Improvements to LS-DYNA Implicit Mechanics

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1 Introduction

LSTC is continually improving the capabilities and performance of Implicit Mechanics especially in the distributed memory computing environment. This talk will review recently added features and performance improvements.

2 Gears

The amazing ingenuity of the LS-DYNA User Community discovered two flaws in the treatment of joints including that in Implicit Mechanics. Joints which transfer motion from one rigid body to the second such as gears, rack and pinion, and screw joints implementation assumed that one of the rigid bodies was not moving. The implementation has been enhanced to allow for both translational and rotational motion of the joint assembly without effecting the relative motion between the two rigid bodies.

The second was the treatment of helix and worm gears. This required enhancement of the treatment of gears to account for the gears not being in the same plane. The conference presentation will show videos of these two enhancements.

3 Modal Dynamics

In response to user requirements the capabilities for modeling using Modal Dynamics was greatly enhanced in LS971 R7.1. This allows fast simulation of models by replacing the nonlinear model with a linearized model based on eigen modes. The next release of LS971 will allow for the use of prescribed motion constraints on such models. We use the constraint mode feature of *CONTROL_IMPLICIT_MODES to compute the force equivalent of a unit displacement for a particular degree of freedom. Then apply an appropriately scaled force during the modal dynamics simulation.

4 Performance Improvements

4.1 Reuse of the Symbolic Factorization for the Sparse Linear Equation Solution

As the models used in Implicit simulations grow larger and the use of larger number of parallel processes the Symbolic Factorization phase of the sparse linear equation solution is becoming more of a bottleneck. One user was working with a model with 90M rows in the linear algebra problem using the Hybrid MPP executable of LS-DYNA. He reported that the wall clock time for the numeric factorization using 4096 processes and 6 SMP threads was scaling down to 160 seconds. However the wall clock time for the symbolic factorization was NOT scaling and staying at 2600 seconds.

LSTC is continuing its long term development of a scalable symbolic factorization but that development, requiring new and innovative research, is taking much longer than expected. As a short term fix we have implemented two enhancements. The first enhancement is to monitor the matrix structure from matrix reformation to matrix reformation. If the matrix structure is the same from the last numeric factorization and the current one we reuse the symbolic factorization. The trade-off with this feature is the additional cost of monitoring of the matrix structure with the up side benefit of reusing the symbolic factorization.

The second enhancement is an MPP only feature. We predict the contact pattern for penalty based (non-tied) contact to allow small changes in the matrix structure due to changes between time steps of contact interface. This has feature can increase the cost of the numeric factorization by adding additional entries to the sparsity of the stiffness matrix. But at the benefit of reusing the symbolic factorization for problems where the contact changes slightly.

4.2 Enhanced Performance of the Numeric Factorization

For large models the wall clock time is dominated by the numeric factorization of the stiffness matrix.

This numeric factorization is based on the multifrontal algorithm which works on dense submatrices in the context of what is called an elimination tree. As you approach the root of the elimination tree there are fewer submatrices than processes so the dense submatrices have to be distributed across the available processes. Historically this has been a one dimensional distribution. For large submatrices with 16 or more processes we are now distributing the work in a two dimensional pattern to provide more load balancing. Again there are trade-offs of improved load balance but at the cost of increase initialization of the work for each process. Initial testing shows that the trade-off favors the two dimensional distribution when the number of processes involved is 16 or greater and the submatrices is large enough.

5 Summary

This presentation outlines the improvements made in LS-DYNA Implicit. Enhanced and new features for joints and modal dynamics have been described. The performance improvements for large implicit simulations have also been presented.