THREE-DIMENSIONAL SLIDELINE CONTACT IN VERSION 68

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ABSTRACT

Slideline contact was first introduced in Version 67.5 of MSC/NASTRAN through a standalone DMAP alter – 'contact.v675' available in the /misc/sssalter directory. This DMAP alter is applicable only for solving static problems. Starting with Version 68, the slideline contact capability is available for solving both nonlinear static (SOL 106) and nonlinear transient (SOL 129) problems as a standard feature. The use of the DMAP alter is no longer required.

This paper shares the experience of using the MSC/NASTRAN slideline contact capability. It (a) demonstrates the capability through real life applications and (b) provides guidelines for effective usage.

INTRODUCTION

Three dimensional (3–D) slideline contact was first introduced in Version 67.5 through a DMAP alter called 'contact.v675' in the SSS alter library. This alter was applicable only to the nonlinear static solution (SOL 106). In Version 68, the capability is available in both the static and the transient nonlinear structured solution sequences (SOL 106 and SOL 129) as a standard feature; the DMAP alter is no longer required. It should be noted that 3–D slideline contact is **not** available in the corresponding unstructured solution sequences.

With this capability a user may model contact between two components that undergo large relative motions within a plane. That is, the contacting components can be three dimensional, however the contact between the components (separation or sliding) must occur in a plane called the slideline plane. The new contact capability is useful for structural problems where two or more separate components may independently come in contact, separate or slide, such as rubber seals, O–rings and rubber springs.

DIFFERENCES BETWEEN VERSION 67.5 AND VERSION 68

Allahabadi [1] described the technical and user interface details and they are, therefore, not repeated here. There have been some improvements and some minor changes in the user interface since the release of Version 67.5, specifically in the meaning and the use of the DMAP parameter ADPCON. These are described below.

In Version 67.5, sometimes, the contact algorithm lead to excessive bisections and entered into an error trap if NO is specified in the INTOUT field of the NLPRAM Bulk Data entry. The algorithm in Version 68 is improved to avoid unnecessary bisections and the error has been fixed. In addition, the adaptive algorithm for penalty values is further improved to overcome convergence difficulties. Therefore, the need to use the parameter ADPCON has been reduced.

In Version 68, parameter ADPCON is allowed to have a negative value. A negative value implies that penalty values are calculated only at the beginning of each subcase, and they are not adjusted as the stiffness of the structure changes due to material or geometric nonlinearities. This feature may be useful for contact between two elastic bodies.

EXAMPLE PROBLEMS

Five real life example problems are presented to demonstrate the 3–D slideline contact capability: These are: (1) pushing in and pulling out of a pipe in a clip, (2) an experimental problem of pressing a tube with side constraints, (3) crushing of a tubular system, (4) insertion of electrical pins into a circuit board, and (5) bumper crash.

Pushing and Pulling of a Pipe in a Clip: A pipe (diameter of 10.1 mm), made of steel, is pushed in and pulled out of a cavity (diameter 10 mm) made of synthetic material at a constant velocity of 5 mm/seconds, as shown in Figure 1. It is desired to find the maximum force required to push in and pull out.

The physical problem is reduced to a two dimensional problem. The pipe is modeled with QUAD4 plane strain elements and the clip is modeled with QUAD4 and TRIA3 plane strain elements. The model with the boundary conditions is shown in Figure 2. It is assumed that inertia effects are not important and therefore nonlinear static analysis is used to solve the problem. Figure 3 shows the deformed shapes at the various stages of push–in and pull–out. Figure 4 shows the force versus displacement relationship for the push–in and pull–out phase. It can be seen from the Figure 4 that the pipe snaps in at a displacement of about 9.5 mm during the push–in phase, and the snaps out for up to 6.5 mm during the pull out phase.

Experimental Problem of Pressing a Tube With Side Constraints: An experiment was conducted by Reddy and Reid [2] to study the use of laterally compressed Aluminum tubes as impact energy absorbers. The experiment model and FEM model are shown in Figure 5. The tube properties are:

Diameter = 25 mm
Thickness = 0.9 mm
Young's Modulus = 69,000 N/mm^2
Plastic Modulus = 1,300 N/mm^2
Yield Stress = 330 N/mm^2

Figure 6 shows the collapse process of the tube and Figure 7 compares the MSC/NASTRAN results with experimental results and those reported by Reddy and Reid [2] in terms of non–dimensional load versus deflection. It can be seen form the Figure that MSC/NASTRAN results match well with the experimental results.

Crushing of a Energy Dissipating Tubular System: Carney, Austin, and Reid [3] studied the energy dissipation characteristics of steel tube structures. A planar view of one of their clusters is shown in Figure 8. There are ten tubes and each tube has the following properties:

Diameter = 50.8 mm
Thickness = 1.59 mm
Length = 12.7 mm
Young's Modulus = 2.05,800 N/mm^2
Plastic Modulus = 4,000 N/mm^2
Yield Stress = 270 N/mm^2

The analysis model consisted of 19 contact regions shown by dark regions in Figure 8. The collapse process of the tube system is shown in Figure 9 and the load versus vertical displacement at the top point is shown in Figure 10.

Insertion of Electrical Pins into a Circuit Board: An electric plug consisting of 300 compliant pins is inserted into a circuit board. It is desired to find if any of the pins will undergo any plastic deformation when the plug is inserted into the circuit board. The pins are made of nickel 00–N–290 class 2 and are plated with gold. A typical shape of the pin is shown in Figure 11.

A two dimensional model is used and only a single pin with symmetric boundary conditions is modeled to see if the pin undergoes any plastic deformation. For both the circuit and the pin the material properties are:

Young's Modulus = 1.6 E4 ksi
Yield Stress = 110 ksi
Strain Hardening = .075 %

The coefficient of friction between the pin and the board is 0.53. Figure 12 shows the model and Figure 13 shows the deformed shape when the pin is fully inserted into the circuit board. The analysis shows that the pin undergoes plastic deformation and the deformed shape looks similar to the real life situation.

Bumper Crash: A barrier moving at five MPH comes into contact with a bumper fixed at the bumper brackets. Figure 14 shows the undeformed bumper model with the barrier. The contact between the barrier and the bumper is modeled using five slideline contact regions with barrier as master and bumper as slave. Each master region consists of two master nodes (grid points) and 23 slave nodes (grid points). Figure 15 shows the crushed bumper after 20 msec of analysis. This analysis is done to demonstrate the concept. A similar bumper crash analysis is being performed using a real bumper from Ford Motor Company (see Figure 16).

GUIDELINES

1. Grid points that define the master and slave regions must be in topological order.
2. Ensure that the normals of master segments point towards the slave region.
3. All the contact regions must be defined at the beginning of the analysis. The contact regions cannot be deleted, added, or extended on restart.
4. The master regions must be extended far enough so that slave nodes do not slide off the master region.
5. It is the user's responsibility to make sure that there are no large relative motions outside the slideline plane.

6. Contact constraints are only enforced for the slave nodes.
7. Use symmetric penetration to enforce contact constraints for the master nodes.
8. Define coarser mesh as the master.
9. Define stiffer body as the master.
10. Automatic penalty values are calculated by:

$$k_s * SFAC * |ADPCON|$$

where k_s = number calculated automatically for a slave node by the program
$SFAC$ = scale factor specified in BCONP bulk data entry
$ADPCON$ = DMAP parameter

Penalty values calculated by the program are generally on a high side. Use parameter ADPCON to reduce the penalty values by an order of a magnitude. That is use PARAM,ADPCON,0.1. Parameter ADPCON applies to both gap and friction.

11. Presence of friction may cause difficulty in convergence. You may override the penalty values calculated for the friction by specifying the penalty value in the FSTIF field of the BFRIC bulk data entry. Specify a lower value than that calculated by the program.
12. Penalty values calculated by the program can be printed using DIAG 35. However, use of DIAG 35 results into enormous amount of output in F06 file.

ACKNOWLEDGEMENT

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REFERENCES

1. Allahabadi, R., "Three Dimensional Slideline Contact," MSC/NASTRAN World User's Conference, May 1993.
2. Reddy, T. Y. and Reid, S. R.,"Lateral Compression of Tubes and Tube Systems With Side Constraints", International Journal Of Mechanical Sciences,21, 187 (1979).
3. Carney, J. F., III, Austin, C. D., and Reid, S. R.,"Energy Dissipation Characteristics of Steel Tube Clusters," Twenty–Third Structures, Structural Dynamics and Material Conference, AIAA/ASME/ASCE/AHS, New Orleans, Louisiana, AIAA 82–0759–CP (1982)

FIGURES

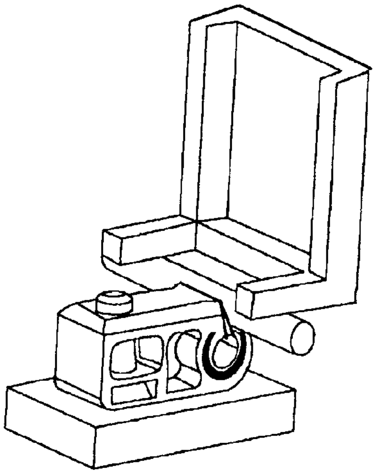

Figure 1. Pipe Push In and Pull Out.

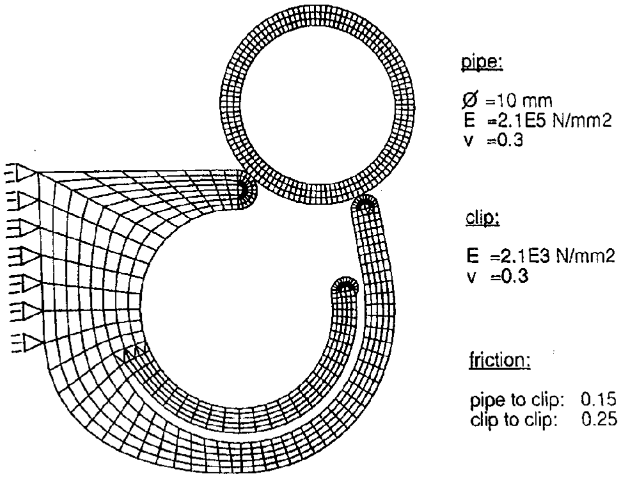

Figure 2. Finite Element Model for Pipe Push In and Pull Out.

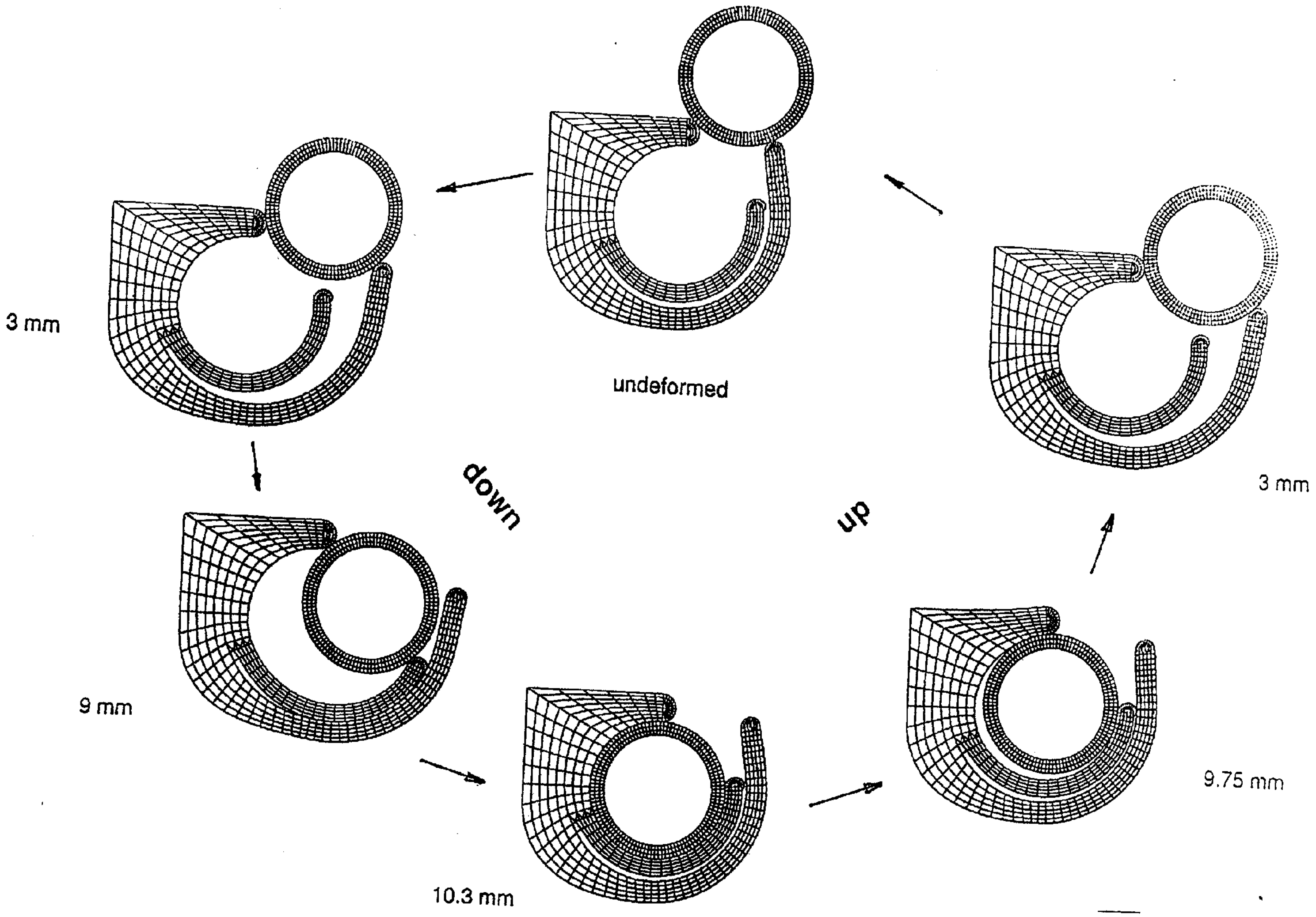

Figure 3. Various Stages of Pipe Push In and Pull Out.

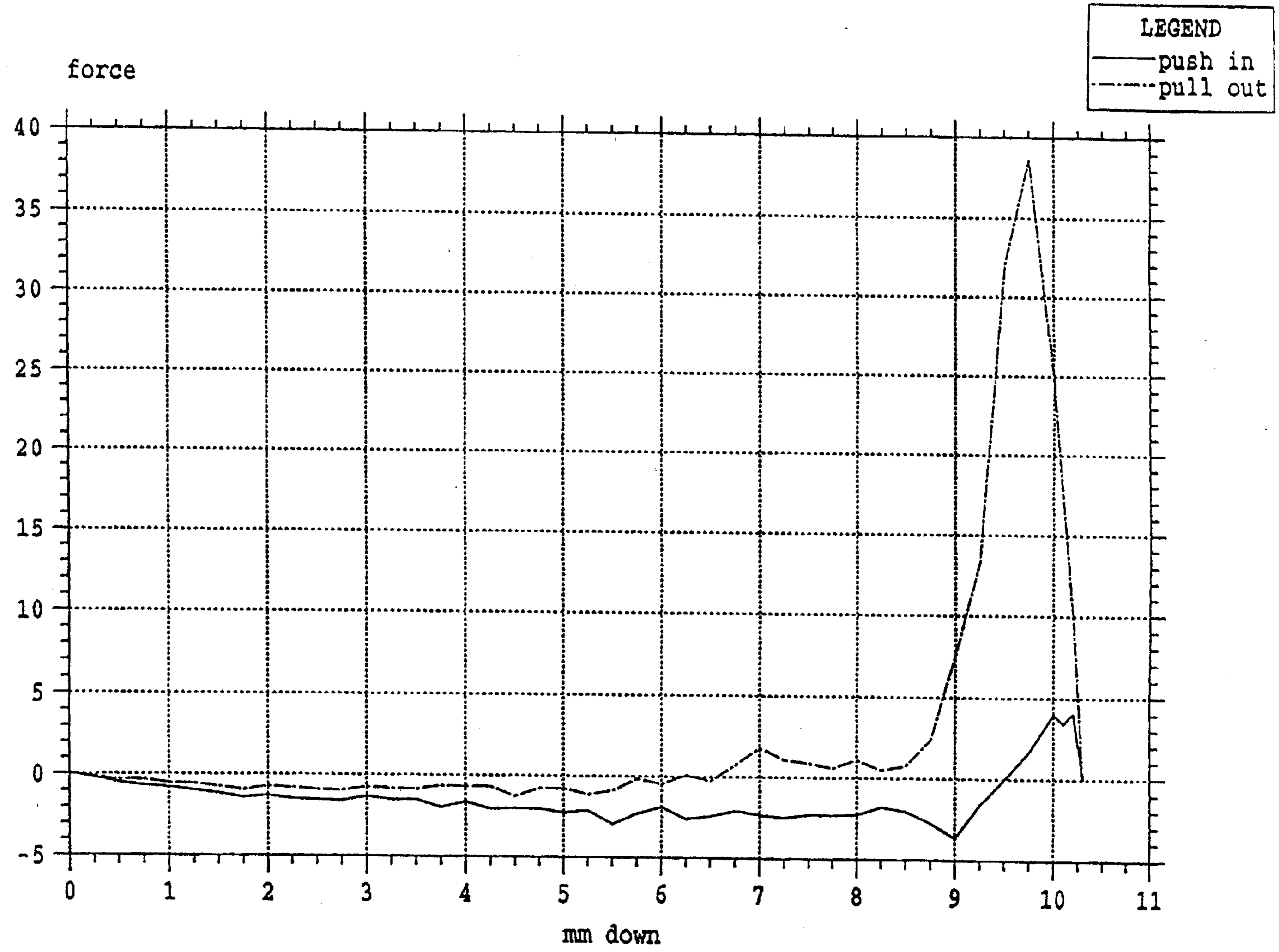

Figure 4. Force Versus Displacements: Pipe Push In and Pull Out.

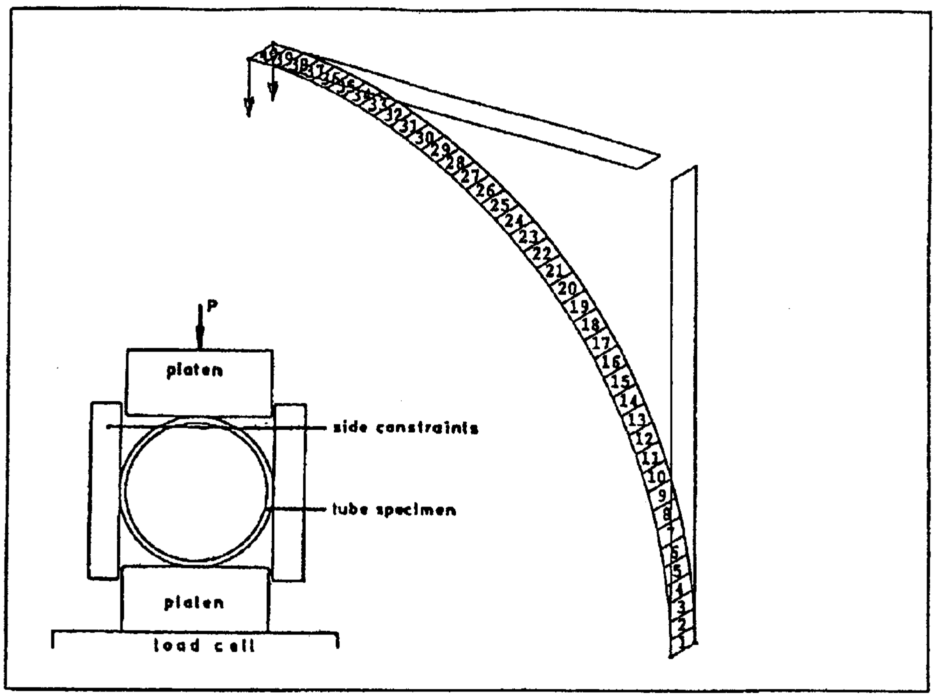

Figure 5. Experimental Arrangement and FEM Model of Tube with Side Constraint.

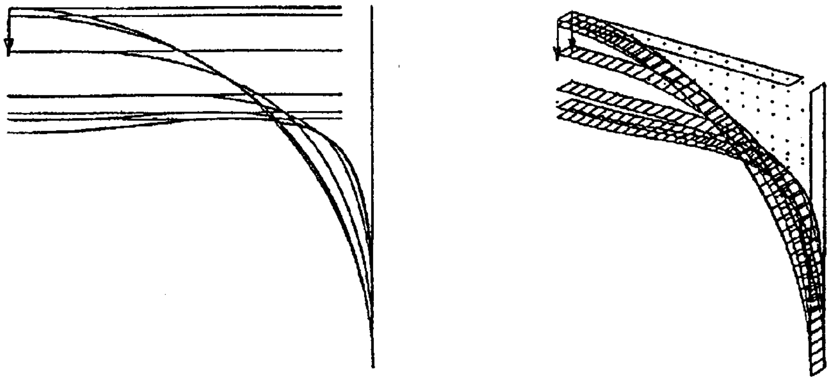

Figure 6. Collapse Process of a Tube with Side Constraint.

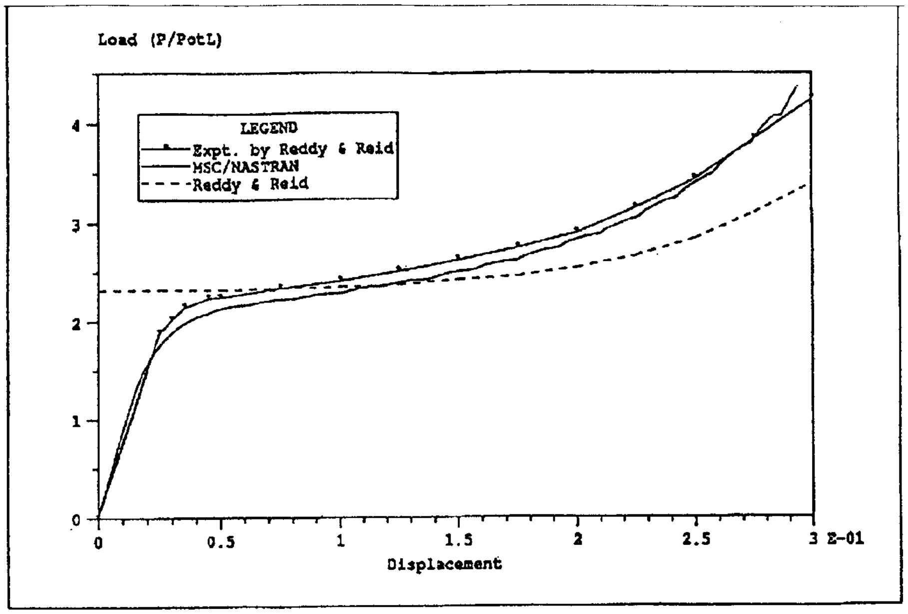

Figure 7. Non-Dimensional Load Versus Deflection For a Tube With Side Constraint.

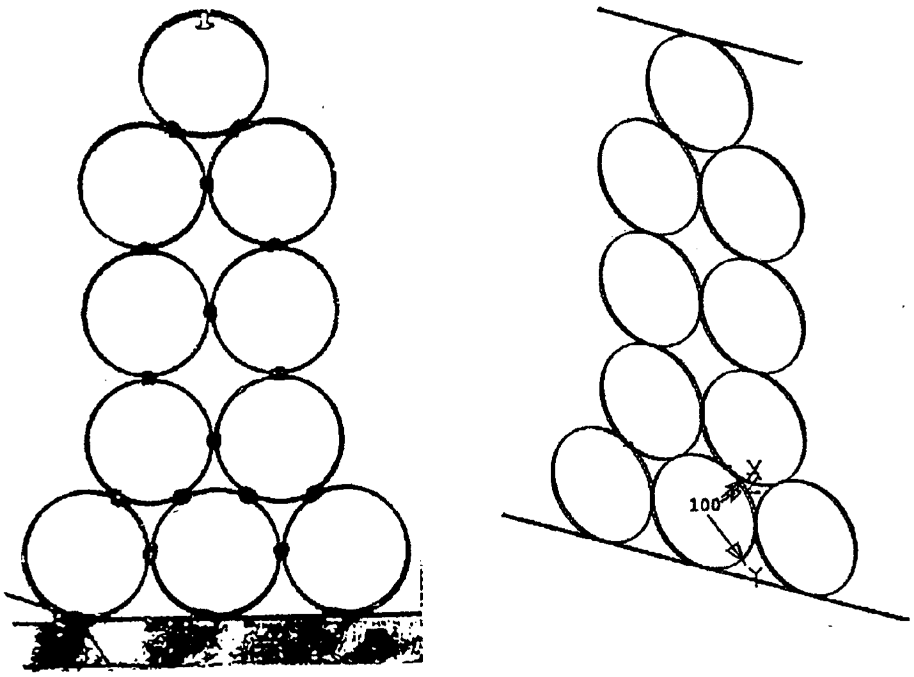

Figure 8. Experimental Arrangement and FEM Mesh of Tube System Module Crash Cushion.

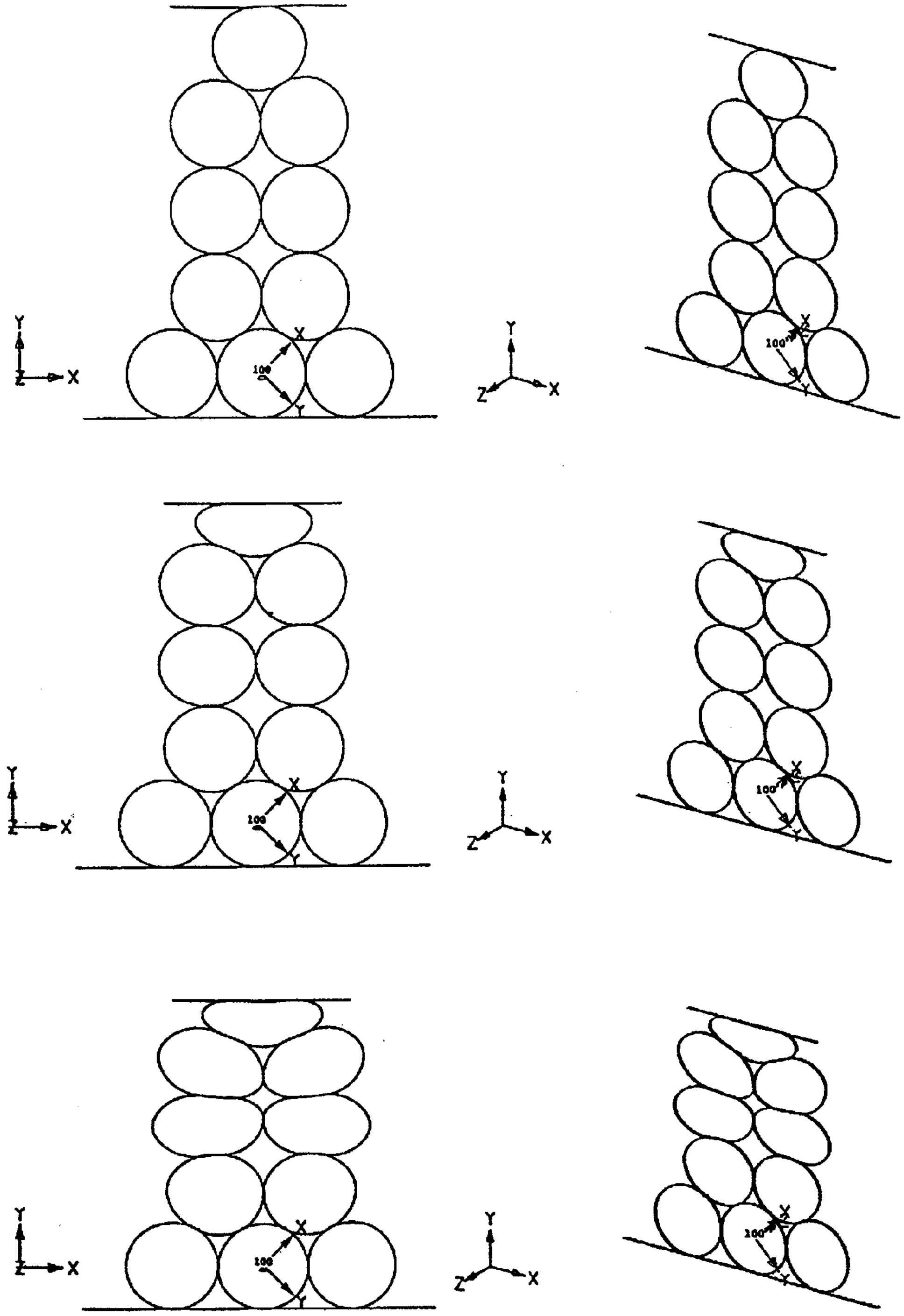

Figure 9. Collapse Process of Tube System.

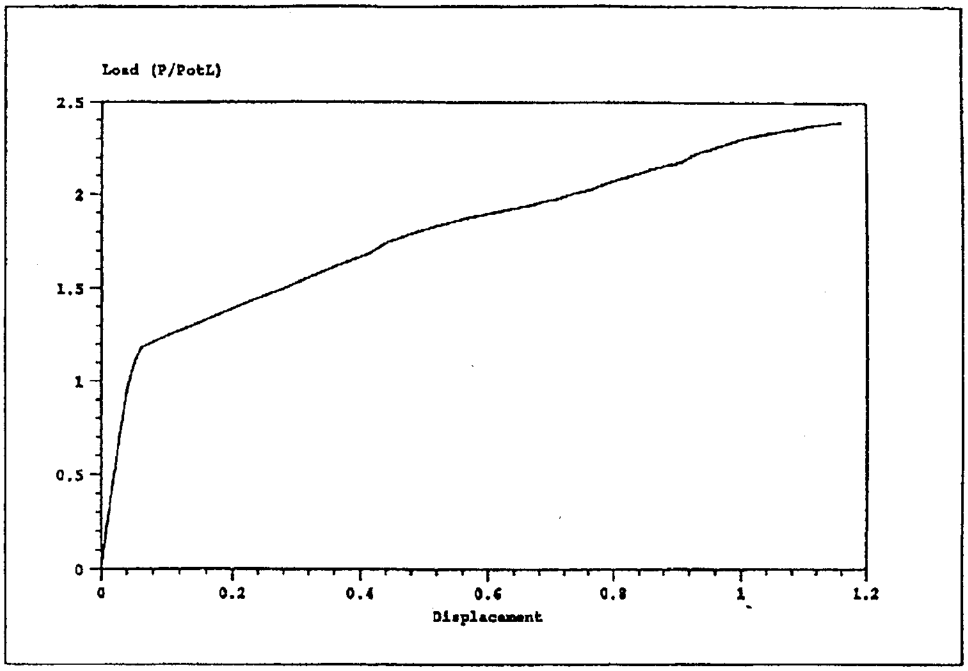

Figure 10. Non-Dimensional Load-Deflection Curve for Tube System.

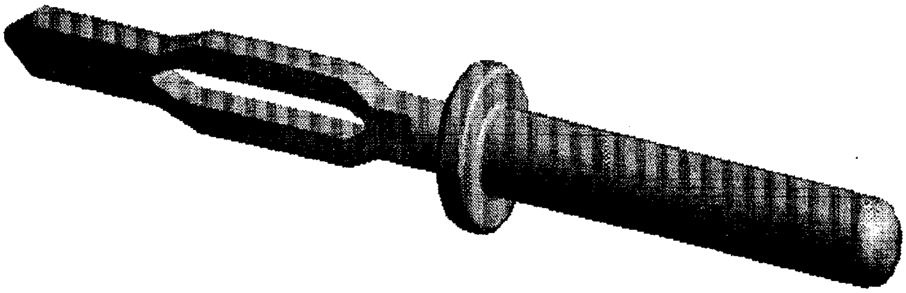

Figure 11. A Typical Electrical Pin.

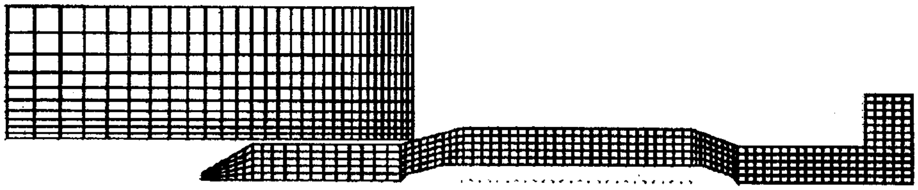

Figure 12. Finite Element Model of the Electrical Pin And the Electric Board.

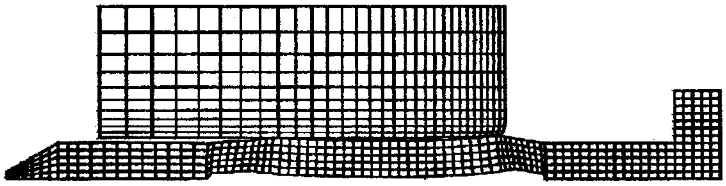

Figure 13. Deformed Shape of the Electrical Pin After Insertion.

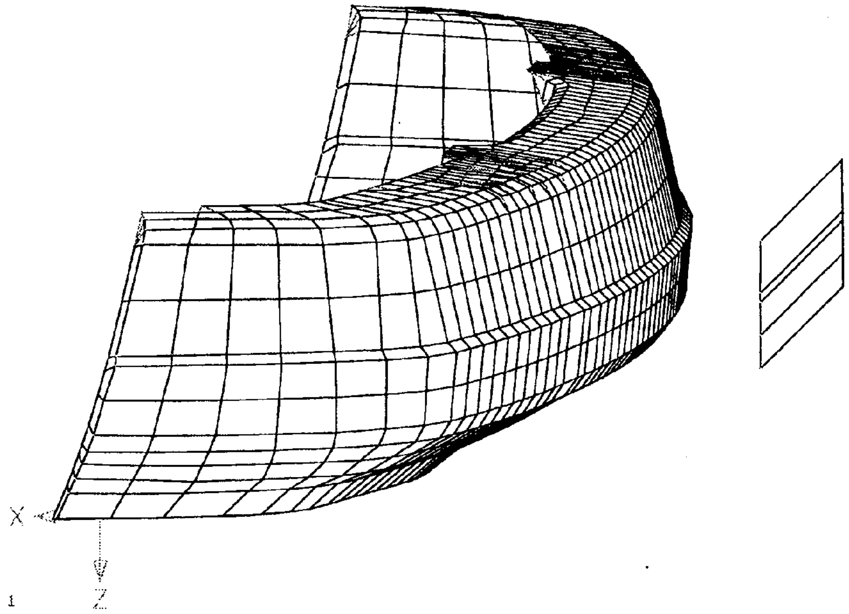

Figure 14. Finite Element Model of a Bumper and Barrier.

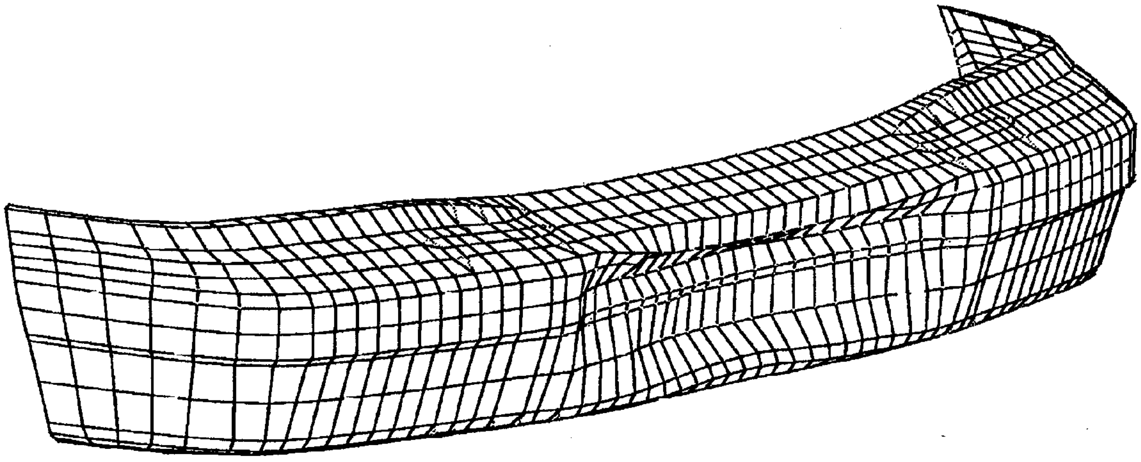

Figure 15. Deformed Bumper After 20 msec of Impact.

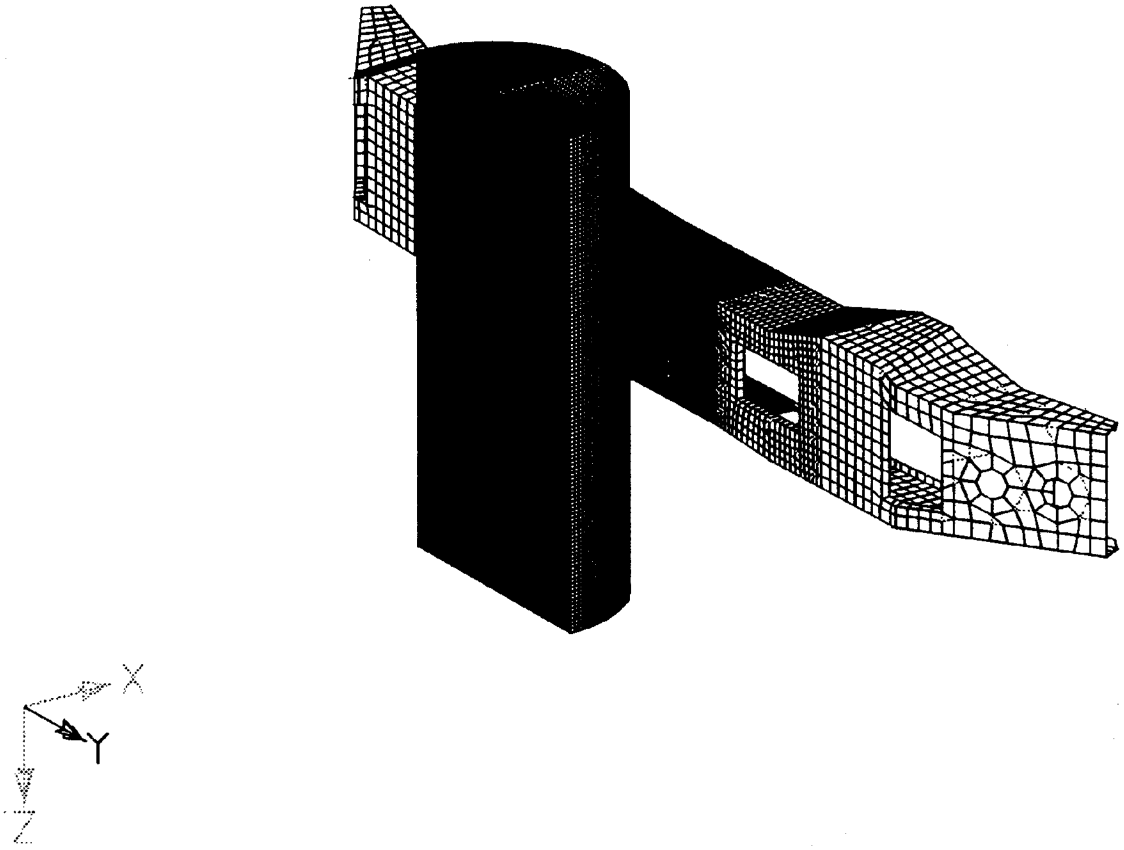

Figure 16. Finite Element Model for the Ford Bumper