A USER'S PERSPECTIVE ON NONLINEAR TRANSIENT DYNAMIC ANALYSIS WITH MSC/DYNA

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ABSTRACT

NKF Engineering has been a user of MSC/DYNA since it was first released in early 1989. NKF engineers have become involved in a variety of analyses well suited to MSC/DYNA in response to the changing needs of its Department of Defense and commercial customers. Some of our DYNA experience has been developmental in nature, i.e., the running of fictitious sample problems in order to become familiar with the code. Recently, we have started using MSC/DYNA on "real" engineering problems. Our investigations have been much aided by the fact that we have been selected by MSC as a beta test site for their DYNA-XL converter so that we have been able to pre- and post-process our DYNA problems with MSC/XL. The purpose of this paper is to provide an overview of our DYNA and DYNA/XL experience by looking at some representative problems we have analyzed, some fictitious and some real.

INTRODUCTION

DYNA's Place Among Continuum Mechanics Codes

The place where DYNA fits on the spectrum of structural/hydrodynamic analyses codes may best be illustrated by examining its capabilities relative to the range of material, deformation, and motion behavior it can effectively simulate. The position of MSC/DYNA relative to MSC/NASTRAN and MSC/PISCES is shown graphically in Figure 1. An explanation of the types of behavior represented by each axis in Figure 1 in order of ascending complexity is shown below.

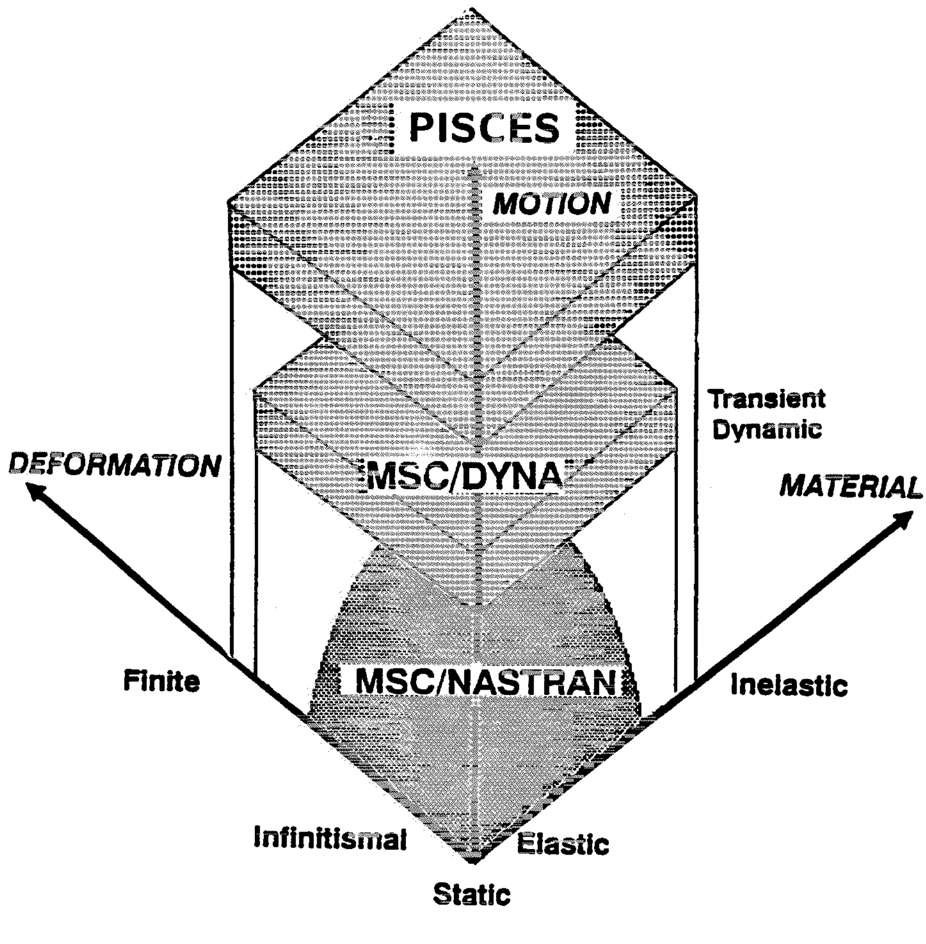


Figure 1. Relationship Between NASTRAN/DYNA/PISCES

Material Axis - Increasing Complexity

NASTRAN	Linear isotropic elastic (design, metals)	
NASTRAN	Mild strain hardening/plasticity	
NASTRAN	Nonlinear isotropic elastic (rubber materials)	
NASTRAN	Linear orthotropic elastic (composites)	DYNA
NASTRAN	Elastic-Perfectly plastic material (limit analysis)	DYNA
	Plasticity	DYNA
	Viscoelasticity (polymers)	DYNA
	Elastic-Creep (metals at elevated temperatures)	DYNA
	Jointed media (rock, concrete)	DYNA
	Creep-Plasticity (metal forming)	DYNA
	Damage accumulation	DYNA
PISCES	Phase changes	DYNA (future)
PISCES	Explosive detonation	DYNA (future)
PISCES	Tearing and failure	DYNA (future)
PISCES	Fluid flow	
PISCES	Fluid structure	
PISCES	Fluid structure interaction	
PISCES	Hydrodynamics, explosive burn	

Deformation Axis - Increasing Displacements

NASTRAN	Infinitesimal small strains and rotations	
NASTRAN	Infinitesimal strains and finite rotations	DYNA
NASTRAN	Finite strains (<20%)	DYNA
PISCES	Finite strains and rotations (>20%)	DYNA
PISCES	Large strains (>100%)	DYNA
PISCES	Contact surfaces	DYNA
PISCES	Moving coordinate system (Lagrangian formulation)	DYNA
PISCES	Fixed cells axis (Eulerian formulation) for large mass and momentum transfer	

Motion Axis - Decreasing Time Scale

NASTRAN	Static (infinite)	
NASTRAN	Quasistatic	
NASTRAN	Vibration, modal analysis	
NASTRAN	Shock and vibration	
PISCES	Stress wave propagation	DYNA
PISCES	Shock wave propagation	DYNA
PISCES	Detonation waves	DYNA
PISCES	Radiation energy deposition	

Constitutive Equations

The form of the equations of motion utilized in MSC/DYNA is derived from virtual work considerations. Briefly, the theorem of virtual work can be expressed as:

$$\delta\pi = \int_V \rho\ddot{x}^k \delta u_k dv + \int_V t^{km} \delta u_{k,m} dv - \int_V \rho f^k \delta u_k dv - \oint_{S1} s^k \delta u_k ds = 0$$

The divergence theorem is employed to reveal the differential equations of motion:

$$\int_V (\rho\ddot{x}^k - t^{km}_{,m} - \rho f^k)\, \delta u_k \, dv + \int_{S^o} \left(t^{km}_{+} - t^{km}_{-}\right) n_m \, \delta u_k \, da$$

$$+ \int_{S^1} \left(t^{km} n_m - s^k\right) \delta u_k \, da = 0 \, .$$

The differential form will vanish if and only if the respective integrands vanish.

The Galerkin equations reduce to:

$$M\ddot{q} = F_{ext} - F_{int}$$

where:

$$\ddot{q} = \{\ddot{x}^{kI}(t)\}, \quad \textit{a vector}$$

$$M = \left[\int_V \rho N_k^I N_k^J dv\right], \quad \textit{a matrix}$$

$$F_{ext} = \left[\int_V \rho f^k N_k^I dv\right] + \left[\int_{S^1} s^k N_k^I da\right], \quad \textit{a vector}$$

$$F_{int} = \left[\int_V t^{km} N_{k,m}^I dv\right\}, \quad \textit{a vector}$$

For a further explanation of these equations and a definition of their terms, see Reference 2.

Integration of Equations of Motion

A big difference between MSC/DYNA and MSC/NASTRAN is in how transient problems are solved. The solution to transient dynamic problems in NASTRAN is based on an implicit integration of the equations of motion. DYNA employs an explicit integration technique. The difference is illustrated by showing the key equations used in a derivation of each method.

First, for implicit integration in MSC/NASTRAN, the Newmark integration scheme is used.

At timestep n+1, the equation of motion is:

$$Ma_{n+1} + Cv_{n+1} + Kd_{n+1} = F^{ext}_{n+1}$$

From a second order finite difference approximation:

$$d_{n+1} = d_n + v_n \Delta^t + ((1\text{-}2B\beta)\ a_n\ \Delta t^2)/2 + \beta a_{n+1}\ \Delta t^2$$

where the first three terms on the right side are referred to as d^*_n which are predictive, i.e., based on previous values and the last term is called corrective, i.e., based on an unknown value, then,

$$d_{n+1} = d^*_n + \beta a_{n+1}\ \Delta t^2$$

A finite difference approximation for the velocity at the next timestep is:

$$v_{n+1} = v_n + (1 - \gamma)\ \Delta a_n\ t\ \gamma + \gamma a_{n+1}\ \Delta t$$

where the first two right side terms are referred to as v^*_n and are known. The last term is unknown. Δt is the timestep, β and γ are constants controlling the stability of solution. Upon substitution of the expressions for d_{n+1} and v_{n+1}, the equilibrium equation becomes:

$$Ma_{n+1} + C(v^*_n + \gamma a_{n+1}\ \Delta t) + K\ (d^*_n + \beta a_{n+1}\ \Delta t^2) = F^{ext}_{n+1}$$

Factoring a_{n+1} and regrouping:

$$[M + C\gamma\Delta t + K\beta\Delta t^2]\ a_{n+1} = F^{ext}_{n+1} - Cv^*_n - Kd^*_n$$

If the coefficients of a_{n+1} are referred to as M^*, i.e., known values, and if the right side is referred to as F^{resid}_{n+1}, also known, the accelerations at n+1 then are given by:

$$a_{n+1} = M^{*-1}\ F^{resid}_{n+1}$$

Inversion of M^* involves inversion of M, C, and K at each timestep where they change due to nonlinearities.

In the case of MSC/DYNA, where the equations of motion are expressed as shown in the previous section,

$$Ma_n = Fn^{ext} - Fn^{int}$$

where: $Fn^{resid} = Fn^{ext} - Fn^{int}$

then,

$$a_n = M^{-1} \, Fn^{resid}$$

where M is made diagonal so no matrix inversion is required. This solution is advanced in time using the central difference method:

$$v_{n+1/2} = v_{n-1/2} + a_n \, (\Delta t_{n+1/2} + \Delta t_{n-1/2})/2$$

$$d_{n+1} = d_n + v_{n+1/2} \, \Delta t_{n+1/2}$$

For the implicit routine:

- Solution unconditionally stable, timestep size dictated by required accuracy
- Timestep must subdivide shortest natural period of interest in structure

Whereas, for the explicit routine:

- Timestep set by requirement to maintain stability
- Timestep must subdivide shortest natural period of mesh
- DYNA automatically calculates telescoping timestep

The required implicit timestep = (10 - 100X) explicit timestep necessary for proper stability.

One of the main advantages of the explicit technique is that matrices are maintained on an elemental level only. A master stiffness is never assembled and hence never inverted. On the other hand, the explicit technique requires a much smaller timestep for numerical stability than does the implicit technique.

For a problem with N degrees of freedom and bandwidth B, increase in mesh density by factor S:

- Implicit - Cost increases as S^7
  - Cost proportional to NB^2
  - N increases as S^3
  - B increases as S^2

- Explicit - Cost increases as S^4

  - Cost proportional NS (S because timestep smaller)
  - N increases as S^3

- If mesh density doubled; implicit x 128, explicit x 16

- Explicit methods have increasing cost advantages over implicit methods as model size increases

MSC/DYNA Key Features

A summary of some of the key features of the MSC/DYNA code follows:

- Large displacement/large strain finite element

- 3-D

- Contact surfaces

  - Contact (single and double)
  - Separating
  - Sliding
  - Friction

- Many material models

  - Elastic materials

    - Isotropic linear elastic
    - Orthotropic linear elastic (composites)

  - Elastoplastic

    - Elastoplastic with kinematic or isotropic hardening (metals)
    - Elastoplastic with isotropic hardening with failure (steel)
    - Rate dependent plasticity
    - Piecewise linear plasticity
    - Resultant plasticity (limit analysis)

  - Compressible plasticity with failure

    - Soils
    - Foams
    - Concrete

-- Honeycombs
-- Wood

- Transient dynamic analysis

  - Short-term events such as explosions, high-speed impact, and penetration
  - Conventional dynamic events (nonlinear equipment response to shock)
  - Dynamic relaxation (quasistatic)

- Detonation analysis with equation of state (future)

- Wide range of elements

  - Solids
  - Shells (bending and membrane)
  - Bars, rods
  - Springs, dampers (simple to very general)
  - Masses
  - Rigid bodies

- Boundary conditions

  - SPCs
  - Tied connections
  - Rigid walls
  - Transmitting boundaries

- Loading

  - Force
  - Pressure
  - Enforced motion
  - Initial conditions

EXAMPLE PROBLEMS

1. Comparison of MSC/DYNA to MSC/NASTRAN

The author's first experience with MSC/DYNA was enlightening. Before attempting a complex nonlinear analysis, it seemed reasonable to attempt a very simple problem with a known and verifiable solution. The problem chosen was a circular clamped plate under constant static pressure of 30 psi, which was sufficient to take the central extreme fibers to a yield stress of approximately 55,000 psi. The plate radius was 60 inches and the thickness held to 1 inch so that the solution could be compared with classical thin plate theory which ignores shear deformation effects. The transverse deflection results for an elastic static analysis with MSC/NASTRAN are shown in Figure 2 which is a deformation contour superimposed on the deformed shape. All pre- and post-processing was done with MSC/XL.

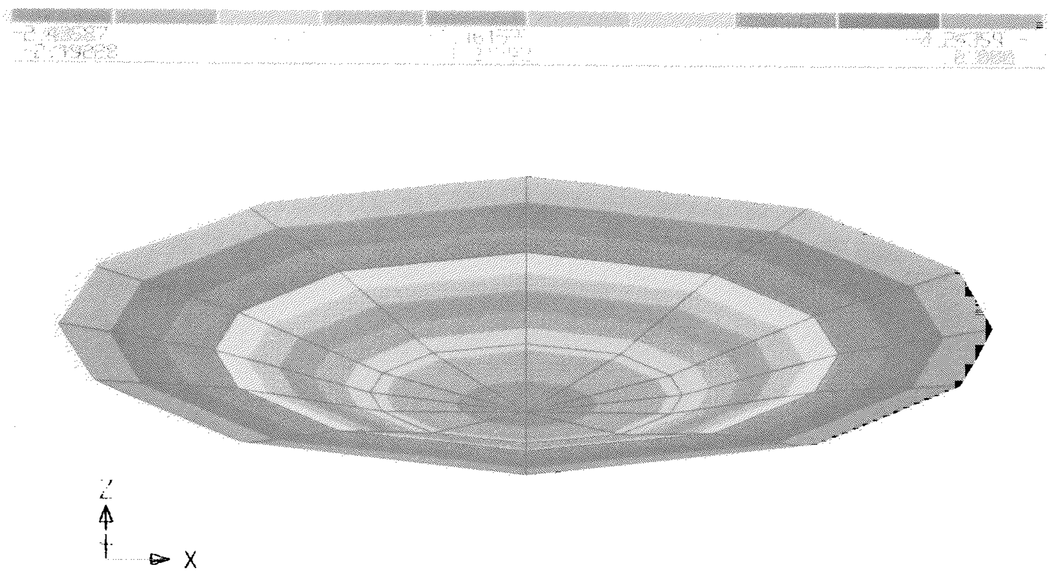


Figure 2. Clamped Circular Plate t=1 in. NASTRAN Deflections

It was desired to perform the same analysis with MSC/DYNA. This can be done in two ways. First, the pressure load can be applied as a ramp load up to full value and then continued at 30 psi. The ramping resists transients due to sudden load application which would take a long time to damp out. The steady state solution then is compared to the NASTRAN static solution.

The other technique is more efficient and a very useful feature of MSC/DYNA. It is called dynamic relaxation and automatically damps out the oscillating response until the problem converges to a steady state solution. There are some user supplied dynamic relaxation parameters required as input when this option is exercised. For this particular problem the defaults worked well and convergence was achieved quickly. When dynamic relaxation is used to obtain a static solution, only the steady state values are retained as output. The results from this analysis agreed with those achieved from the DYNA transient analysis, with a big reduction in computation time.

The DYNA solutions however did not agree with the NASTRAN static analysis results. The maximum NASTRAN central deflection was approximately double the DYNA result as can be seen by examining Figure 2, and the DYNA solution, Figure 3.

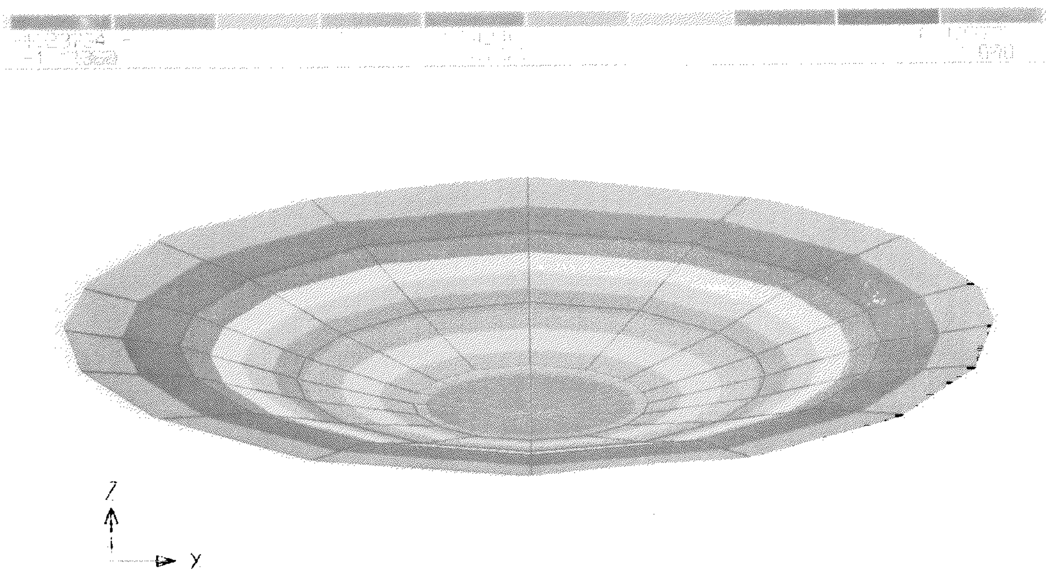


Figure 3. Clamped Circular Plate, t=1 in. DYNA Deflections

The NASTRAN result was verified with a classical thin plate textbook solution. In an attempt to explain why DYNA would not yield the same result, the author spent considerable time refining meshes, trying different element formulations in DYNA, checking input files, etc. None of this helped. Finally, while pondering the next step, the thought occurred that because DYNA was a large deflection code, the element membrane stiffness would be coupled to transverse deflections. For a relatively thin plate such as the one under consideration, this membrane stiffness was equal in significance to the bending stiffness. Therefore the plate was much stiffer than elastic small deflection theory would indicate. To verify this, the plate thicknesses were increased to 7 inches in the NASTRAN and DYNA input files and both problems rerun. The results were nearly identical, with a small discrepancy probably due to the same effect. The results are shown graphically in Figures 4(a) and 4(b).

Both codes were correct in the sense that they were doing what they were designed to do. The author learned that one must think "nonlinear" before attempting to use DYNA. This was a good lesson to keep in mind before moving onto more sophisticated analyses.

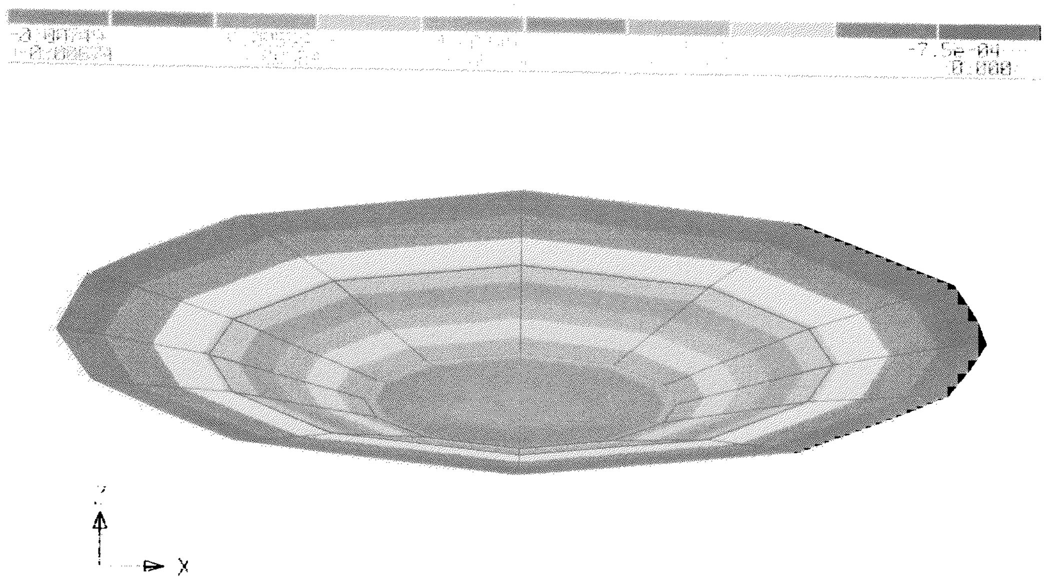


Figure 4(a). NASTRAN Deflections for 7-Inch Thick Plate

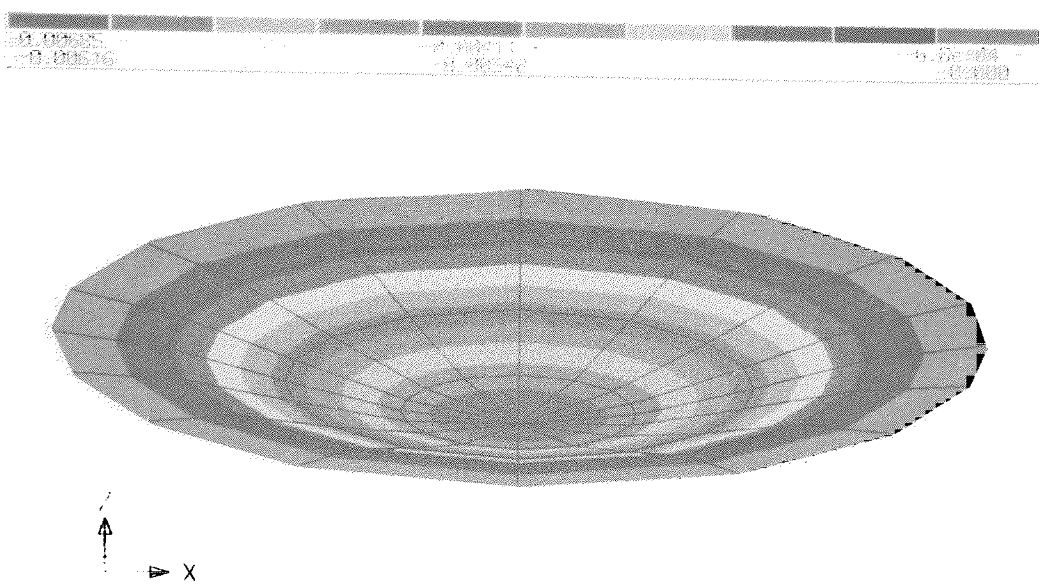


Figure 4(b). DYNA Deflections for 7-Inch Thick Plate

2. *Blast Containment*

In this class of problem, a combination of material plasticity and large deformation are the effects to be simulated. The problem involved a compartment in a transport vehicle subjected to a rapid overpressure due to a detonation in the compartment. The objective was to see if the compartment could isolate the effects of the blast so that adjoining compartments would remain intact. An interesting challenge was found in a sliding door used to access the compartment. Contact surfaces and gap elements had to be employed. This is easy to do with MSC/DYNA. It was possible to utilize a half model with appropriate boundary conditions due to symmetry.

Figure 5 shows a plot of the finite element model along with the experimentally determined pressure pulse, which acts normal to each internal wall, and the nonlinear material properties. The top and bottom surfaces had break away panels to help vent the pressure. These were assumed to be gone. One half of the door can be seen as the portion of the inner vertical wall with higher aspect ratio elements.

In order to check the model, a static pressure was applied first to the vertical walls only. Creation of pressure load cards was difficult with MSC/XL. Unlike the MSC/NASTRAN pressure loads which are easily applied to surfaces or groups of elements, the DYNA pressure loads had to be individually specified for each element. This was cumbersome. We understand that this will be simplified in the next version.

For the static analysis, the dynamic relaxation option was used. In this case, the problem would not converge to a steady state solution with the default dynamic relaxation parameters. This was evident when energy balances were checked. It took a few iterations to get energies to balance. A deformed shape contour for the static analysis is shown in Figure 6.

The nonlinear transient analysis ran very efficiently. In fact, the model was constructed to be identical to an existing model of the compartment run with another commercially available code on a CRAY supercomputer. The DYNA analysis simulating the same loading duration time, run on NKF's VAX 8350, used less CPU time than the CRAY analysis with the other code! This demonstrated the efficiency of MSC/DYNA. Needless to say, the agency for whom we were running the analysis was impressed.

Figure 7 shows major principal stresses at two microseconds. Note how the sliding door in the inner face behaves differently than the adjoining panel due to a lack of rotational and in plane connection between the two surfaces. Deformation contours for the same time are shown in Figure 8. The deformation scale is not exaggerated. Note the separation of the door from the adjoining panel.

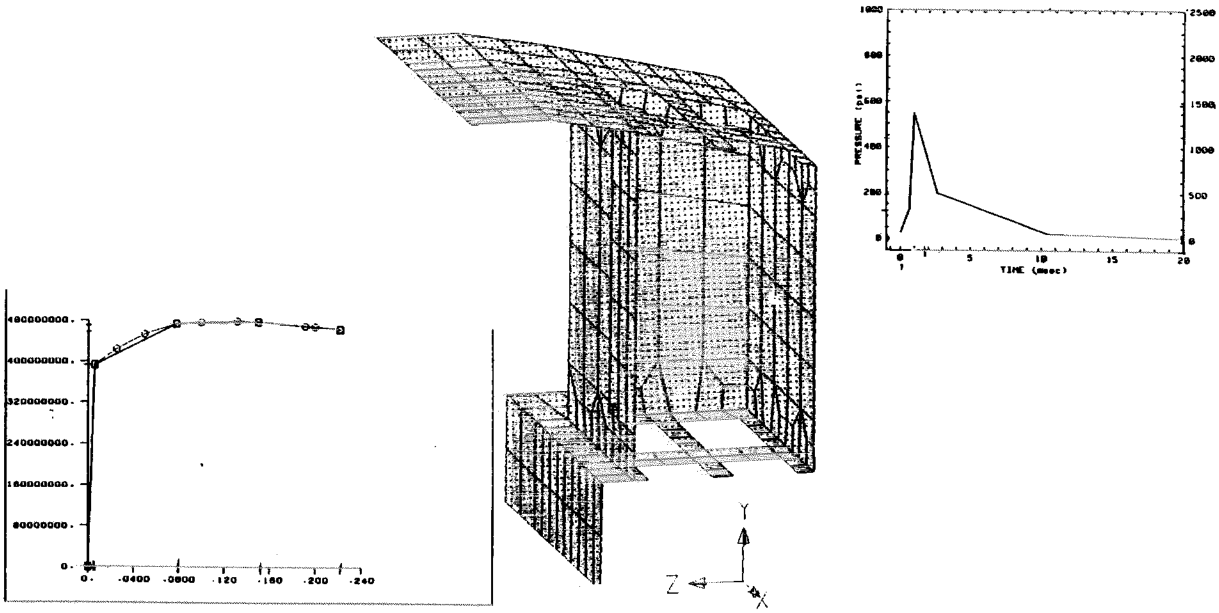


Figure 5. Containment Problem, Loading and Material Properties

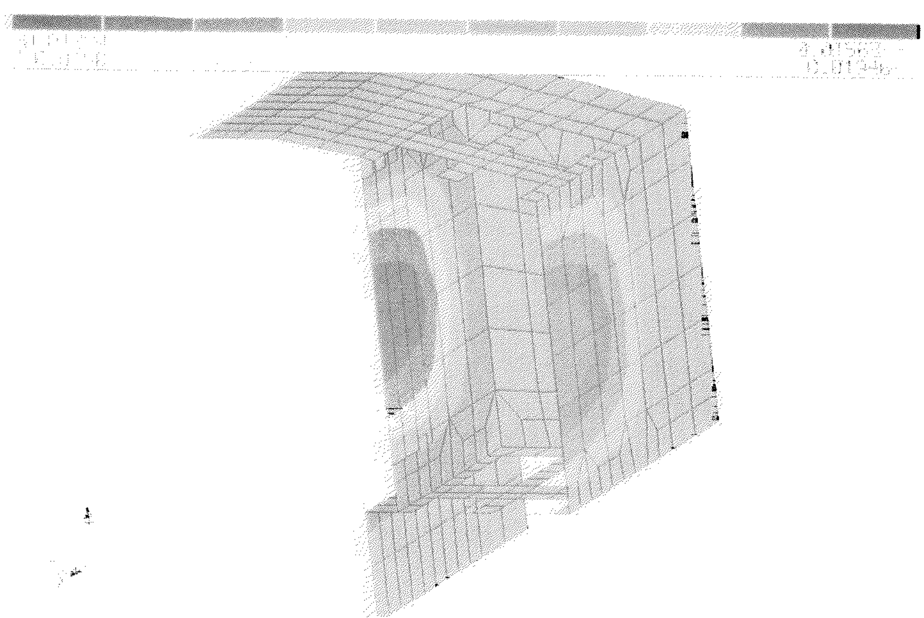


Figure 6. Blast Containment Problem Static Deformation

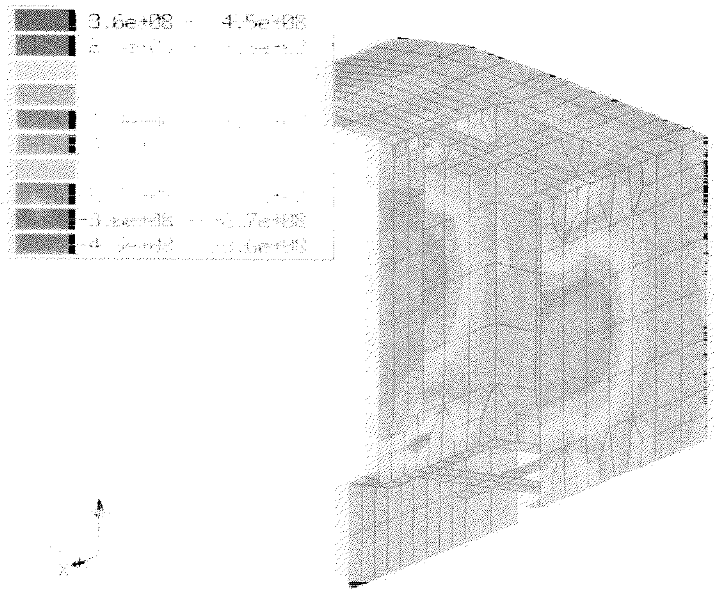


Figure 7. Blast Containment Problem, Stress at 2 m.s.

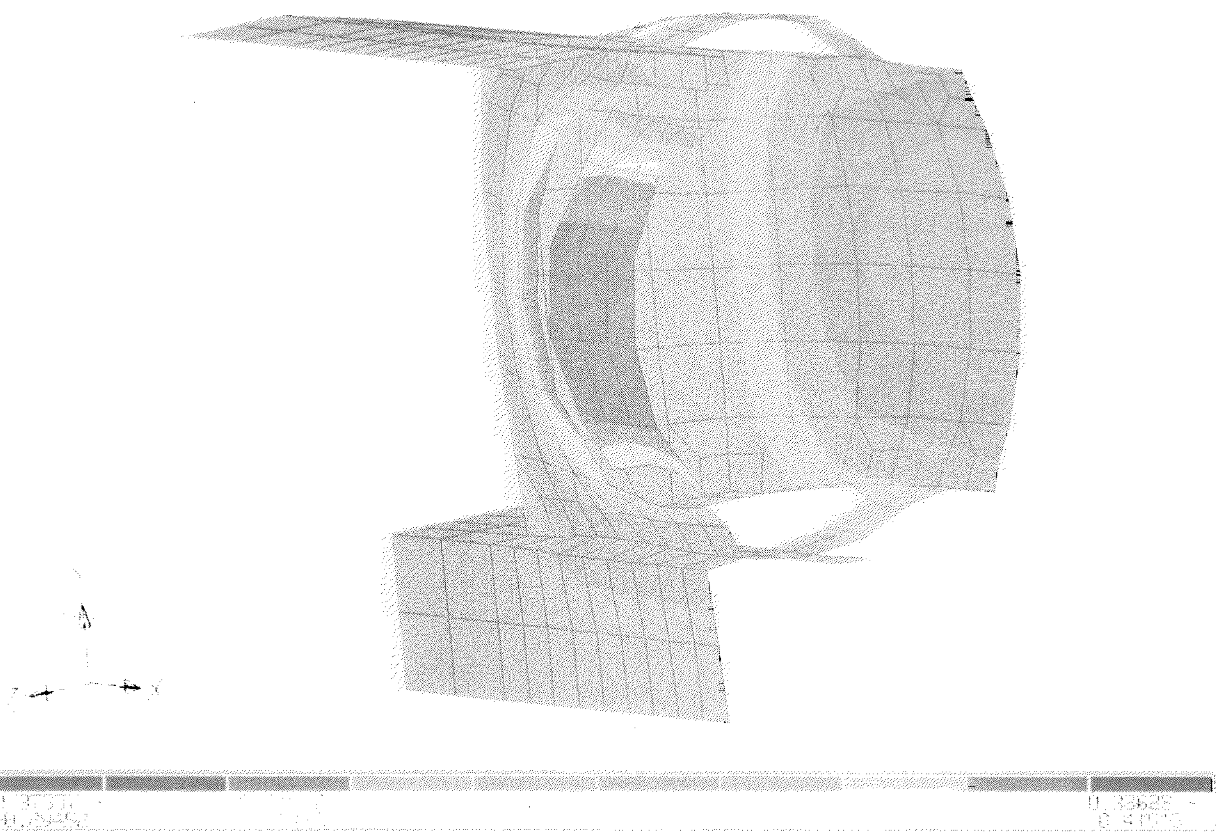


Figure 8. Blast Containment Problem, Deformation at 2 m.s.

Figure 9 illustrates another useful feature of MSC/DYNA. The figure shows the deformed shape at the same time with failed elements removed. A strain failure criteria is supplied on the material card and effectively prevents an element from carrying load once the maximum strain is exceeded. Physically removing the failed elements from the finite element model plots is a simple cross-hair pick with MSC/XL. These features make it easy to visualize where the structure has become compromised. Another useful feature is the ability to plot plastic strains in elements. We haven't yet been able to do this with our beta version of the DYNA to XL translator, but are told that this option will become available with its first commercial release.

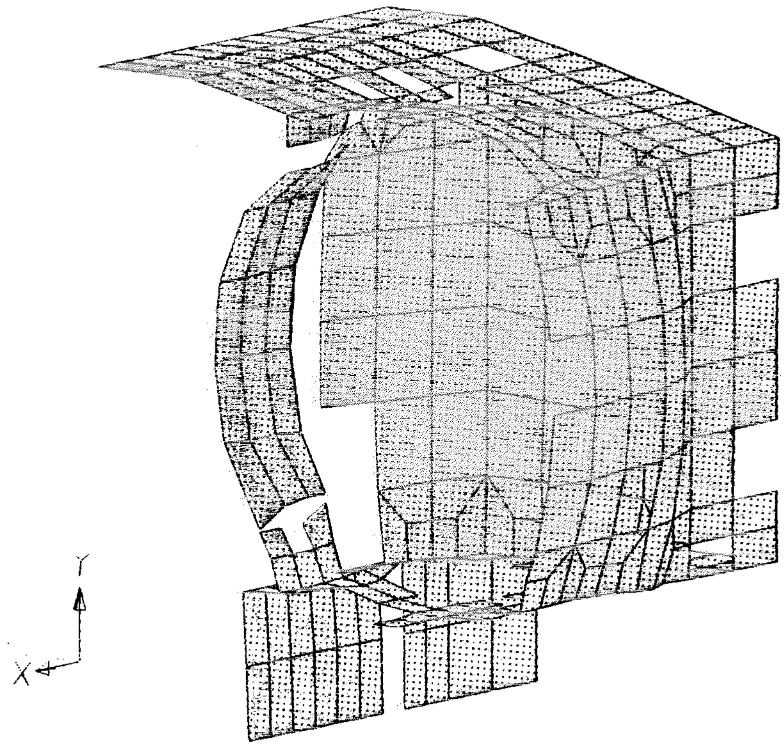


Figure 9. Blast Containment Problem, Failed Elements Removed

3. *Rigid Wall Impact*

Another useful feature in MSC/DYNA is in the area of impact when the structure of interest collides with a rigid wall. This feature can provide a bounding case for many impact and penetration problems where the behavior of the impacting structure is of concern. For example, if an armor piercing warhead is being designed, it can be subjected to a rigid wall impact as a first case to test the model. If the penetrator survives, it is probably overdesigned.

A sample problem was run just to test the feature. A solid block with high initial velocity was impacted into a rigid wall. In a grossly simplified manner, this is the kind of simulation one might perform when crashing a vehicle into a barrier. The initial configuration along with the impact sequence is shown in Figures 10 through 12. A finer mesh would have provided more detailed deformation patterns.

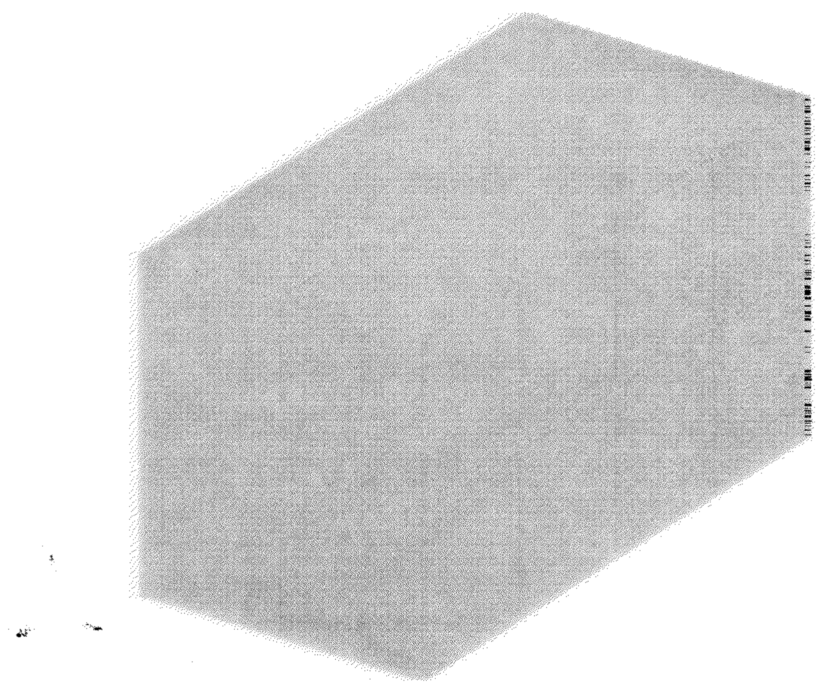


Figure 10. Rigid Wall Impact, Initial Configuration

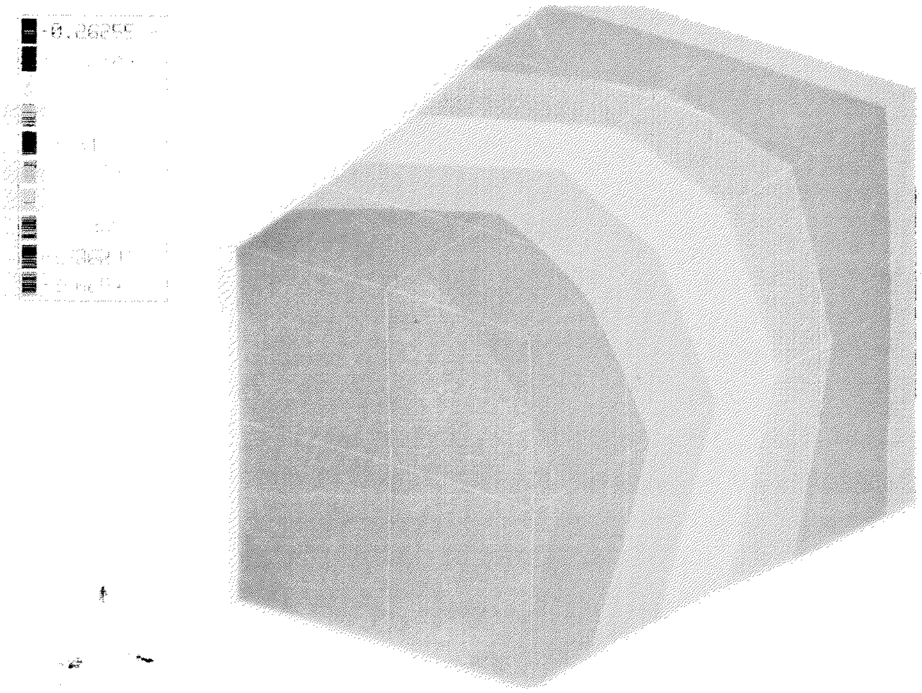


Figure 11. Rigid Wall Impact, Early Time Deformation

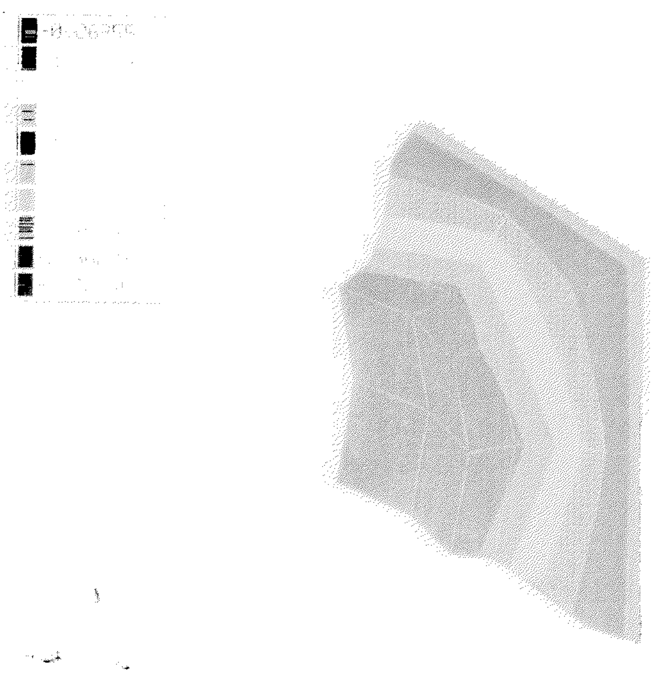


Figure 12. Rigid Wall Impact, Late Time Deformation

4. *Penetration Problems*

We have run a number of sample penetration problems with MSC/DYNA in anticipation of actual work in support of commercial and government customers. The knowledge we have gained on these sample problems has proven useful in the understanding of the actual penetration problems we are now investigating for our customers. We have learned that, while it is fairly simple to get a problem to successfully execute in MSC/DYNA, it takes significantly more effort to achieve correlation with experimental results. The model building time is probably the smallest portion of the effort.

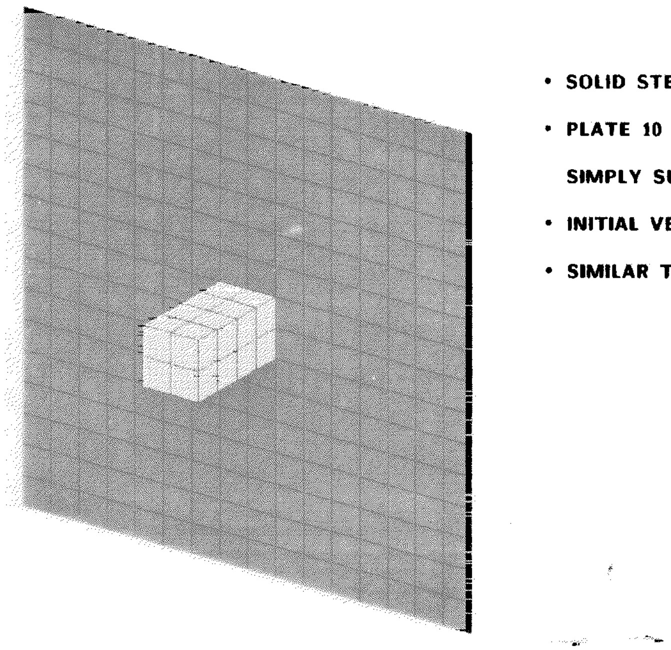
Many parameters come into play depending on the particular problem. MSC/DYNA simulates them very well but the quality of the solution depends on how accurately the user defines the various effects. Such items as initial mesh configuration versus deformed mesh configuration, friction, strain rate dependent of material properties, definition of contact surfaces, boundary conditions, failure mechanisms and a host of other considerations make these problems challenging. Some of this input data can only be accurately determined through testing.

If the design parameters are well established, MSC/DYNA is robust enough to provide accurate solutions. If all the required parameters are not well established MSC/DYNA can still be a very powerful tool in the design process.

Many designers use DYNA in conjunction with experimental data to determine the appropriate properties to achieve the desired level of correlation. If a "validated model" can be established in this manner, then design modifications can be "tested" analytically and expensive hardware testing only performed for final designs. Because of the complexity of the behavior in this class of problems, it is better to work in conjunction with a testing program if possible. This is very different than the requirements for linear elastic static and dynamic analysis where the parameters are generally well known.

A few sample problems have been run and are presented to illustrate our user experience with MSC/DYNA and its MSC/XL interface. Figure 13 shows the initial configuration of a solid slug about to impact a thin plate at high velocity. Figure 14 shows the deformation and penetration of the plate while Figure 15 shows emerging projectile with failed plate elements removed. An actual problem of this nature would require a finer mesh both for the penetrator and the target. Figures 16 and 17 show target deformation contours at early and late time for the same problem.

A second example is somewhat more complex. In this case a hollow projectile is impacting a rib stiffened shell. The projectile was modelled with plate shell



- SOLID STEEL SLUG 1 X 1 X 4
- PLATE 10 X 10 X .001 IN THICK
  SIMPLY SUPPORTED ON 2 ENDS
- INITIAL VELOCITY OF SLUG = 3000 FT/SEC
- SIMILAR TO CIWS PROJECTILE ON MISSILE SKIN

Figure 13. Solid Slug Impacting Thin Plate, Initial Configuration

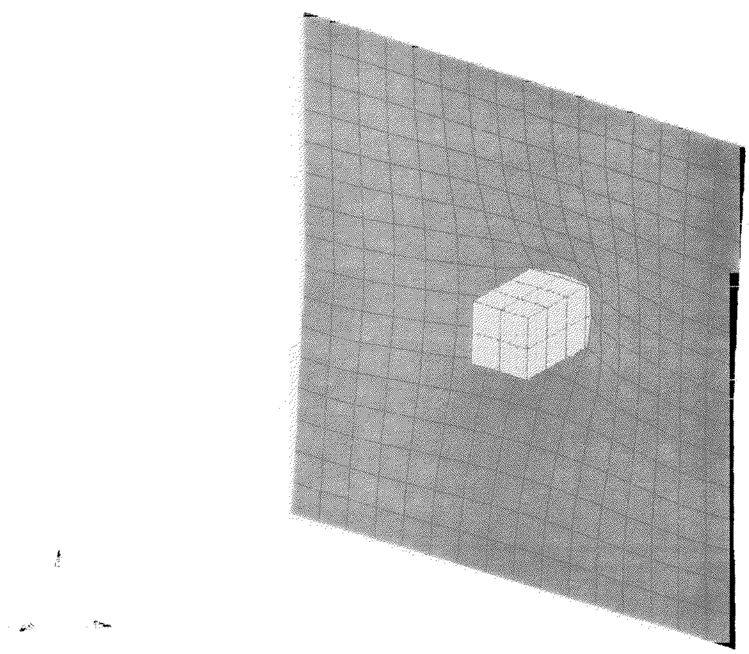


Figure 14. Solid Slug Impacting Thin Plate, Early Time

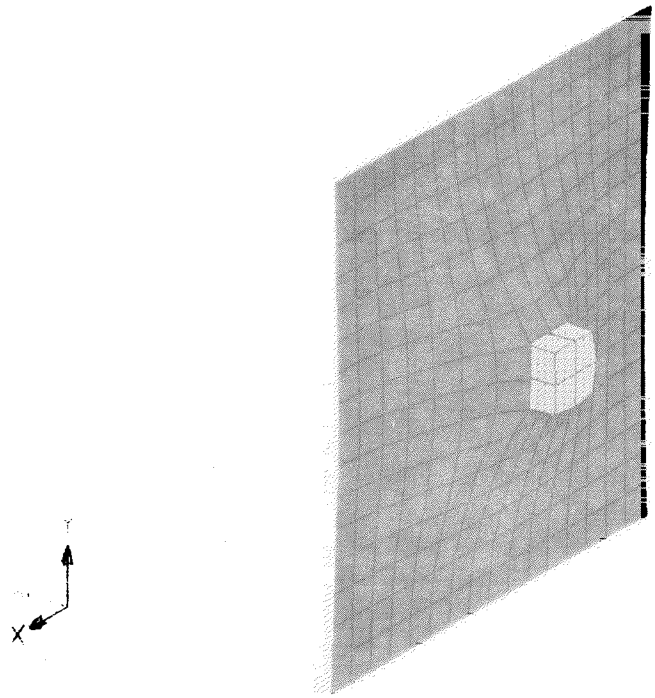


Figure 15. Solid Slug Impacting Thin Plate, Emerging Projectile

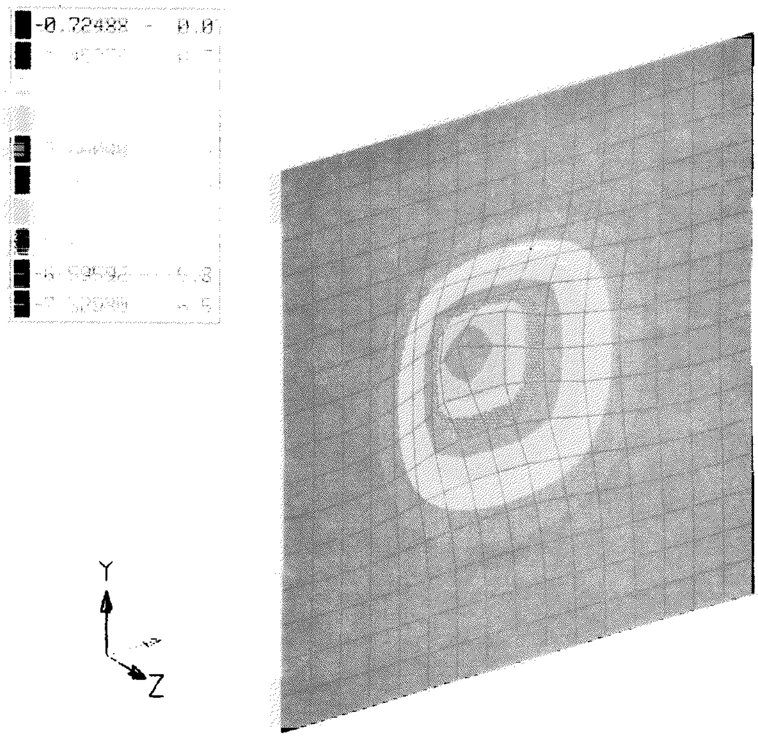


Figure 16. Solid Slug Penetrating Thin Plate, Deformation Field, Early Time

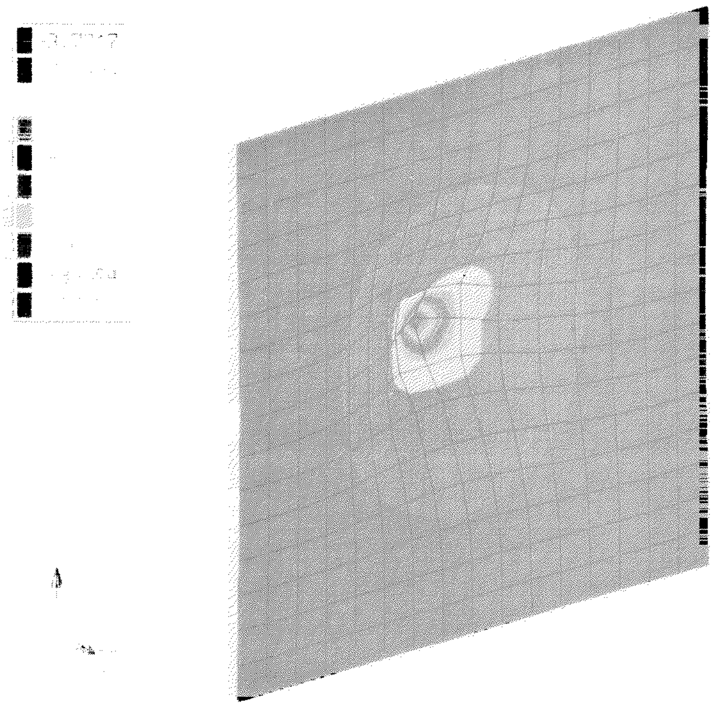


Figure 17. Solid Slug Penetrating Thin Plate, Deformation Field, Later Time

elements as was the target cylinder. The stiffening ribs were simulated with beam elements. The initial configuration is shown in Figure 18. The penetration sequence is shown in Figures 19 and 20 including the emerging projectile with failed elements in the target cylinder removed. Close examination of the emerging projectile shows that its head has undergone significant crush.

Figure 21 illustrates late time stresses of the system on the undeformed shape. Inclusion of the penetrator skews the contour range. A more accurate picture of the target cylinder response can be seen in Figures 22 and 23 where the projectile has been removed. Both early and late time snapshots are shown. Finally, Late time stresses for the penetrator superimposed on the undeformed shape are shown in Figure 24.

As this paper is being written we are performing a penetration verification test for an actual problem for which experimental data is available. Analysis of this experiment has already been performed with at least two other penetration codes. The MSC/DYNA solution will be compared both to the experimental and analytical results. Unfortunately, at this time, the analysis is incomplete. A plot of the preliminary MSC/DYNA analysis problem setup is included in Figure 25 to illustrate the nature of the problem. Preliminary results at 50 microseconds at a deformation scale of 5 are shown in Figure 26.

- **PROJECTILE**

  DIAMETER 3 IN
  LENGTH 9 IN
  INITIAL VELOCITY 1000 FT/SEC
  THICKNESS OIL IN

- **CYLINDRICAL PLATE (RIB STIFFENED)**

  RADIUS 10 FT
  LENGTH 10 FT
  90° SEGMENT
  THICKNESS 0.01 IN
  BAR ELEMENTS

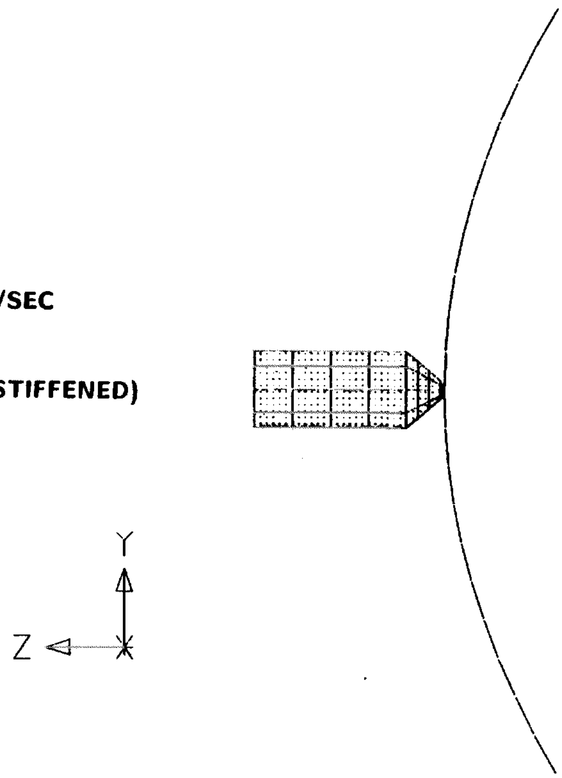


Figure 18. Hollow Projectile Impacting Rib Stiffened Shell Problem Definition

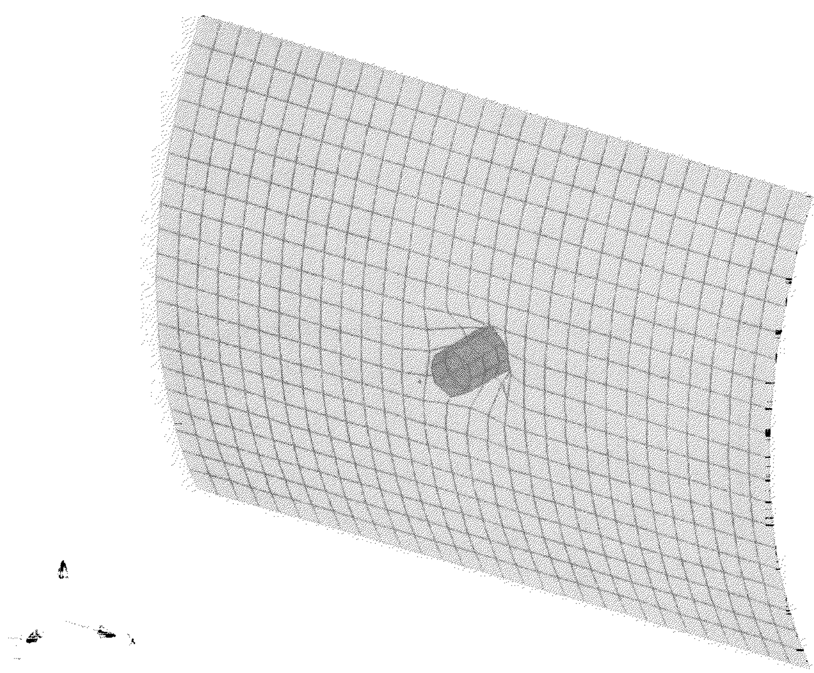


Figure 19. Hollow Projectile Impacting Rib Stiffened Shell - Early Penetration

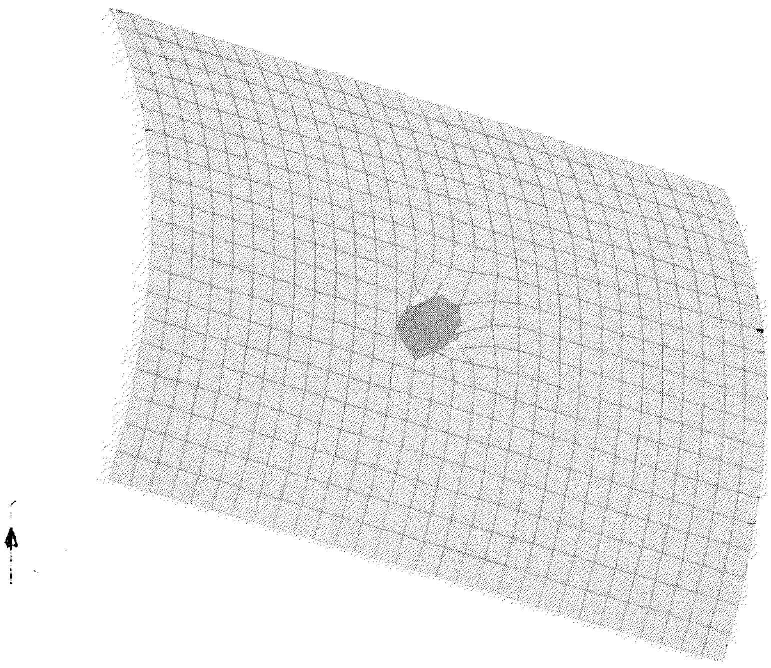


Figure 20. Hollow Projectile Impacting Rib Stiffened Shell - Emerging Projectile

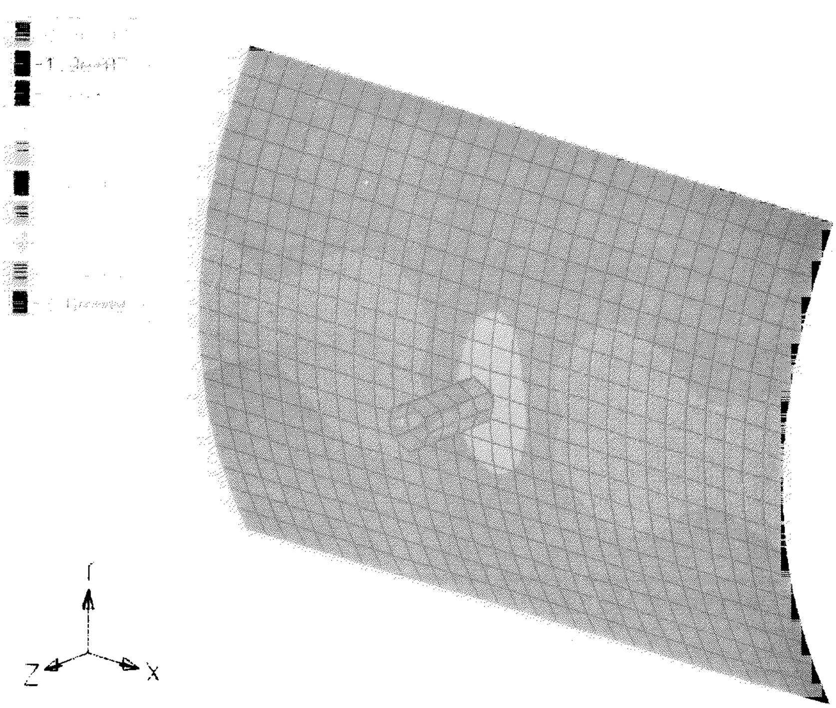


Figure 21. Hollow Projectile Impacting Rib Stiffened Shell - Late Time Stresses on Undeformed Shape

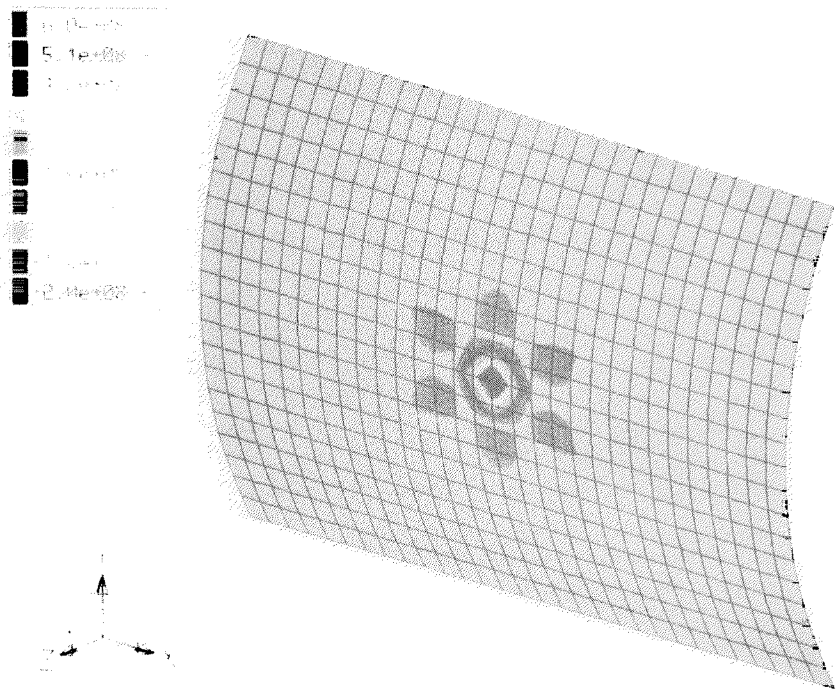


Figure 22. Hollow Projectile Impacting Rib Stiffened Shell - Early Time Target Cylinder Stresses

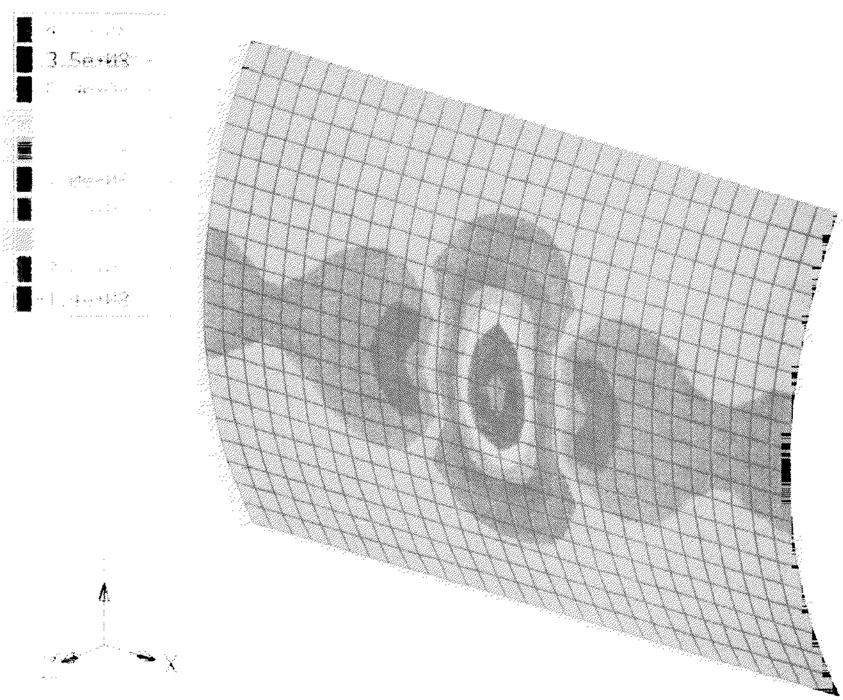


Figure 23. Hollow Projectile Impacting Rib Stiffened Shell - Late Time Target Cylinder Stresses

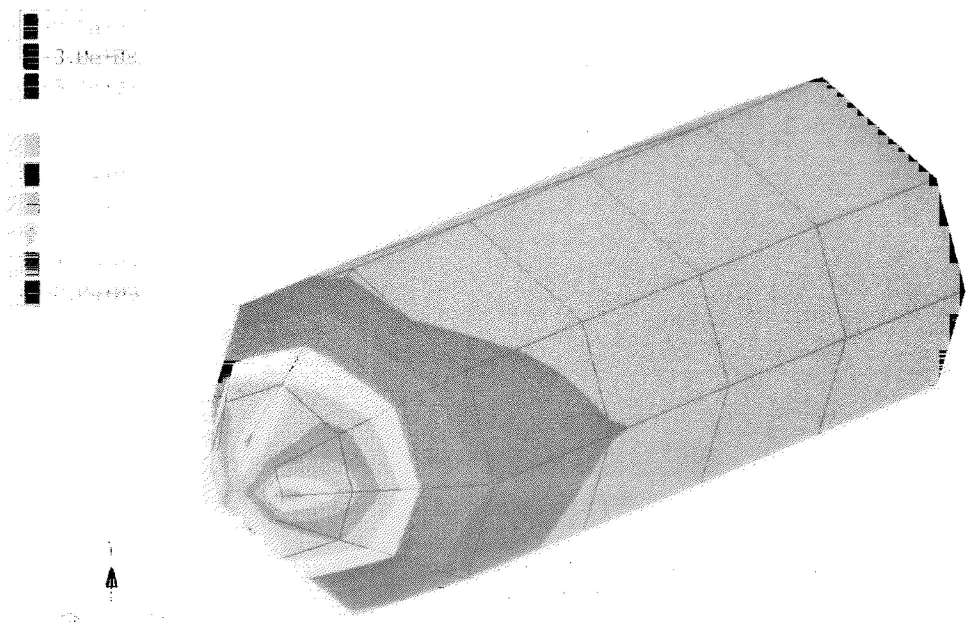


Figure 24. Hollow Projectile Impacting Rib Stiffened Shell - Late Time Stresses on Projectile Undeformed Shape

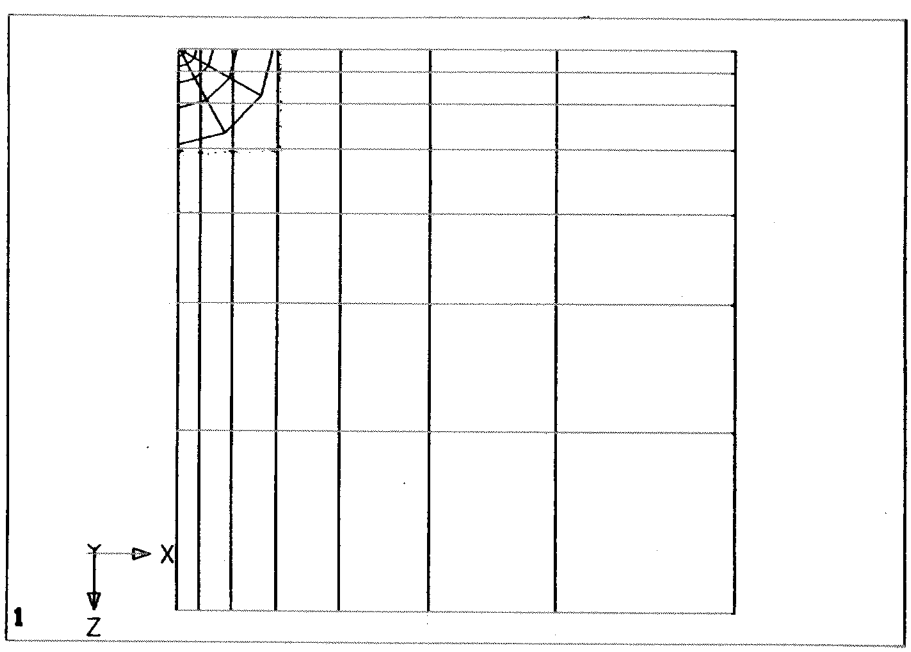


Figure 25. DYNA Verification Problem (Preliminary) Top View of Projectile and Target Mesh in Contact Area

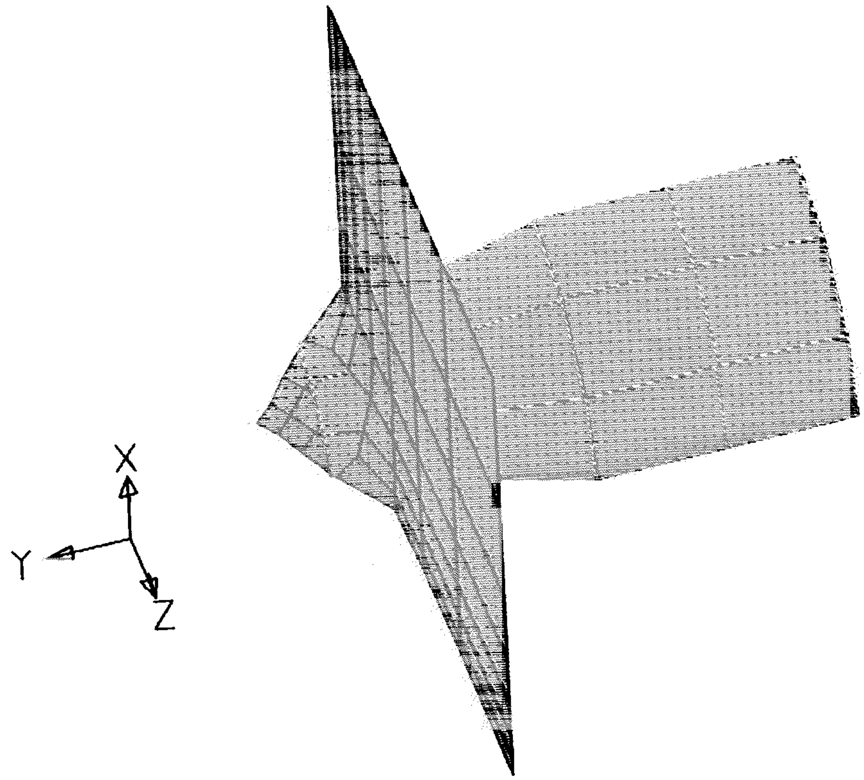


Figure 26. DYNA Verification Problem (Preliminary) Penetration at 50 microseconds at Deformation Scale = 5

5. *Compressible Plasticity Problem*

One of the MSC/DYNA material models proved very useful in a recent analysis of a blast shelter we were performing for one of our government customers. The shelter itself, which was subjected to a direct airblast loading supersonic pressure wave, was a steel design and analyzed with MSC/NASTRAN. In order to reduce the blast loading which was being magnified by a factor of 3 over the the free field pressure upon reflection off the structure, the use of an energy absorbing earth berm was considered.

The crushable plasticity model (DYMAT5) in MSC/DYNA was employed to simulate the interaction of the blast wave with the soil. This model is suitable for materials such as foam, soil, concrete, honeycomb, or wood and considers the pressure to vary with the volumetric strain of the material. The user supplies the appropriate material properties, in this case a number of soil constants, including the soil bulk modulus K which determines the slope of the initial and unloading curves. These were obtained from the Army Corps of Engineers. A typical user defined pressure-strain curve is shown in Figure 27.

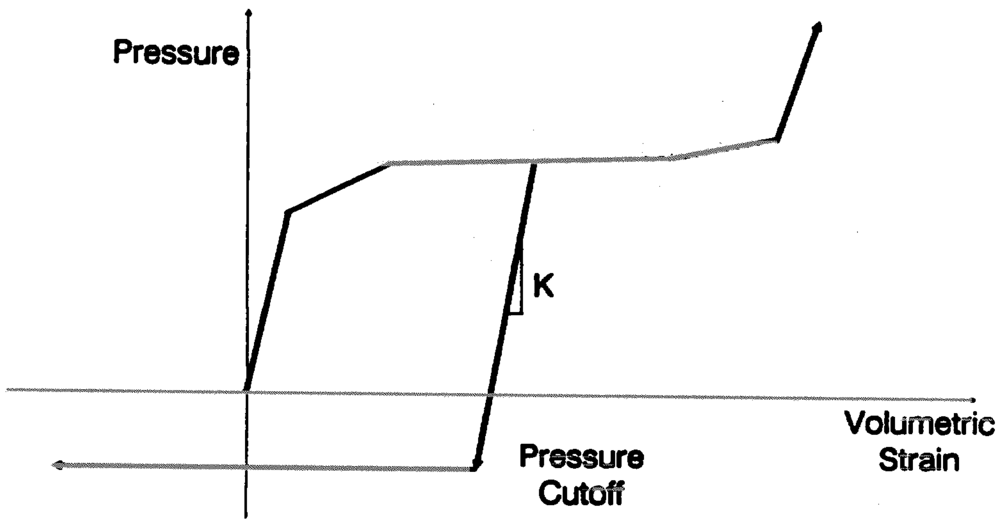


Figure 27. Compressible Plasticity Model (DYMAT5)

The steel structure was assumed rigid and simulated with SPCs in the translational directions at the soil structure boundary. DYMAT5 requires the use of solid elements so four elements across the berm slice were considered. Plane strain boundary conditions were implemented along the sides of the slice. The free field pressure transients were applied as a triangular pulse of 18 m.s. duration on the leading and top edges of the berm, appropriately phased for their varying arrival times. The result was that the soil absorbed much of the blast energy such that the steel shelter only saw pressures equal to 1.3 times the free field pressure. This aided the design significantly. Figures 28 through 30 show the model and its dynamic pressure response as calculated with DYNA for use as loading input into the NASTRAN shelter model. Note that the shelter structure is located in the hollow inner section of the earth berm. Deformation "criteria" plots of average element deflections are superimposed on the deformed shapes with MSC/XL.

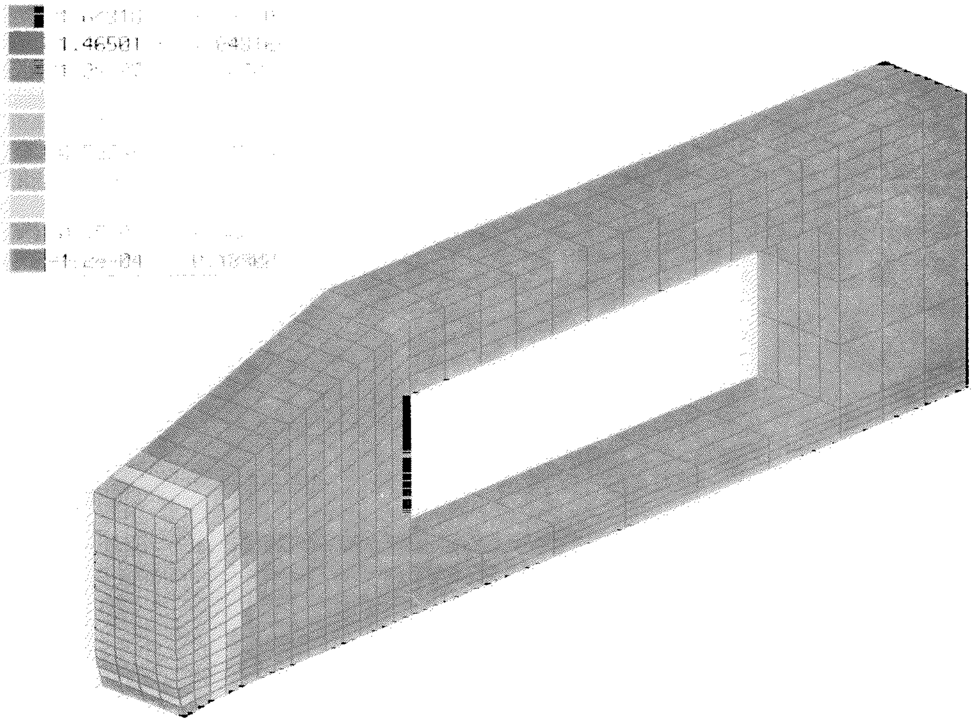


Figure 28. Earth Berm Deformed Shape - 3 m.s.

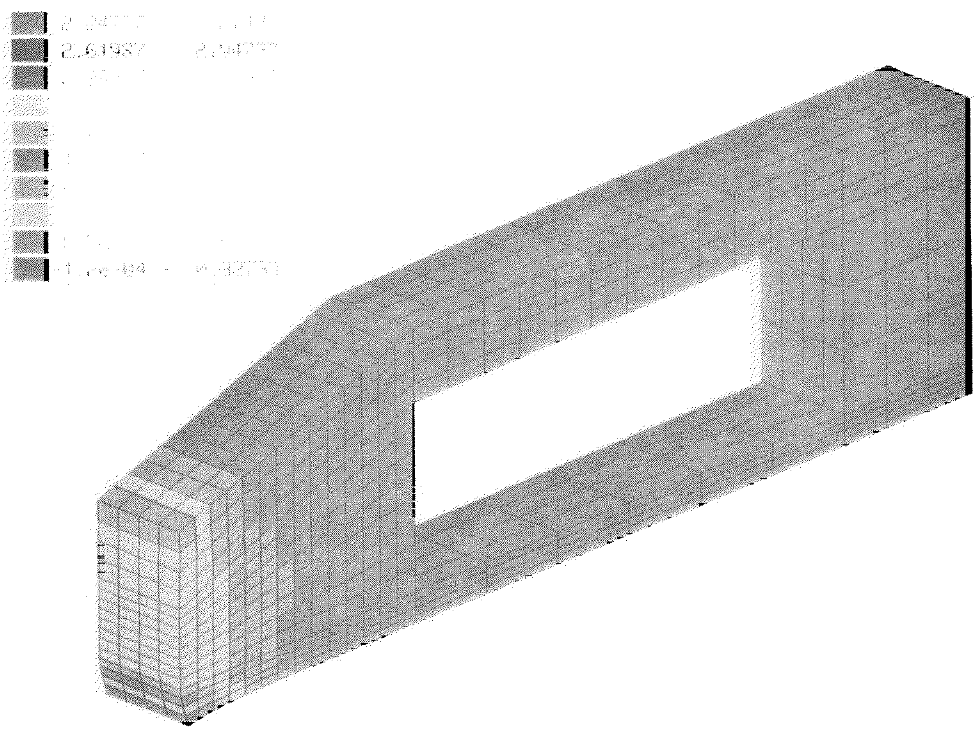


Figure 29. Earth Berm Deformed Shape - 6 m.s.

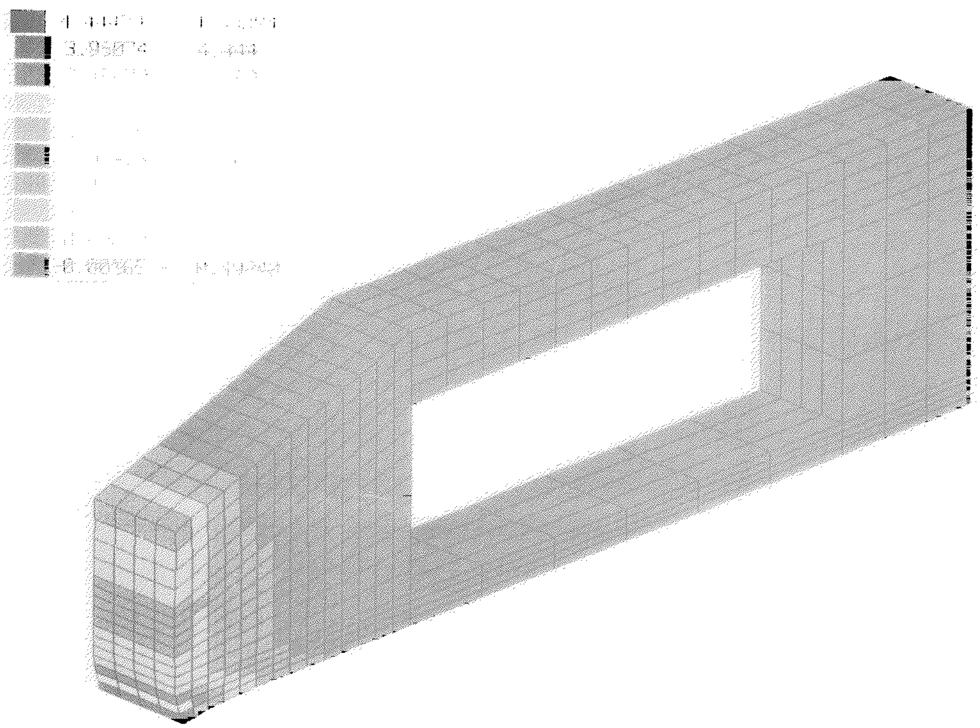


Figure 30. Earth Berm Deformed Shape - 9 m.s.

CONCLUSIONS/RECOMMENDATIONS

In our 1 year of experience with MSC/DYNA we have arrived at the following conclusions and recommendations:

Conclusions

- DYNA is an extremely powerful code which greatly enhances the user's structural analysis capability over what can be done with MSC/NASTRAN alone.

- The combination of MSC/NASTRAN and MSC/DYNA provides a full range of structural analysis tools.

- MSC/DYNA is extremely easy to use because of its format compatibility with MSC/NASTRAN. The fact that a NASTRAN input file is also a valid DYNA input file offers the NASTRAN user two advantages:

  - Not having to learn a new code with very different structure and data format
  - The ability to generate and post-process DYNA models with MSC/XL

- Though MSC/DYNA is easy to use procedurally, there is a much greater possibility of an inexperienced analyst getting results that are inaccurate.

- Successful use of MSC/DYNA requires a good understanding of nonlinear continuum mechanics and a significant background in finite element modeling.

- We have found that user support for MSC/DYNA and MSC/XL is excellent due to the implementation of a dedicated staff of MSC analysts. This offers a big advantage over some other public domain codes which are not as well documented and supported.

Recommendations

- When possible, it is recommended that MSC/DYNA analysis be run in conjunction with a testing program so that data input parameters can be verified and analysis results can be validated.

- If testing is not feasible, it is recommended that a simple form of the type of problem under consideration be analyzed and compared to a known theoretical or test solution.

- Some simple format changes, especially in the area of pressure load application, would reduce input generation time.

- We would like to see the implementation of user defined multipoint constraint equations and more information on DYNA's DMAP structure to afford the user the opportunity to add special enhancements as one can do with MSC/NASTRAN.

REFERENCES

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3. "MSC/DYNA Theoretical Manual," Version 1, The MacNeal-Schwendler Corporation, April 1989

4. "MSC/NASTRAN User's Manual," Version 65, The MacNeal-Schwendler Corporation, 1985

5. "MSC/XL User's Manual," The MacNeal-Schwendler Corporation, 1989