ADVANCES IN NONLINEAR ANALYSIS IN MSC/NASTRAN

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New capabilities and improvements to existing code have been added to the nonlinear system for MSC/NASTRAN Version 62. The goal of the continuing project is to provide an advanced, general-purpose tool for nonlinear analysis using existing MSC/NASTRAN elements, constraints, and modeling conveniences. Major new features include three-dimensional nonlinear elements, transient analysis with geometric and material nonlinearities, and new Quasi-Newton solution methods. Several interesting test problems are presented to illustrate the system capabilities.

CONTENTS

REVIEW OF NONLINEAR DEVELOPMENTS IN MSC/NASTRAN

1970 - INITIAL DELIVERY

RF 4 - DIFFERENTIAL STIFFNESS

RF 5 - BUCKLING

RF 6 - PIECEWISE LINEAR

RF 9 - TRANSIENT WITH NØLIN

1973 - THERMAL ANALYSIS (HEAT)

NONLINEAR STATICS (CONDUCTION & RADIATION)

NONLINEAR TRANSIENT (RADIATION)

1976 - RF 4 WITH ITERATIONS

1978 - NONLINEAR GEOMETRY - DMAP4

1981 - NONLINEAR STATIC ANALYSIS - SØL 66

SØL 66 STATUS IN V61, V61B

- RELEASED IN APRIL - MAY 1981 WITH:
  - LARGE DISPLACEMENTS AND NONLINEAR MATERIALS
  - BEAM, QUAD4, TRIA3, RØD ELEMENTS
  - NEW GAP ELEMENT
  - NEW DATABASE METHODS
  - NEW ITERATION/SEARCH MODULE
- OVER 200 USERS IN FIELD
- ERRORS WERE QUICKLY UNCOVERED AND REPORTED. NONE WERE MAJOR.
- MSC/V61B HAS ERRORS FIXED AND DATABASE METHODS IMPROVED.

ENHANCEMENTS FOR V62

MAJOR PROJECTS

HEXA AND PENTA ELEMENTS

SØL 99 TRANSIENT ANALYSIS

QUASI-NEWTON/LINE SEARCH ITERATIONS

EXPAND EXISTING OPTIONS

PROVIDE FOR UPSTREAM SUPERELEMENT LOADS

ALLOW THERMAL LOAD SEQUENCE

2D AND 3D NONLINEAR ELASTICITY

CLEAN-UP

IMPROVED PLASTIC LOADING/UNLOADING METHODS

BETTER LARGE ANGLE COMPUTATIONS (AND MANY MORE)

FUTURE PLANS (TENTATIVE)

MAJOR PROJECTS

- CREEP AND SWELLING
- LARGE STRAINS AND ELEMENT DEFORMATION
- COMPOSITES AND ANISOTROPIC MATERIALS
- HEAT TRANSFER

MINOR PROJECTS

- CONCRETE, SOIL, AND ROCK MATERIAL MODELS
- FOLLOWER FORCES
- BUCKLING PREDICTIONS
- MORE ELEMENTS - SHEAR, CELAS

HEXA AND PENTA ELEMENTS

(FOR NONLINEAR APPLICATIONS)

- PLASTICITY MEASURED AT 8 (AND 6) GAUSS INTEGRATION POINTS FOR GOOD ACCURACY.
- ELEMENTS ARE COMPATABLE WITH ELASTIC VERSIONS
- DIFFERENTIAL STIFFNESS USES PLASTIC STRESSES
- ALL NONLINEAR MATERIAL OPTIONS ARE PROVIDED

NEW ITERATION METHODS

THE BFGS METHOD

LINE SEARCH:

THIS PROCESS SCALES THE ESTIMATED DISPLACEMENT VECTOR INCREMENT DURING THE SEARCH PROCESS. MINIMIZES ENERGY ERROR.

QUASI-NEWTON:

THIS PROCESS ACTS LIKE A CORRECTOR TO THE INVERSE OF THE TANGENT MATRIX. WHEN LINE SEARCH DISCOVERS MAJOR CHANGES, THE FORCE AND DISPLACEMENT INCREMENTS ARE SAVED AND SERVE TO CORRECT FUTURE VECTORS. ALL OPERATIONS USE VECTOR ARITHMETIC.

ADVANTAGES:

FAST CONVERGENCE FOR SIMPLE NONLINEAR EFFECTS

AVOIDS DIVERGENCE FOR COMPLEX PROBLEMS. (ERROR IS NOT ALLOWED TO INCREASE).

AVOIDS COSTLY MATRIX UPDATES

DISADVANTAGES:

USES EXTRA CPU COST PER ITERATION

REQUIRES ADDITIONAL FILE AND MEMORY SPACE

NONLINEAR TRANSIENT ANALYSIS - SØL 99

IT WILL HANDLE:

A) S.E. MODELS WITH NONLINEAR RESIDUALS

B) MASS AND DAMPING FOR ALL ELEMENTS

C) MULTIPLE SUBCASES WITH CHANGES IN LOAD AND STEP SIZE

D) EXISTING "TLØAD" APPLIED LOADS

E) EPØINTS

F) DMIG's AND TF's

G) ALL SØL 66 NONLINEAR EFFECTS

H) RESTARTS FROM SØL 66 OR SØL 99

I) NORMAL DATA RECOVERY

IT WON'T HANDLE (AT PRESENT):

A) RECOVERY OF UPSTREAM S.E. DATA

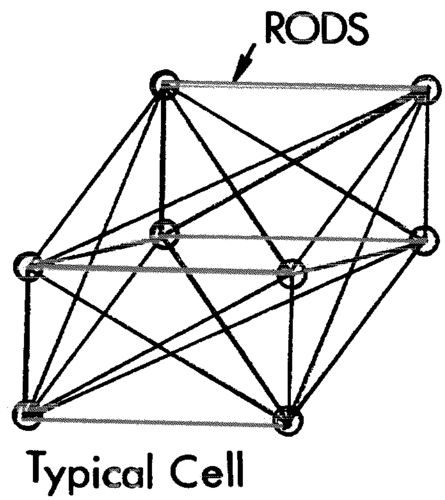
B) NONLINEAR FORCES OF CONSTRAINT (SPCF)

C) RESTART WITHIN A SUBCASE

D) CHANGE TIME STEP WITHIN A SUBCASE

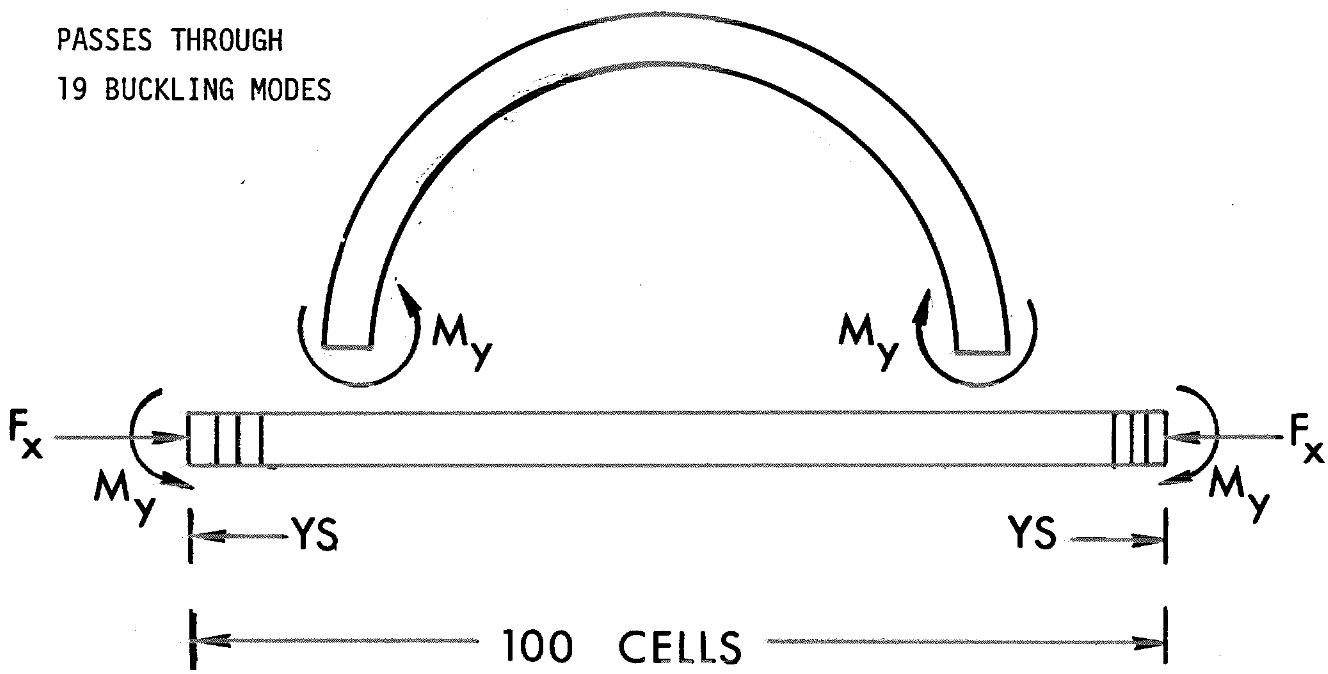
E) INITIAL VELOCITIES

TRUSS ANALYSIS



NOTE:

PASSES THROUGH
19 BUCKLING MODES



TRUSS COST STATISTICS (10 CELLS)

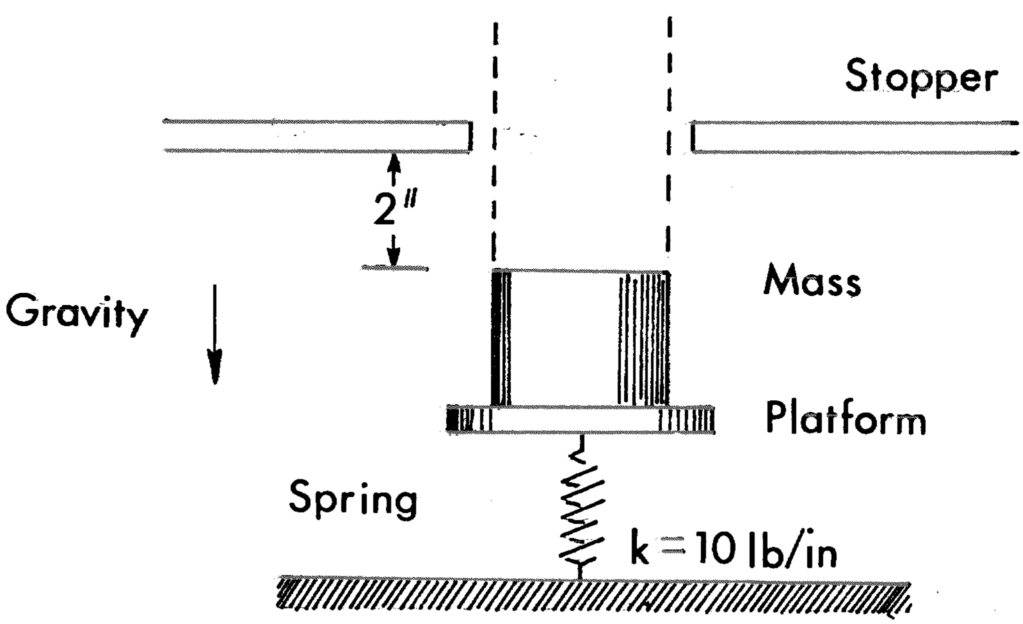
	10 CELL	50 CELL
G SIZE:	264	1224
A SIZE:	108	508
NO. OF ELEMENTS:	226	1106
NO. OF LOAD STEPS:	4	10
METHOD (V62):	SEMIQN	SEMIQN
TOTAL CPU TIME:	619	6435
MATRIX LOOP TIME:	29.2	121
INNER ITERATIONS:	4 - 15	25 - 50

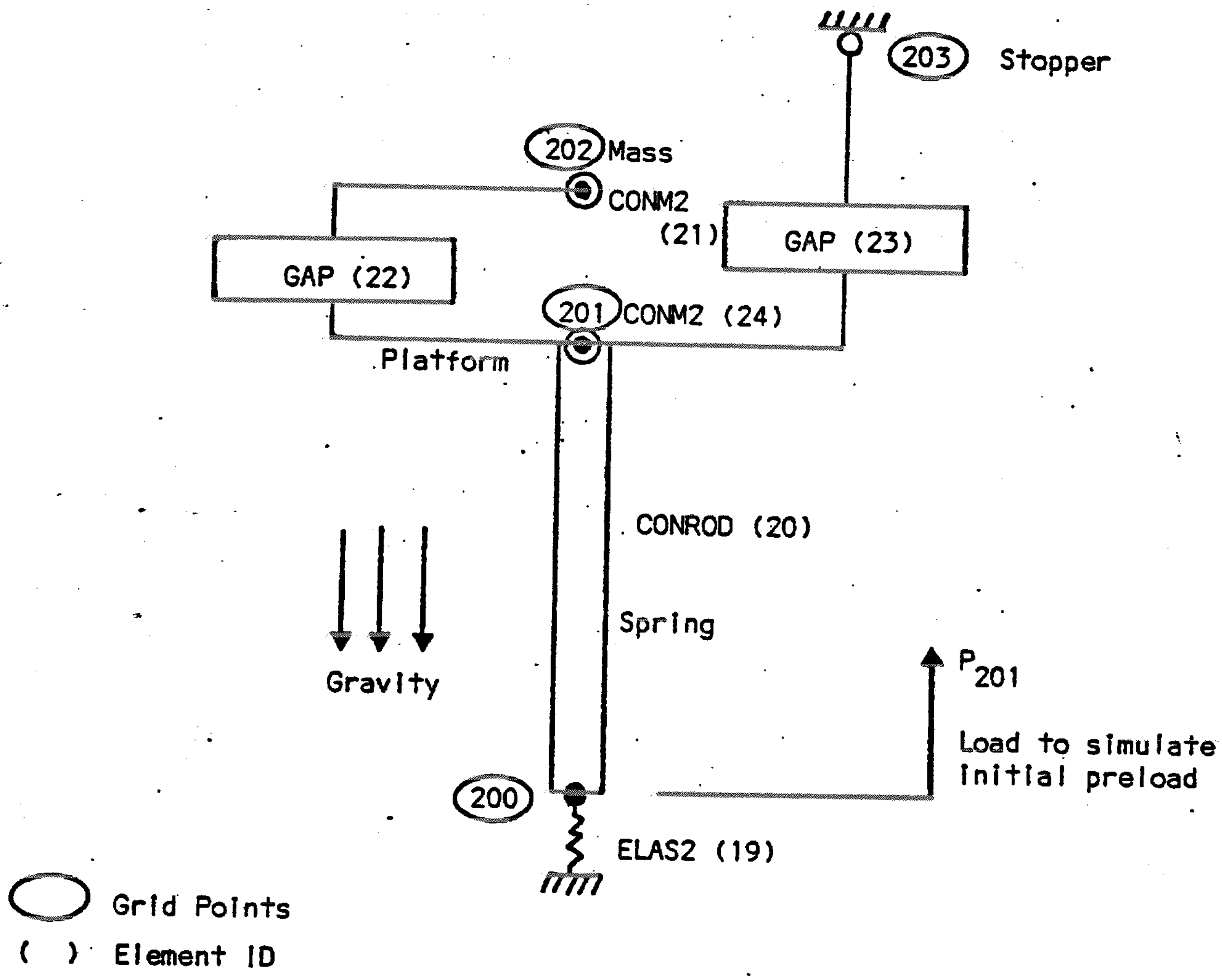
$$\frac{\text{NONLINEAR TIME}}{\text{LINEAR TIME}} = \frac{619}{89} = 6.95$$

GAP PROBLEM

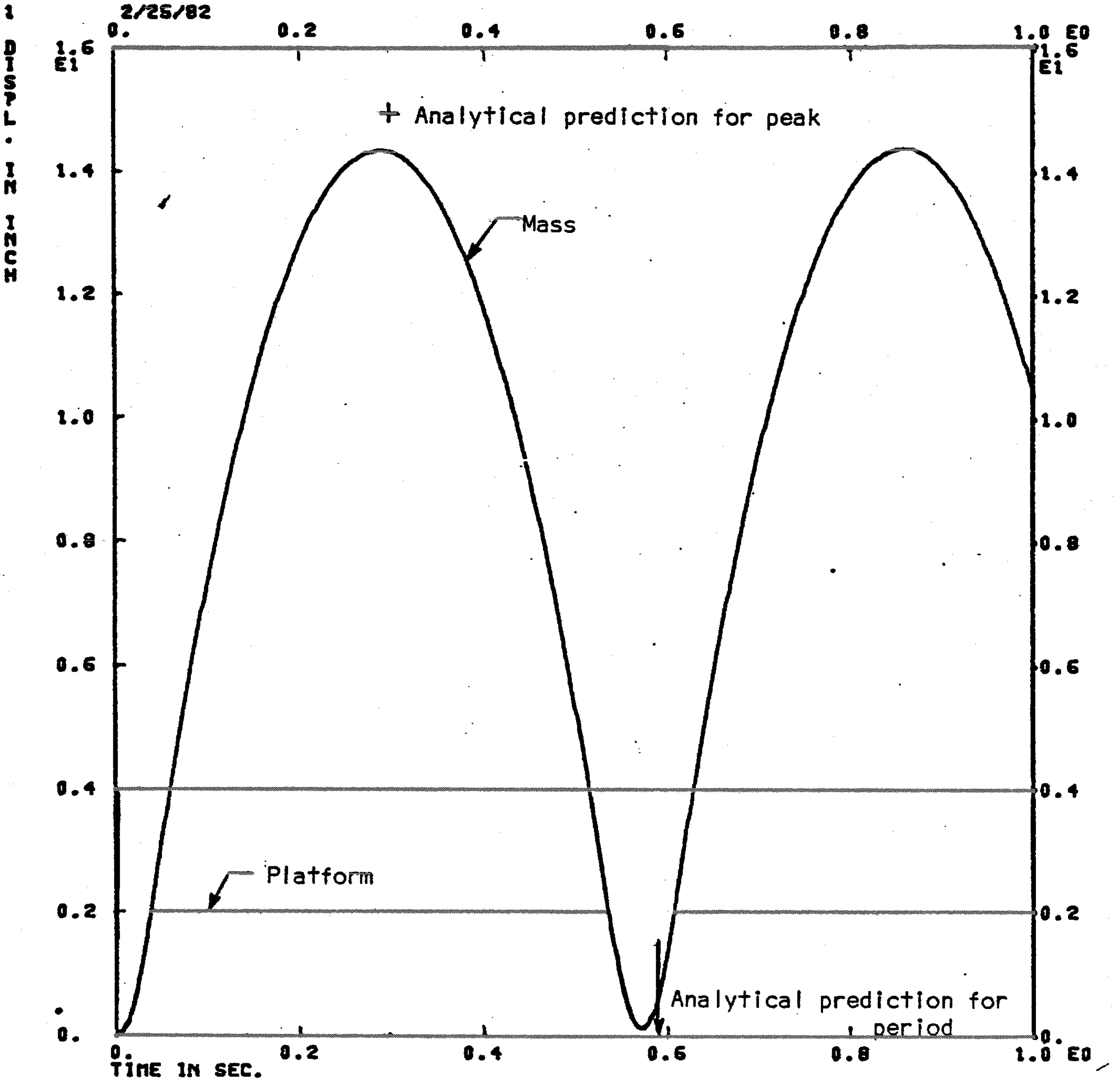
THE PROBLEM ILLUSTRATES:

- ABILITY TO OVERCOME LARGE STIFFNESS CHANGES
- HIGH FREQUENCY/LOW FREQUENCY COMBINATIONS
- METHOD FOR PRELOADING
- USING STATIC LOADS FOR TRANSIENT PROBLEM





SYMBOLIC MSC/NASTRAN MODEL

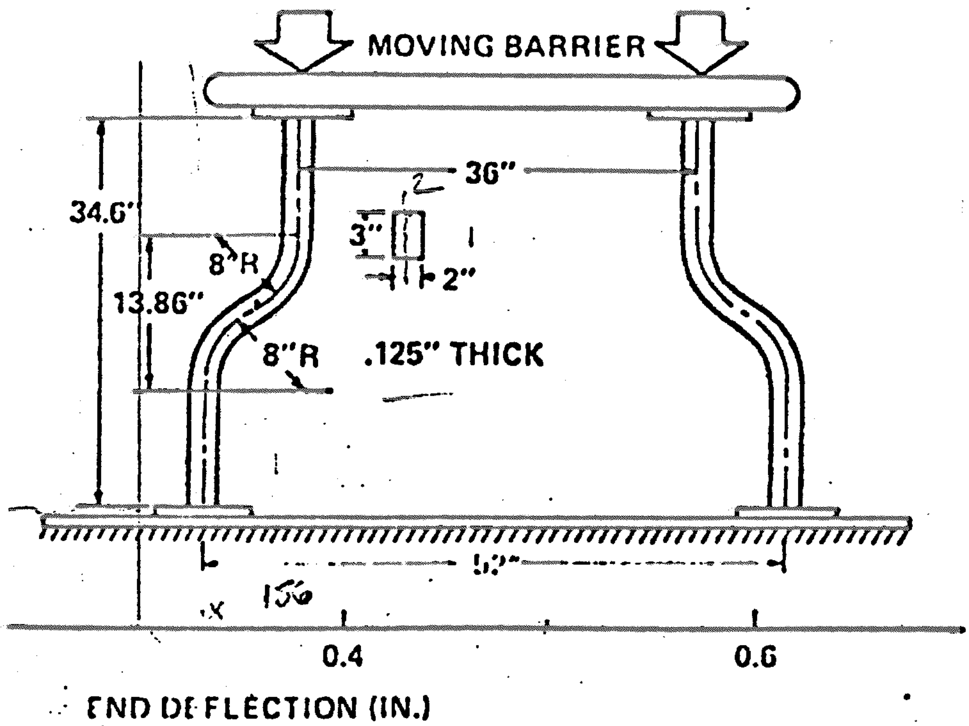


GAP VERIFICATION
NONLINEAR TRANSIENT ANALYSIS

$\Delta t = 0.0025$ sec

MSC/NASTRAN Response Analysis

CURVED BOX BEAM PROBLEM



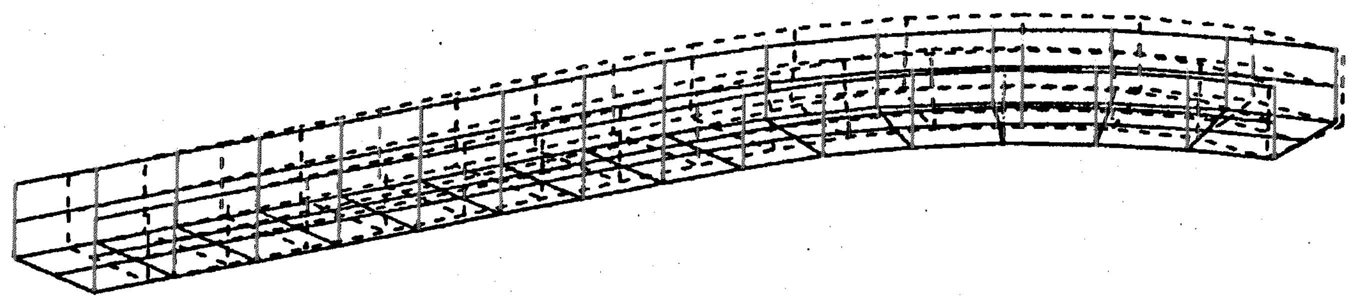
MSC STUDY:

- BUILT UP FROM QUAD4 PLATES
- NO CROSS SECTION FUDGE FACTORS
- TWO PLANES OF SYMMETRY
- 105 GRID POINTS, 463 SOLUTION DOF
- TIMES ON VAX 11780:

  12 STEPS = 83 MIN

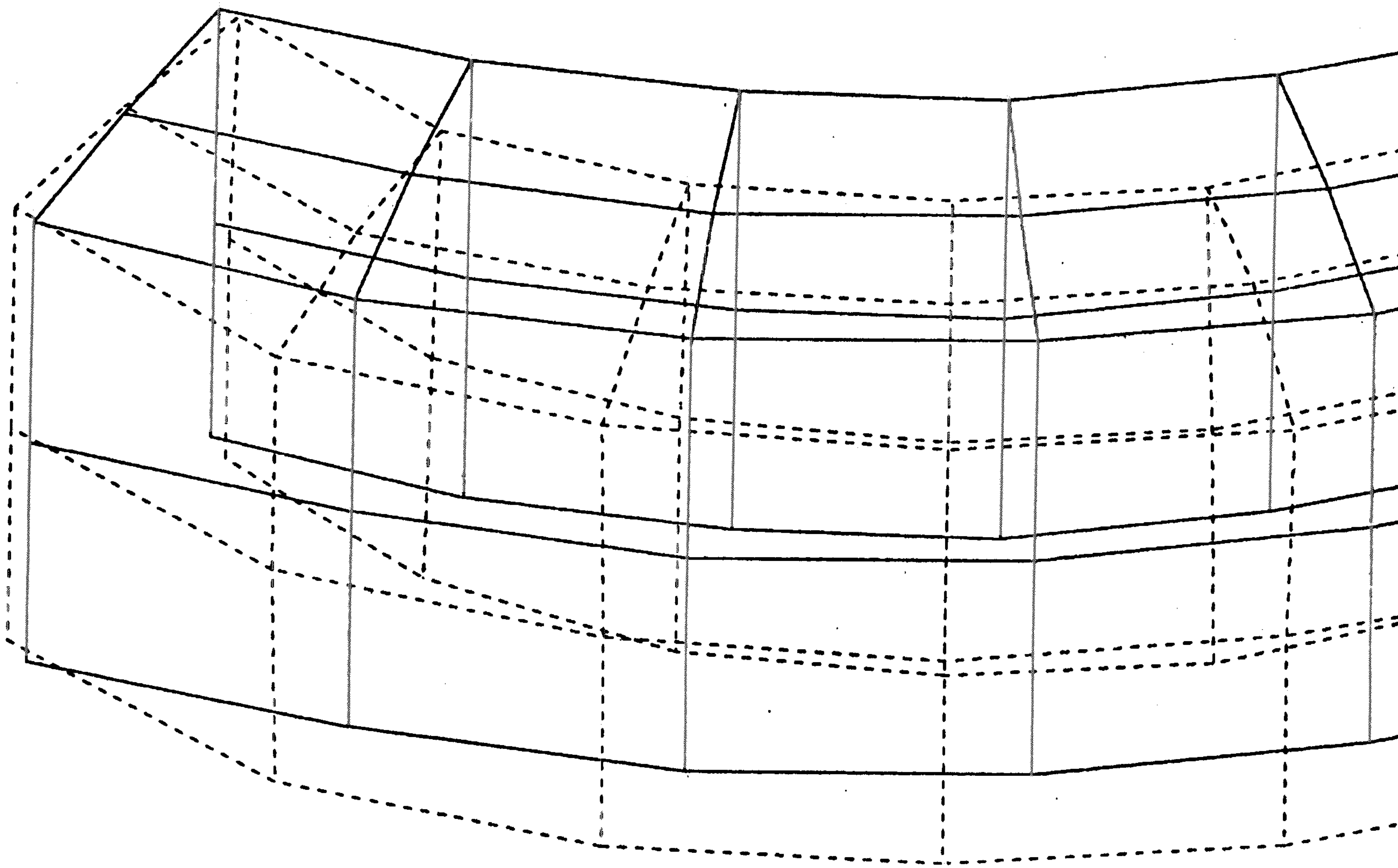
Ref 1: Ni, Chi-Mou, "Impact Reponse of Curved Box-Beam-Columns with Large Global and Local Deformations", AIAA Paper No. 73-401, 1973.

LAST PLOT, 0 R OR OUT
12 1/20/88 MAX-DEF. = 0.30388798
DEFORMED AND UNDEFORMED GRID PLOT



SFRAME PROB. FOR FORD

STATIC DEFOR. SUBCASE 1 LOAD 100



BOX BEAM PROBLEM

Deformations At $\Delta u = 0.6$

BOX BEAM PROBLEM

STATIC ANALYSIS