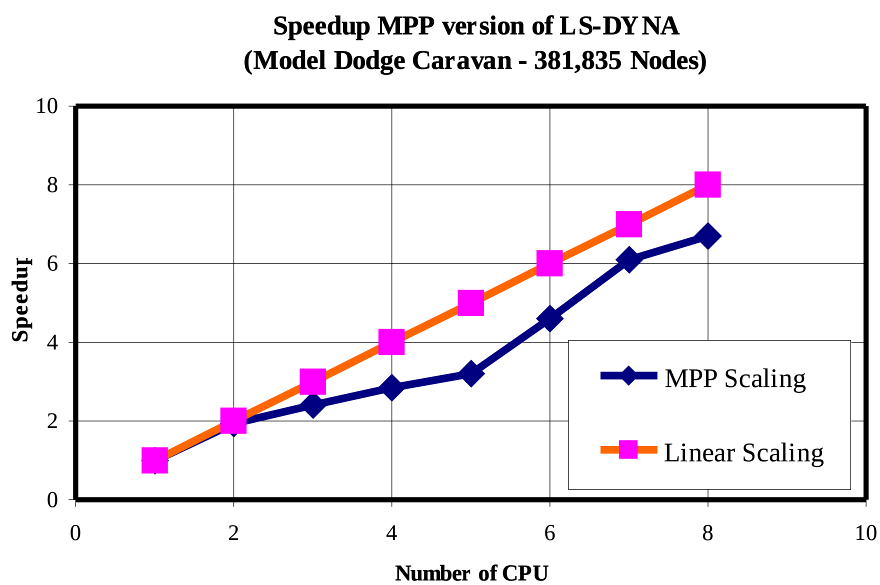

Figure 9. Scaling of MPP 940 for Case 1

<u>*Accuracy, Consistency and Reliability*</u> – Repeatability of the MPP version has been improved over the past few years as also observed in this study. The comparison of certain acceleration results using different number of processors for MPP version showed relatively lower consistency. While improvement has been made in the past few years on

consistency issue, this still remains to be a critical issue that needs to be resolved by software developers.

<u>*Comparison between MPP and SMP*</u> – Although direct comparison between MPP and SMP versions of the code is not included in this paper, several runs using SMP were carried out. It was observed that when smaller number of CPUs is used the SMP version actually outperforms the MPP version, which is consistent with the previous findings [7]. However, MPP version offers better performance in terms of CPUs timing and scalability when more that six CPUs are used.

Summary

The MPP versions of LS-DYNA are used for two case study of simulation of crash/impact events up to 150 milliseconds. Large size finite element vehicle models, up to 380,000, were used in both cases. The performance of MPP version is evaluated in terms of CPU timings, scalability, consistency and reliability.

While performance of the current SMP version showed significant improvement in terms of CPU timing and scalability, MPP version has shown maturity in terms of consistency and reliability. When same large numbers of CPUs are used, MPP version out perform SMP version in those aeras. However, the fact that MPP is running considerably slower than SMP, when the number of CPUs is small, indicates additional improvements are still needed.

Reference

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