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Stamping Simulation in Pentium PC & Linux Environment

K.P. Li, R. Costello, C. Wang, J. An, T. Sreekanth, L. Zhang
DaimlerChrysler Corporation

P. Zaboulakis
Hewlett Packard

ABSTRACT

This paper describes the performance improvement and cost savings achieved by the Stamping Technology Department at DaimlerChrysler Corporation (Chrysler group), in migrating from Unix workstations with RISC technology to Linux PCs with Intel Pentium technology. Performance comparisons of various engineering applications running on these two system configurations are analyzed. The major aspects such as hardware configuration, operating system, software availability, compatibility, reliability, accuracy and consistency of simulation results are discussed.

The improvement in computing speed and deviations in simulation results between MPP LS-Dyna and SMP LS-Dyna are presented.

1. BACKGROUND

Applications of finite element simulation technology in various phases of engineering development such as product design, optimization, sheet metal formability, crashworthiness, NVH etc., have become increasingly important in the automotive industry. Thanks to the remarkable progress in FEA technology in recent past, companies around the globe are replacing costly physical prototyping and testing with FEA simulations. The continuously increasing dependence on simulation has necessitated faster, more reliable and accurate solutions.

Stamping Technology Department at DaimlerChrysler has been applying FEA simulation technology in sheet metal stamping tool developments since 1992. The team has established a strong reputation in the industry for technological innovations and application of state-of-the-art FEA know-how in stamping production environment. The department has primarily been using Unix-based workstations with RISC processors over the past decade. To support the corporate cost cutting efforts initiated in the first quarter of 2001, each department has been looking for opportunities in all areas. In summer of 2001 efforts were stepped up at Stamping Technology Department to reduce hardware cost, computing time and to improve overall efficiency.

2. INTRODUCTION

Selection of hardware was the top priority. During the 90s, clock speed upgrade on PC chips was phenomenal. One cannot help but notice the rapid pace of change in PC performance and cost as compared to traditional Unix workstations. However, research is needed in taking this off-the-shelf technology and applying it in the production metal stamping simulation. Some small-scaled tests done earlier on Pentium II machines provided encouraging insight for potential speed-up of typical stamping simulations.

Then came the subject of operating system. Since most of the FEA applications are primarily based on the Unix operating system and most of the simulation engineers are trained and experienced in this environment, a similar operating system on PC was preferred. Furthermore, the operating system had to be simple, reliable, programmable, serviceable and easily manageable. It should also take minimum amount of time and effort to reprogram all existing in-house supporting software. The Linux operating system was chosen due to its compatibility with Unix. Since there was no previous document in the industry to apply something other than Unix or Windows (NT) operating system in PC chips, the risks involved were high. Because of the criticality of stamping simulation in the process of product design and development at the Chrysler group, the transition had to be smooth without any glitch. Therefore, detailed plans were sketched out for a rigorous testing of the selected operating system.

One of the decision criteria on Linux operating system was the opportunity for MPP (Massively Parallel Processing) LS-Dyna on PC within the department. With Linux, no additional software (license) is required for MPP. It is noted here that at Chrysler group each department has full control of its own PCs. Having full control of the machines, network and operating system means much shortened time from testing to implementation. Previous experiences indicated that high level of Unix expertise was needed to cluster Unix/RISC machines for MPP applications. The introduction of Linux operating system made it easier for mechanical engineers to tackle the network/MPP on a cluster of PCs.

Software compatibility was one of the other major concerns. Close collaboration from former Compaq Corporation enabled the team to acquire evaluation machines to conduct various software performance and reliability tests at the onset of the project. Cooperative efforts from LSTC and ETA were crucial during the initial months of assessment phase. The above companies promptly made their respective software compatible to Linux. All in-house developed supporting software for stamping simulations were also redesigned for Linux environment.

Previously proven production jobs were repeatedly run on the Pentium/Linux system to evaluate accuracy of the software and reliability of the machines. All the engineers were encouraged to get hands-on experience so as to familiarize themselves with the new computing environment, including floating calculation and graphic performance. Since graphic quality of PC was one of the most critical concerns in the beginning of the project, more attention was focussed on the performance during testing. All software needed for a complete stamping simulation run were thoroughly examined. The programs include all in-house macros, simulation report generation program, word-processing and e-mail functions.

3. DISCUSSION

3.1 SELECTION OF BASIC HARDWARE

The machines used by the department consisted of Unix workstations and servers (few) as shown in Table 1. The workstations were used mainly by individual engineers for graphical application including FEA modeling, post-processing and simulation report generation. The servers were used exclusively for running simulation and were very expensive to acquire and maintain. In spite of an in-house developed batch queuing software for better management of computing resources of the servers, there were occasional struggles to complete all jobs in a timely fashion especially when large springback simulations were in queue.

To replace those high performance Unix machines, the then best available Intel Pentium-IV CPUs (2.2GHz Xeon processor) were selected. To allow for multi-tasking on the workstation, each PC was equipped with two CPUs. To account for post-processing of large FEA models and springback simulations on the machine, a main memory of 2GB RDRAM was allocated. RedHat 7.1 Linux operating system was installed after delivery of the machines. Table 2 lists the details of system specification for Linux PCs.

Feature	Workstation	Server
CPU	1 – 300 MHz MIPS R12000 Processor	8 - 300 MHz MIPS R12000 Processors
Main Memory	2GB	4GB
Data Cache	32KB	32KB
Graphics	EMXI	EMXI
OS	Unix	Unix

Table 1: *Specification of Unix machines*

Feature	PC
CPU	2 – 2 GHz Intel(R) Xeon(TM) Processors
Main Memory	2GB RDRAM
Data Cache	512 KB
Graphics	3D labs 5110 Wildcat
OS	Linux – RedHat 7.1

Table 2: *Specification of Compaq machines*

The purchase of Compaq PCs includes a ‘3 year/24 hour’ on-site hardware service contract to ensure uninterrupted operation. During the first year, hard drives on two separate machines broke down. They were promptly replaced by Compaq engineers within the promised time frame.

3.2 GRAPHIC CARD

The selection of graphic/video card was critical, as its performance had to match or exceed that of the Unix machines. In the course of evaluation, several types of graphic/video cards were tested as following:

- NVIDIA QUATRO (with 64MB of memory)
- ATI FireGL4 (with 128MB of memory)
- ATI FireGL8800 (with 64MB of memory)
- 3DLab WildCat 5110 (with 128MB of memory)

The 3Dlab WildCat 5110 was finally chosen due to its superior quality as compared to others. This card was designed for professional graphic users who work mostly on graphic intensive applications. It is a ‘designer card’ and in Linux environment it requires a special graphic driver and various libraries developed by a separate vendor, XI Graphic Corporation. Further to its relatively high price, an additional license fee is required for the special graphic driver. However, performance of this card was superior to the other cards tested.

3.3 ETA/DYNAFORM

Dynaform, pre and post-processing software from ETA, Inc. was used extensively to create finite element models for LS-Dyna applications. The software performed much faster in the Linux environment in the areas of response time, model translation, rotation and animation. However, many new problems surfaced later with the ‘designer’ graphic card, especially in post-processing. Some examples of the problems are described below.

- Machine crashes, freezes or logs out while plotting either thinning or mean stress contour.
- Core dumps or crashes while listing either thinning or mean stress values.
- Unable to handle more than 500 points in one line segment.
- Thicker element outlines appear when generating element boundary line.
- Crashes or core dumps while reading d3plot files.
- Unable to reverse the background colors.
- When animating contour plots, colored range bar turns white immediately after rotating the model.
- "FILL SCREEN" malfunction.

The root cause of these problems was mostly related to the incompatibility of graphics libraries’ usage under Linux environment. ETA focussed their efforts to quickly resolve all the problems reported above.

3.4 LS-DYNA AND ITS MPP APPLICATION

LS-Dyna, a general purpose FEA solver from LSTC, Inc. was the software primarily used for metal stamping simulation at Chrysler group. There was no significant problem when tested on the new Pentium/Linux configuration.

Table 3 shows computing time required to simulate various panels in Unix servers (4-CPU) and in Compaq PCs (2-CPU). An average speed increase of 46% was achieved.

Part	CPU(hrs) Unix Server	CPU(hrs) Linux PC	% of Speed Increase
BSA Extension	5.5	3.1	44%
BSA Outer	28.0	14.0	50%
A-pillar Inner	5.5	2.9	47%
Liftgate Outer	11.2	6.6	41%
Fr Door Outer	40.8	20.3	50%
Floor Pan	42.1	23.2	45%
Fender Outer	10.8	6.1	44%
Average			46%

Table 3: *Comparison of Processing Time between Unix server and Compaq PC*

Despite high speed with compaq machines, there was no loss in accuracy. Figure 1 shows thinning contours for a liftgate-outer using Unix server and Compaq PC. The comparison indicates no difference in results (see table 4).

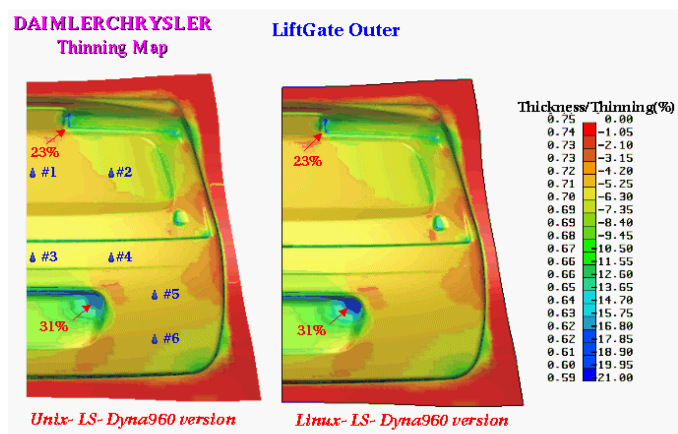

Figure 1: *Thinning Comparison*

Location	σ_m (Mpa) Unix/Linux	ε_1 x 100 Unix/Linux	ε_2 x 100 Unix/Linux	**Thinning %** Unix/Linux
#1	216/216	3.9/3.9	0.9/0.9	4.5/4.5
#2	221/221	4.4/4.4	1.3/1.3	5.3/5.3
#3	211/211	4.8/4.8	1.4/1.4	5.9/5.9
#4	212/212	4.1/4.1	1.3/1.3	5.1/5.1
#5	215/215	3.6/3.6	1.2/1.2	4.5/4.5
#6	222/222	5/5	0.6/0.6	5.2/5.2

Table 4: *Mean stress, major strain, minor strain and thinning % at selected locations between Unix and Linux versions of LS-Dyna*

One of the important goals of the migration was to explore the scalability, accuracy and feasibility features of MPP LS-Dyna in production environment. Figure 2 illustrates the scalability of MPP for selected parts in comparison with SMP in terms of CPU time. All MPP simulations presented in the figure were conducted on a cluster of four machines (each with 2-CPU) total 8-CPUs.

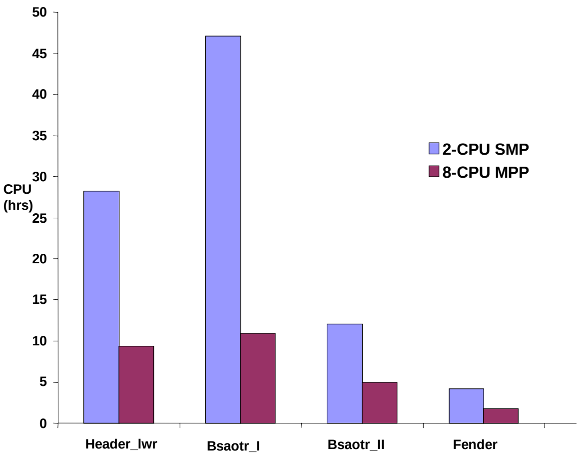

Figure 2: *SMP-MPP CPU Comparison*

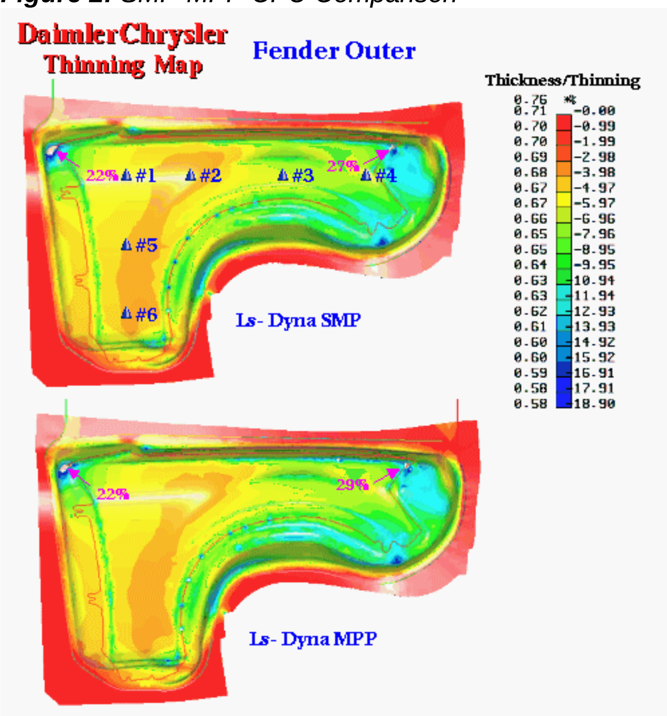

Figure 3: *SMP-MPP Results Comparison*

It is observed that the scalability of MPP is mostly job-dependent. Also for all the parts tested here that MPP runs on a cluster of two machines each with 2-CPU (total 4-CPUs) could reduce CPU time by 50% in comparison with an SMP run on a 2-CPU machine. In the case of a body side aperture outer, the CPU time was reduced by four times as the cluster size was doubled (total 8-CPU) as shown in Figure 2. This shows a nearly linear scalability, which is perfect for an MPP run on a Linux cluster. Also it is worth noting that this performance was achieved with a local network of 100Mbps capacity and not with the recommended Gigabit network.

However, an example of poor scalability was seen in case of a fender outer (see Figure 2). A cluster of four machines each with 2-CPU (total 8-CPU) produced 60% reduction in CPU time while 50% reduction in CPU time was gained with a cluster of two machines each with only 2-CPU (total 4-CPU). Therefore, high level clustering does not appear to be necessary for smaller parts.

For stamping simulation, it was also noted that MPP runs with user-specified domain decomposition has no significant improvement in CPU time reduction compared with those from automatic domain decomposition.

Figure 3 shows an example of comparison of thinning contours between SMP and MPP runs. No significant difference could be found in the pattern of thinning contours. For a more quantitative analysis, six locations were identified for illustration. Table 5 shows differences in mean stress, major strain, minor strain and thinning percentage for each of the six locations.

It reveals that results from SMP and MPP differ at an average of 3.7% in thinning at the six locations selected. This value represents only 0.3% (absolute value) of difference in thinning between SMP and MPP, which is acceptable for industrial applications. Same conclusions can also be drawn for mean stress, major strain and minor strain components.

Location	σ_m (Mpa) SMP/MPP	ε_1 x 100 SMP/MPP	ε_2 x 100 SMP/MPP	**Thinning%** SMP/MPP
#1	280/274	4.3/4.25	2.0/1.97	5.9/5.8
#2	230/228	4.5/4.5	-0.2/-0.2	3.9/4.1
#3	265/260	7.6/8.3	0/0	7.3/7.6
#4	306/301	6.5/6.75	2.8/2.65	8.5/8.3
#5	240/210	3.3/3.4	1.4/1.3	4.5/4.4
#6	242/220	2.9/2.95	1.9/1.7	4.5/4.2
Diff.	**2 Mpa to 30 Mpa**	**0% to 0.7%**	**0% to 0.2%**	**0.1% to 0.3%**

Table 5: *Average difference between SMP and MPP in mean stress, major strain, minor strain and thinning % at selected locations*

3.5 CLUSTER CONFIGURATION

Figure 4 describes the network setup for successful implementation of Linux cluster. In order to speed up the communication among clustered machines, an extra internal network was employed, using a high-speed local network switch. This setup assured an uninterrupted communication channel among the PCs clustered together. Currently the local network has 100Mbps capacity and it is in the process of upgrading to a Gigabit network. The set-up of this local network requires advanced proficiency in Linux network system administration.

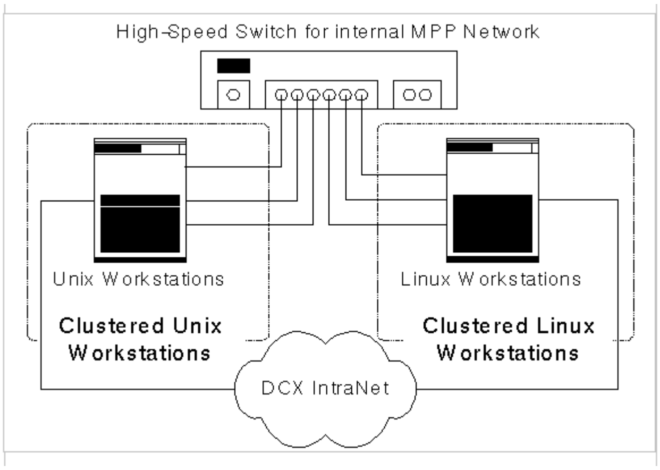

Figure 4: *Network Diagram*

In case of Message-Passing Interface (MPI), both software LAM and MPICH were tested. Each had its own merits and demerits. For example, setup and management of MPP runs under LAM is quite simple, while MPICH provides a more reliable and sophisticated MPI environment. Under LAM, only one version of MPI can be installed at a time, whereas many versions of MPICH can co-exist peacefully and user can choose a favorable version with ease. In this case both software LAM and MPICH are installed in all the new PCs. Furthermore, set-up of a Linux cluster with either LAM or MPICH requires only a minimum knowledge of network functions.

3.6 LS-POST

LS-POST, a software developed by LSTC, is primarily used for post-processing binary plot files to plot contour maps, time histories and deformed shapes. Migration from Unix to Linux caused no problem with this software. However in the Linux environment improvements have been observed in the areas of response time, model translation, rotation and animation of simulation. Combined efforts between LSTC and Stamping Technology Department are still progressing towards improving other capabilities and adding new user-desired features.

3.7 IN-HOUSE CAE UTILITY SOFTWARE

Most in-house developed CAE utility software are used to achieve various tasks. One example of these tasks is automatic input setup generator for multistage forming processes - drawing, trimming, flanging and springback. Another example is CFORM, an in-house developed software primarily used for binder wrap simulation. These applications are mainly developed using FORTRAN, C, and C++. While the Unix based compilers were commercialized and cost extra, Linux provided these compilers for free.

3.8 DOCUMENTATION AND PRESENTATION

One of the major tasks for the simulation group is documenting simulation results, recommending countermeasures and presenting them to the customers. Previously the group used Unix based utilities such as *snapshot, xv,* and *showcase* for documentation, presentation and conversion of these documents to commonly accessible formats.

After the migration, applications like *Star-Office, Xpaint, Xpdf,* and *Image-Magic* have been successfully explored to achieve documentation tasks in Linux. The capability of *Star-Office*, a freeware office suite provided by SUN Microsystems to save in MS-Office compatible formats makes these tasks even more flexible, efficient and universally accessible.

3.9 E-MAIL COMMUNICATION

The iNotes capability provided by Lotus Notes has been utilized to make email accessible anywhere through internet browsers like Netscape/Explorer. The IMAP capability, in addition to Star-Office has provided the Linux users all functionality provided by Citrix, a Windows emulator available for the Unix systems.

3.10 BATCH QUEUING

Batch queuing is an in-house developed program used to connect all available machines in the network and to submit jobs sequentially depending upon availability of the individual machines. This enables an optimal usage of computing resources within the department.

Under Linux environment, this capability has been explored, implemented and re-enhanced via the cluster. It provides the user flexibility of selection between SMP and MPP. It can also automatically exclude certain individual PCs from the cluster during working hours and include them in the off-hours to ensure optimal usage between solver calculations and the pre/post processing tasks, both of which are CPU intensive. Consequently the queuing program plays an important role in coupling the Linux cluster and MPP LS-Dyna to maintain overall computing resources at peak performance.

3.11 DATA STORAGE

Before migration to PC workstations, all data were backed up every night for a cycle of two weeks by Central Technical Computing. This task now falls within Stamping Technology department. The nightly 'incremental' backup is extremely important to safeguard jobs in progress. To keep the data backup simple and manageable, only a few important file types were selected, such as LS-Dyna input decks, Dynaform files and simulation reports. The selected few file types reduce the entire backup process for all the machines to 2 to 3 hours. This minimizes network traffic and interruptions to the simulation jobs running during nights. The nightly backup is accomplished via a local tape drive (Ecrix V17 VXA) on a designated machine. In order to automatically backup to and retrieve from the tape drive, an in-house script was developed. The script uses the GNU tar utility combined with NFS service in Linux. The NFS allows mount/dismount of file systems from remote machines. The successful implementation of the back-up strategy proved crucial in restoring two hard drives crashed during the first year of migration.

Permanent storage of files is achieved through archiving onto central storage machines in Corporate Technical Computing Center. Simulation results and reports dating back many years are readily accessible via this service.

3.12 COST COMPARISON

In addition to performance, migration to Compaq PCs rendered savings in annual hardware spending in excess of 80%.

4. CONCLUSIONS

Extraordinary efforts were made to explore alternatives to high cost of computing structure.

The implementation of Linux operating system in Pentium PC was successful in a high production stamping simulation environment. The project reduced over 80% of annual hardware spending while improving the efficiency by an average of 46%, with no compromise in accuracy.

The project not only demonstrated feasibility of Linux operating system in PC for metal forming industry but also paved road for similar applications in NVH and impact/crash simulation.

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