Metal Forming Applications using Implicit Mechanics Features of LS-DYNA®

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Abstract

The authors will present the use of LS-DYNA for a variety of metal forming applications. They will present some new features and improvements in Version 971 of LS-DYNA such as Inertia Relief and Contact Penetration Detection. The presentation will include applications of gravity loading, binder wrap, flanging, springback and die transfer.

Introduction

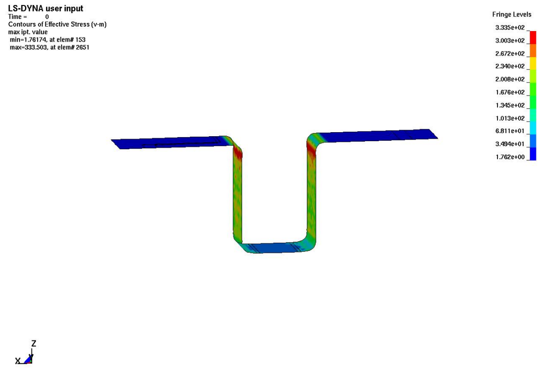
LS-DYNA is a well-known, heavily used finite element package. It is best known for its explicit analysis capability, simulating applications of short time duration with major deformations such as automobile crash. For the last decade LSTC has been integrating implicit capabilities into LS-DYNA. Since LS-DYNA v. 970 the implicit capabilities offer a full range of analysis features supporting the majority of explicit analysis options in both SMP and MPP implementations. A major focus of the implicit capabilities has been towards metal forming applications. This paper presents a number of new features and improvements in LS-DYNA v. 971 that vastly improve the performance and accuracy of implicit results for metal forming applications.

Inertia Relief

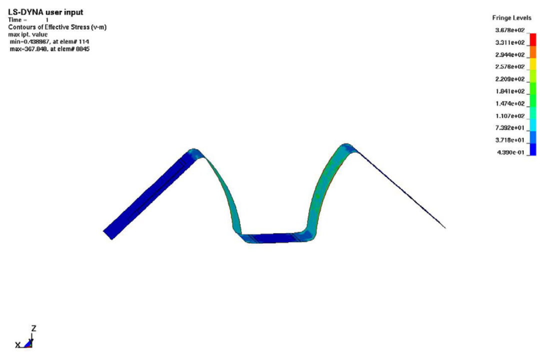
Borrowing from the rich history of Nastran we have adopted the Inertia Relief Using Auto-Support. This capability allows analysis of structures not grounded such as aircraft fuselage in flight. This can be used in metal forming applications such as springback to avoid artificial support constraints to remove model singularities. For this feature LS-DYNA computes the rigid body modes **R** and then constrains the model so that it does not move in the directions given by **M*R** where **M** is the mass matrix. The implementation allows an arbitrary number of rigid body modes.

This new feature is simply illustrated with the following springback example.

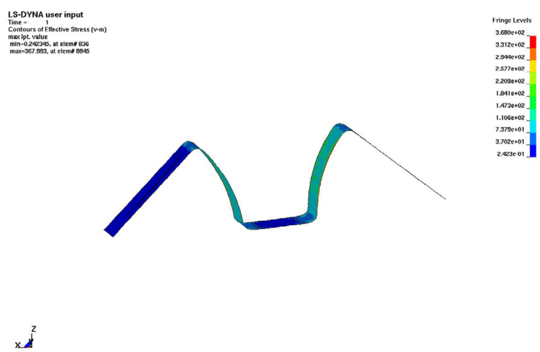
Initial Stress



Springback using Support Points



Springback using Inertia Relief



The user can select Inertia Relief using the keyword *CONTROL_IMPLICIT_INERTIA_RELIEF. Alternatively the user can specify no support points for *INTERFACE_SEAMLESS_SPRINGBACK.

Contact Penetration Detection

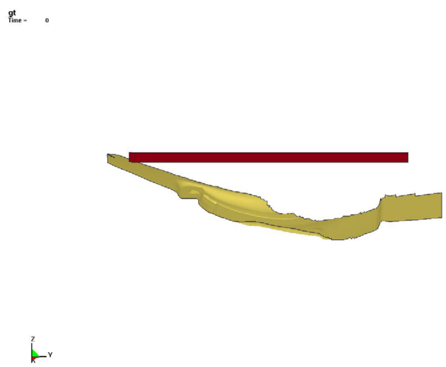
Historically contact dominated metal forming problems have been difficult for LS-DYNA implicit. One contributing factor is that the mesh of the work piece is usually coarse on input expecting adaptive technology of explicit to refine the mesh as needed. This approach in implicit applications, with its larger time steps, leads to contact penetration that then entangles the meshes of the parts leading to nonconvergence.

In the R4 version of LS-DYNA V. 971 we have incorporated a tighter coupling between contact algorithms and the implicit nonlinear solution algorithm. We call this Contact Penetration Detection. This assures that the solution avoids any contact penetration and mesh entanglements. This leads to fast accurate implicit solutions for problems with contact. Also, adaptive mesh refinement will work correctly after the implicit time step.

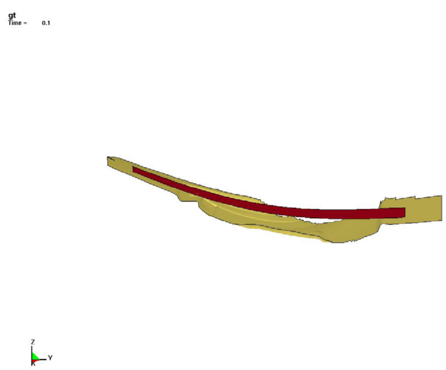
Gravity Loading

To illustrate this new feature we will use a gravity loading problem that was difficult to get to converge using implicit technology in previous versions of LS-DYNA.

Initial State



Final State

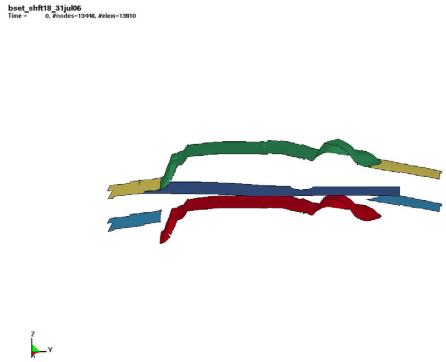


To make constructing LS-DYNA keyword input files easier we have added a new implicit keyword *CONTROL_IMPLICIT_FORMING. Using the value of 1 in the first field for this keyword, with no other implicit keywords, allows gravity loading problems to converge in one time step and few nonlinear iterations.

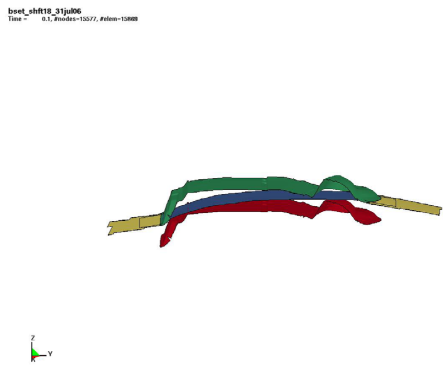
Binder Wrap

A second example of the use of Contact Penetration Detection is binder wrap applications. This application was very difficult for prior versions of LS-DYNA due to mesh entanglements caused by coarse mesh/fine mesh contact penetration. With the new features these types of applications are solved much more efficiently and robustly.

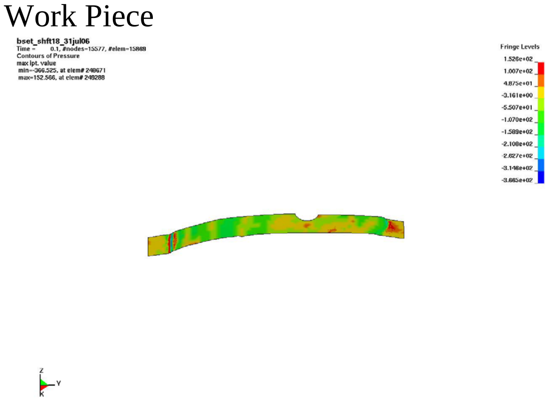
Initial Position



At Closure



Final Pressure Loading on Work Piece



For binder wrap applications we use the new *CONTROL_IMPLICIT_FORMING keyword with a "2" in the first field. The difference between "1" and "2" is that for applications we expect to take only one time step we use "1", otherwise we recommend "2".

More examples will be found in the section entitled MORE EXAMPLES.

Nonlinear Solution Algorithmic Improvements

With exposure to more and more implicit problems from the LSTC user community we noticed a number of problem characteristics that caused unnecessary convergence problems with the nonlinear solution algorithms in previous versions of LS-DYNA, even earlier releases of V. 971. One particular annoying drawback was the strict use of relative convergence tolerance for problems where little motion was occurring. We have overhauled our nonlinear solution algorithm to be more robust and more efficient. This has had a positive impact for metal forming applications.

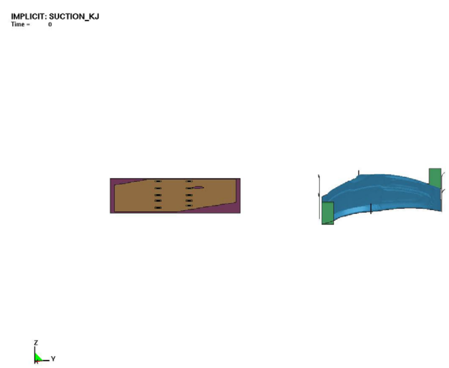
More Examples

Two metal forming applications where LS-DYNA has had great difficulties until our newest enhancements have been die transfer and flanging.

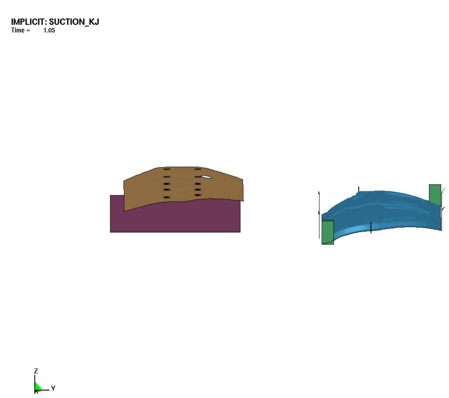
Die Trasnfer

With die transfer the work piece is transferred from one station to another. Implicit dynamics must be used to accurately compute the motion of the work piece to assure clearance with the manufacturing environment including guide pins of the fixtures and the starting and ending positions. Finally the die transfer finishes with a gravity loading into the final fixture. This example is best demonstrated with a movie but the limitations of paper restrict us to a series of still shots. All illustrations from this paper, movies of the examples, and additional metal forming examples can be found in the AVI Library at www.lstc.com.

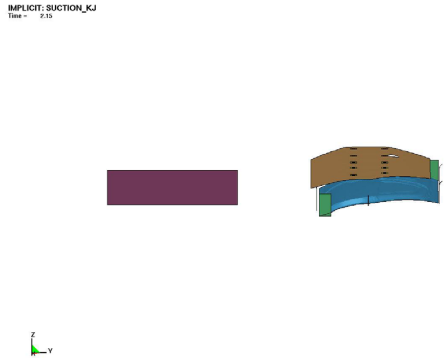
Initial Position



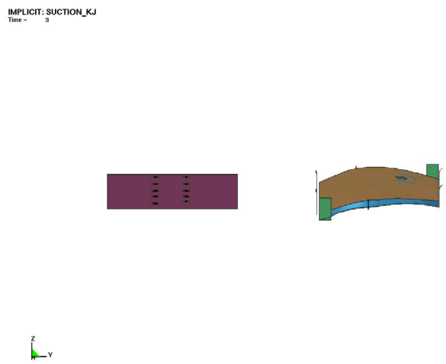
After Lift



Before Dropping into Final Position



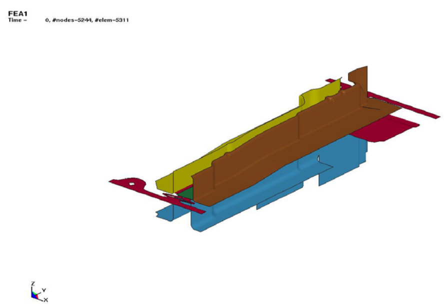
Final Position



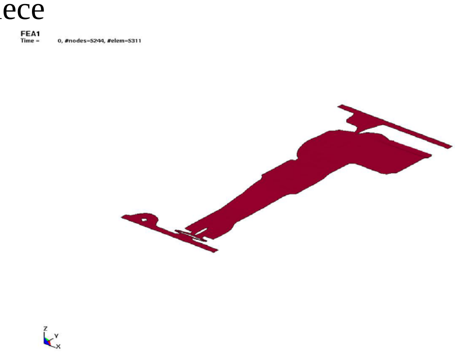
Flanging

A more difficult example is simulating the flanging operation where the work piece is bent over a rigid die. Again this is a contact driven application with significant deformations.

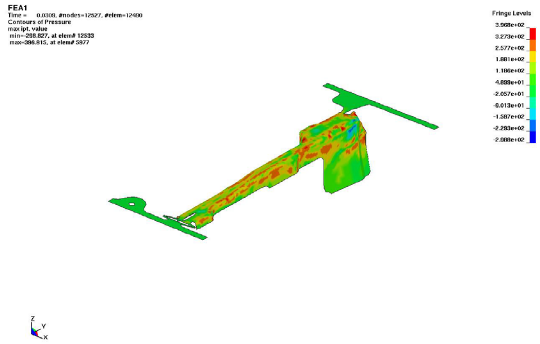
Initial Position



Initial Position of Work Piece



Pressure Contours on Work Piece in Final Position



Performance

In this metal forming study we used ten test cases from application areas of gravity loading, binder wrap, flanging, springback and die transfer. Most of these problems could not be solved in versions of LS-DYNA prior to V. 971 R4. To complete this paper we provide the wall clock time required for the computation on a single CPU of IBM550, a 3 year old IBM Power 5 PC Model 550 computer running AIX 5.3, in house at LSTC. This computer was chosen mainly because it has a large disk that allowed accumulation of all of the test data, d3plot files, and jpeg and AVI files without undue effort. None of these jobs required any more computational resources than a usual laptop or desktop computer.

Test Cases	Wall Clock
Gravity Loading Simple	00:00:26
Gravity Loading Guide Pin	00:06:47
Binder Wrap Simple	00:01:39
Binder Wrap Hood	00:17:32
Flanging Case 1	00:58:17
Flanging Case 2	00:09:13
Flanging S-Rail	00:04:59
Springback Simple	00:01:56
Springback S-Rail	00:03:34
Die Transfer	00:21:27

Conclusions

LSTC recommends that those users with metal forming applications try out LS-DYNA V. 971 R4 and its new features, especially the new *CONTROL_IMPLICIT_FORMING keyword.

Again, pictures and movies of the test cases used in this paper can be found in the AVI Library at www.lstc.com.