Fast Road Barrier Car Safety Calculation on a Cray XC

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1 Road Barrier Car Safety Calculation

Despite progress achieved in the last decade, 70 people die and more than 650 are seriously injured every day on Europe's road. As one of the most cost-effective safety infrastructure solutions available to policy makers, vehicle restraint systems can greatly contribute to alleviating the consequences of road accidents and increase levels of safety on European roads. Since 1 July 2013, all vehicle restraint systems for non-temporary use sold within the European Union and which are subject to the provisions of the Construction Products Regulation (CPR) must bear a 'CE Marking', i.e. prove that they comply with the requirement of Annex ZA of the European Standard EN 1317-5.[1]

1.1 Construction Product Regulation (EU) no 305/2011

In Construction Product Regulation (EU) no 305/2011 of the European parliament and of the council of 9 march 2011 laying down harmonized conditions for the marketing of construction products and repealing council directive 89/106/eec it is said that:
(34) to avoid the unnecessary testing of construction products for which performance has already been sufficiently demonstrated by stable test results or other existing data, the manufacturer should be allowed, under conditions set up in the harmonized technical specifications or in a commission decision, to declare a certain level or class of performance without testing or without further testing.
(35) to avoid duplicating tests already carried out, a manufacturer of a construction product should be allowed to use the test results obtained by a third party.
(36) conditions should be defined for the use of simplified procedures for the assessment of the performance of construction products, in order to reduce as far as possible the cost of placing them on the market, without reducing the level of safety. the manufacturers using such simplified procedures should demonstrate appropriately the fulfilment of those conditions.[2]

1.2 Experiences with EN1317-1, 2 and 5

European Standards EN1317-1, 2 and 5 describe assessment methods for conducting real crash tests and conducting modifications, in order to evaluate performance of road restraint systems. Above mentioned standards include 11 crash tests scenarios which are the base for defining containment level, impact severity level, dynamic deflection, working width and vehicle intrusion for road restraint system.
Throughout last six year about 100 full scale crash tests were performed according to EN 1317 by Stalprodukt S.A. Taking into consideration received results following conclusions on EN1317 could be learned:

- norm defines only basic information for impactor models. Impactor models are not defined unambiguously, which leads to possibility of using different impactor models,
- norm defines tolerances for test performing. The combination of tolerances for speed, impact angle and vehicle mass given in standard would influence the impact energy for the same test scenario,
- for the time being norm defines only general rules for modifications of products when using definite elements method,

- a lot of additional equipment can be installed on road restraint system. Motorcyclist protection, acoustic panels and this areas are not covered by the norm by now. It is not possible to perform full scale crash tests for all devices in all configurations.

1.3 LS-Dyna and the computational requirements

In order to cope with issues described above LS-Dyna solver could be used with huge precision and effectiveness. There are three main ways for solving problems when using LS-Dyna:

1. development of new products according to Design of Experiment (DOE) method. Large number of experimental simulations need to be performed for prototype of new devices. For final design as much as possible results should be in area of desired properties under impact according to EN1317,
2. modification of the product. When desired properties under impact are not achieved in a full scale crash tests, but at the same time in accordance to the norm result of the test is positive – all acceptance criteria included in a Standard are fulfilled – it is possible to modify device in order to achieve desired properties. These actions can be done without reproducing full scale real crash tests under following conditions. Validation of a numerical model in practice is done in accordance with TR16303. After validation, modification clear from the physical point of view could be applied. Influence on the properties under impact for modified road restraint system should be under limits described in TR16303. If influence on properties under impact is over the limits, at least one full scale crash tests should be performed in order to validate numerical model of modified road restraint system. In accordance to the standard evaluation of independent third body is needed in order to fulfil requirements of CE marking procedure. CE mark can be obtained for modified road restraint system.
3. Adding additional elements to the road restraint system. When road restraint system is being used in a specific installation conditions or additional equipment is installed on the barrier computer simulations could be reliable tool for assessment of this type of modification. Example of the first case is installation of a barrier with slope behind. Example of second case is e.g. acoustic panels installed to the barrier. Validation of a numerical model should be done in accordance with TR16303. Simulations should evaluate performances under impact in abovementioned conditions. CE mark or/and the extension for applicability of road restraint system can be obtained.

These three ways however useful, require huge computing power. Proceeding in compliance with DEO method during creation of new products and defining the area of possible results require huge number of calculations. Validation of the model in accordance with TR16303, depending on a system require from 10 to 100 simulations to be performed. In some cases reproduction of complicated phenomena of road restraint system or impactor is needed. Models of a barrier with additional equipment or specific ground conditions can be large, around 1 million elements and with termination time up to 3.0 s. with a lot of contacts applied. The need to carry out large amounts of computation were observed during year's 2012, 2013 and 2014 in Stalprodukt S.A., and this amount increased from year to year. As a solution of a problem introduction of Supercomputer were proposed. Assumed target was to reduce calculation time for any simulation of crash test according to EN1317 at least 15 times. CRAY XC30 had been chosen as solution.

1.4 Stalprodukt's Cray XC30-AC

The Cray system installed at Stalprodukt is an air-cooled Cray XC30-AC. The single rack configuration hosts 384 processor cores on 24 compute nodes. The nodes are connected with a Rank1 Aries HPC network. Almost all production runs make use of the full parallel compute power of all nodes.

2 Cray MPT

To make best use of the 384 processor cores available for LS-Dyna production runs the Cray MPT software stack is used. In the following some features of this MPI implementation are explained.
A widely spread high-performance and portable implementation of the MPI standard is MPICH. This implementation is developed and supported by the Argonne National Laboratory. Cray Message Passing Toolkit (MPT) consists of a highly optimized implementation of an MPICH based MPI library as well as a Cray SHMEM library. Both Cray MPI and Cray SHMEM have been optimized for low

latency, high bandwidth and large scaling making optimal use of the Aries interconnects for on-node and across node point-to-point, RMA and collective operations.

2.1 The Aries Interconnect and Cray MPT

The HPC network for the Cray XC systems is called Aries. Aries implements a number of features which makes it a highly performing and scaling network not only but in particular for large and very large installations. All those features are fully integrated in the production software stack and thus available for the optimal performance of applications on this network. In this paper we want to highlight only one of the unique features of Aries.
The Aries Collective Engine accelerates key latency sensitive reduction operations and barriers. Reduction operations are performed over a tree spanning the NICs used in each job. The result is broadcast back down this tree. Supported operations include min, max and sum on integer and floating point types together with bitwise and logical versions of AND, OR and XOR on integer types. Performing reductions in the NIC avoids time consuming host interface crossings. It also reduces the impact of OS noise – the requirement to have a main CPU thread scheduled in order to make progress is removed. The Aries Collective Engine supports shallow reduction trees with high branching ratio spanning tens of thousands of nodes. A network reduction over the largest of systems is completed in much the same time as a single local shared memory reduction over one node, 5-6 microseconds for each element of the reduction being typical on a large system. Scalability is excellent, reductions over thousands of nodes take much the same time as those over hundreds of nodes. The Cray MPI library makes use of the Aries Hardware Collective Engine for MPI_Barrier as well as small message MPI_Allreduce and MPI_Bcast collectives where performance improvements of 2X to 3X have been seen compared to the software only collective optimizations.

2.2 MPICH ABI Compatibility Initiative

The goal of the MPICH ABI Compatibility Initiative is to provide and maintain ABI (Application Binary Interface) compatibility between the MPI implementations provided by the initiative members. Cray is a member of the MPICH ABI Compatibility Initiative along with Intel, IBM, and Argonne National Laboratory's MPICH development group (ANL MPICH). Cray, Intel, and IBM's MPI implementations are all derived from the ANL MPICH implementation. It should be noted that the IBM MPI participating in the ABI Compatibility Initiative is not Platform MPI. At this time there is no indication that Platform MPI will become part of the ABI Compatibility Initiative.

ABI compatibility allows dynamically linked applications built with one ABI-compatible MPI to use a different ABI-compatible MPI at run time. The MPICH ABI Compatibility Initiative defines additional requirements (initiative compliance) beyond ABI compatibility. These additional requirements allow ABI compatibility to be easily used, in particular by having common shared library names. Further details on initiative compliance can be found on ANL's ABI Compatibility Initiative WIKI page [1].

ANL MPICH 3.1.1 is the first release to achieve full compliance with the MPICH ABI Compatibility Initiative. This MPICH release has the additional ABI initiative compliance requirements in it. As the other initiative members transition their MPI implementations to this version of MPICH, their MPI implementations will become compliant with the initiative.

While not fully compliant with the initiative, Cray's MPI (Cray MPICH) became ABI-compatible with MPT 7.0.0 released in June 2014.
Intel released their MPI 5.0 late in 2014, allowing us to complete our ABI Compatibility support for Intel MPI 5.0. Beginning with MPT 7.1.3 Cray MPICH supports ABI compatibility with Intel MPI 5.0 and ANL MPICH 3.1.1 and newer releases. Full compliance with the ABI Compatibility Initiative requires dynamic shared library name and version number changes that would cause downward ABI incompatibilities with previous MPT versions and existing Cray PE software built with previous MPT releases.

To use ABI Compatibility the application must conform to the following requirements:

- The application must be built with a Intel or GNU compiler that is compatible with the Cray MPT release the application will be linked to when the application is run.

- The application must be built with an MPI implementation that is ABI compatible with ANL MPICH 3.1.2.
- The application must be linked dynamically to the MPI libraries.

2.3 LS-Dyna on a Cray XC

With the release of MPT 7.0.0 all ISV applications which satisfy the above described requirements can be run natively on the Aries network. However, LS-Dyna in particular is linked directly with native Cray XC MPI.

3 Summary

- LS-Dyna is a very useful tool for development and modifications of products introduced to the market in accordance EN 1317.
- Usage of LS-Dyna for modified products certification process fulfils assumptions of CPR (Regulation European Union No 305/2011).
- Supercomputer computation power is needed in order to fulfil requirements of EN1317, especially in order to modify properly construction product.
- Cray XC30 comes with a tightly integrated MPI software stack that takes full advantage of the Aries interconnect. This allows extremely short computational times for production runs using the entire configuration.

4 Literature

[1] ERF- European Union Road Federation: "ERF Position Paper ", 2015, page 4

[2] Regulation (EU) No 305/2011of the European Parliament and of the Council of 9 March 2011 laying down harmonised conditions for the marketing of construction products and repealing Council Directive 89/106/EEC OJ L 88 of 4 April 2011, pint 34

[3] http://wiki.mpich.org/mpich/index.php/ABI_Compatibility_Initiative