High Performance Computing
for Welding Analysis

As an integral part of the PRACE SHAPE project "HPC Welding" [1], the parallel solvers of LS-DYNA were used by Ingenieurbüro Tobias Loose to perform a welding analysis on the Cray XC40 "Hazel Hen" at the High Performance Computing Center Stuttgart (HLRS).

A variety of test cases relevant for industrial applications have been set up with DynaWeld, a welding and heat treatment pre-processor for LS-DYNA, and run on different numbers of compute cores. The explicit mechanical solver was tested on up to 4080 cores with significant scaling. As far as we know, it was the first time that a welding simulation with the LS-DYNA explicit solver was executed on 4080 cores.

Welding simulation

Welding structure simulation is a highly sophisticated finite element (FE) application [2]. It requires a fine mesh discretisation in the weld area so that, in combination with large assemblies and long process times, welding simulation models are very time consuming during the solver run.

HPC with massively parallel processors (MPP) can provide a solution to this issue. In crash applications and forming analysis, it is known that the commercial finite element code LS-DYNA, using the explicit solution algorithm, provides good performance on HPC

systems. However, at the authors' knowledge, performance benchmarking of LS-DYNA for welding simulations have never been performed prior to this study. This project has analysed the feasibility of welding analysis with parallelised LS-DYNA solvers and its performance.

In this project a Cray-specific LS-DYNA mpp double precision (I8R8) version has been used. The version used, named as revision 103287, was compiled by Cray using the Intel Fortran Compiler 13.1 with SSE2 enabled. The Extreme Scalability Mode (ESM) was used.

In addition, the commercial pre-processor DynaWeld [3, 4] is used to set up the welding simulation models for the solver.

Welding tasks

The welding technique covers a very wide range of weld types, process types, clamping and assembly concepts and assembly dimensions.
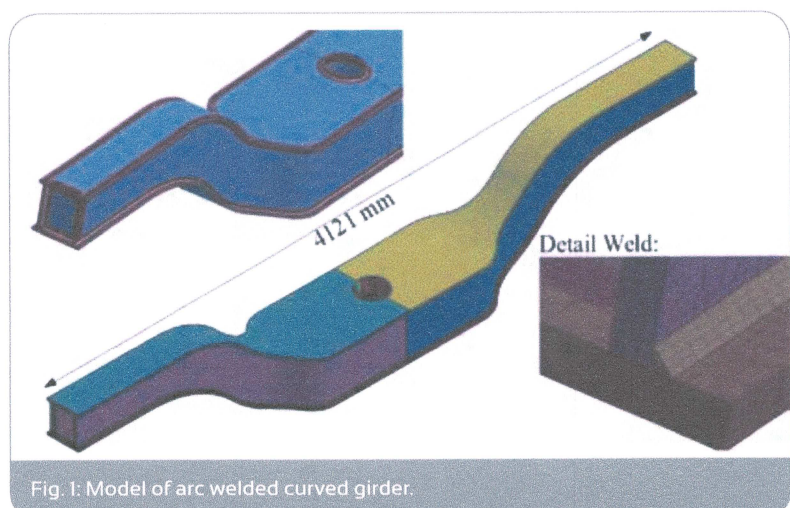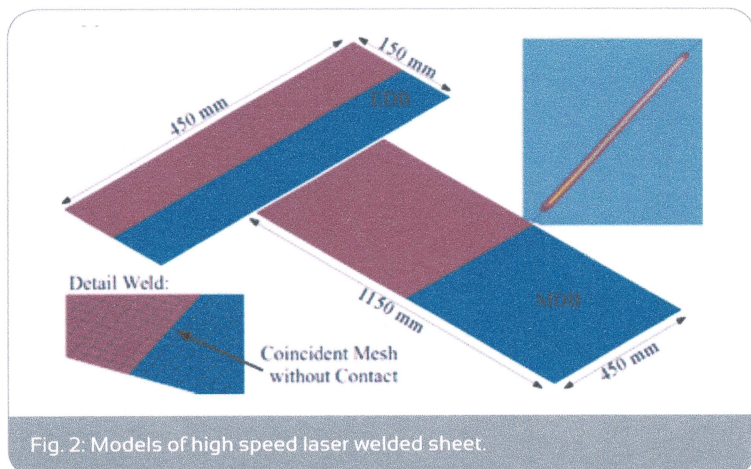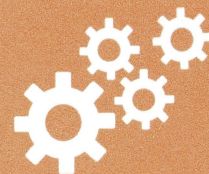

Fig. 1: Model of arc welded curved girder.

Fig. 2: Models of high speed laser welded sheet.

girder. This model covers a complex and large industrial case with many welds. A high speed laser welded thin sheed was the test case for the explicit analysis of the project (figure 2). This case was modelled with 200,000 shell elements (EDB) and 1 million shell elements (MDB).

Results of the project

The results of the test cases with explicit analysis provided the following results: The scaling behaviour in the double-logarithmic scale is linear with nearly constant gradient up to 4080 cores (figure 3). Above 96 cores the model MDB with 1 million elements provides a better scaling than the model EDB with 200 000 elements due to the fact that the number of elements per core domain is larger in this case. Regarding the parallel efficiency (the ratio of speedup and number of cores), the larger

For example: arc weld, laser weld, slow processes, high speed processes, thin sheets, thick plates, single welds, multi-layered welds, unclamped assemblies, fully clamped assemblies, prestress and predeformations. This shall illustrate that there is not only one „welding structure analysis" but a wide range of modelling techniques to cover all variants of welding. In consequence, welding simulation cannot be checked in general for HPC, but every variant of modelling type has to be checked separately.

This project considers several representative modelling variants for welding structure with the aim to cover a range as wide as possible. Figure 1, for example, shows a model of a gas metal arc welded curved
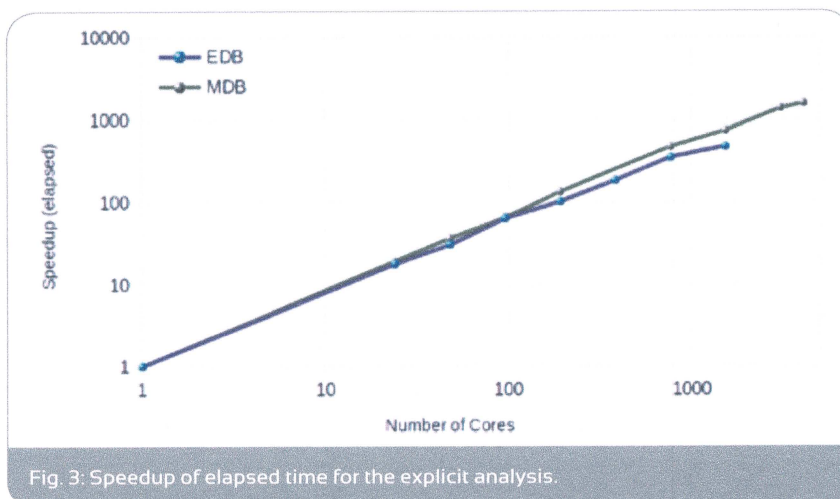

Fig. 3: Speedup of elapsed time for the explicit analysis.

model has a ratio of 0.45 at 768 cores, and at the highest number of cores (4080) a ratio of 0.4.

As a result of the project in general, recommendations for the number of cores in order to obtain the optimal performance are provided and the expected speedup is given. Both the number of the cores and the speedup depend on the model type.

The overall effort for welding analysis on HPC is now much better known with the help of this SHAPE project [1], leading to the ability of a more accurate cost estimate of welding consulting jobs. This project provides a good basis for further investigations in high performance computing for welding structure analysis.

References

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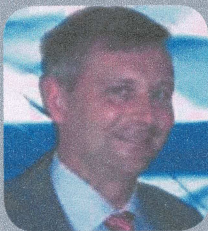
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