Topic 22

A Demonstrative Computer Session Using ADINA—Nonlinear Analysis

Contents:

- **Use of ADINA for elastic-plastic analysis of a plate with a hole**
- **Computer laboratory demonstration—Part II**
- **Selection of solution parameters and input data preparation**
- **Study of the effect of using different kinematic assumptions (small or large strains) in the finite element solution**
- **Effect of a shaft in the plate hole, assuming frictionless contact**
- **Effect of expanding shaft**
- **Study and evaluation of solution results**

Textbook:

Appendix

References:

The use of the ADINA program is described and sample solutions are given in

Bathe, K. J., "Finite Elements in CAD — and ADINA," *Nuclear Engineering and Design,* to appear.

ADINA, ADINAT, ADINA-IN, and ADINA-PLOT Users Manuals, ADINA Verification Manual, and ADINA Theory and Modeling Guide, ADINA Engineering, Inc., Watertown, MA 02172, U.S.A.

References: (continued)

Proceedings of the ADINA Conferences, (K. J. Bathe, ed.)
Computers & Structures
13, No. 5–6, 1981
17, No. 5–6, 1983
21, No. 1–2, 1985

The contact solution procedure used in the analysis of the plate with the shaft is described in

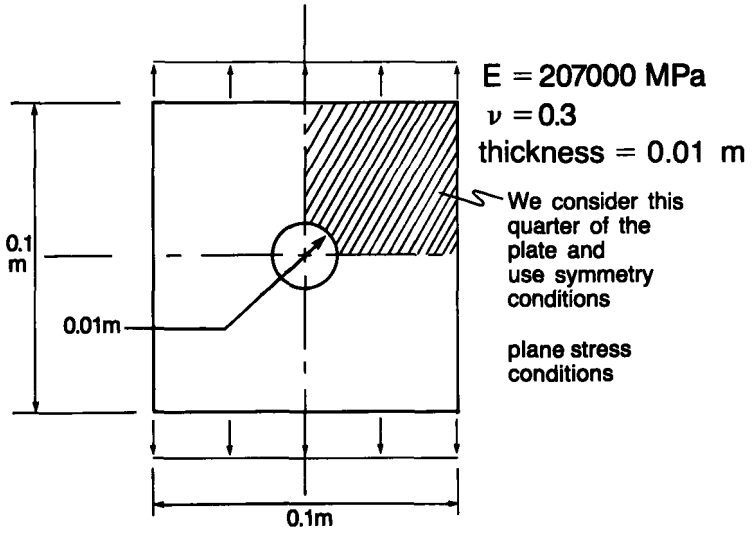
Bathe, K. J., and A. Chaudhary, "A Solution Method for Planar and Axisymmetric Contact Problems," *International Journal for Numerical Methods in Engineering, 21*, 65–88, 1985.

A FINITE ELEMENT ANALYSIS — NONLINEAR SOLUTION

- We continue to consider the plate with a hole.
- A nonlinear analysis should only be performed once a linear solution has been obtained.
  The linear solution checks the finite element model and yields valuable insight into what nonlinearities might be important.

Transparency 22-1

Plate with hole: Schematic drawing

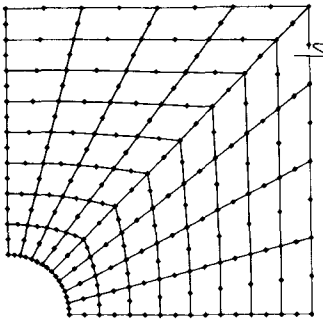


Transparency 22-2
(Repeat 21-4)

Transparency 22-3
(Repeat 21-25)

Finite element mesh to be generated using ADINA-IN:

- Mesh contains 64 elements, 288 nodes.



Transparency 22-4

- Some important considerations are now
  - — What material model to select
  - — What displacement/strain assumption to make
  - — What sequence of load application to choose
  - — What nonlinear equation solution strategy and convergence criteria to select

- We use the ADINA system to analyse the plate for its elasto-plastic static response.
- We also investigate the effect on the response when a shaft is placed in the plate hole.

Transparency 22-5

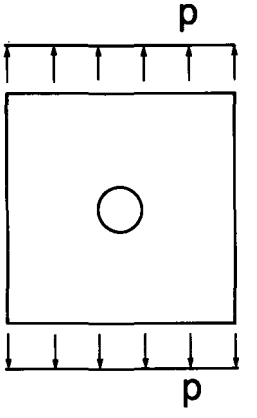
Some important observations:

- The recommendations given in the linear analysis are here also applicable (see previous lecture).
- For the nonlinear analysis we need to, in addition, be careful with the
  - — sequence and incremental magnitudes of load application
  - — choice of convergence tolerances

Transparency 22-6

Transparency 22-7

Limit load calculations:

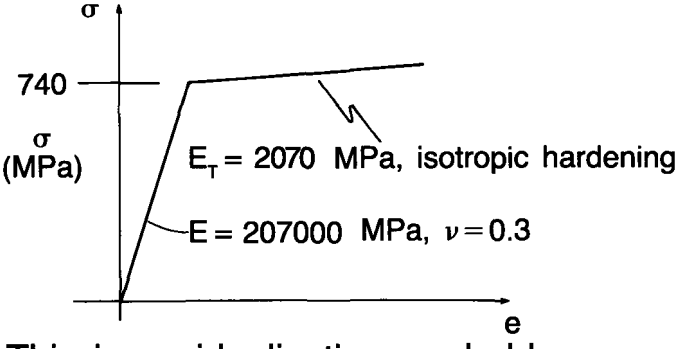


- Plate is elasto-plastic.

Transparency 22-8

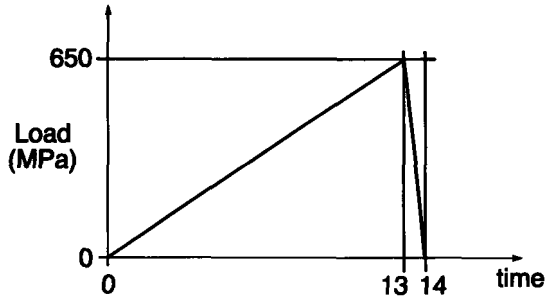
Elasto-plastic analysis:

Material properties (steel)



- This is an idealization, probably inaccurate for large strain conditions (e > 2%).

Load history:



- Load is increased 50 MPa per load step.
- Load is released in one load step.

Transparency 22-9

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                    USER-SUPPLIED

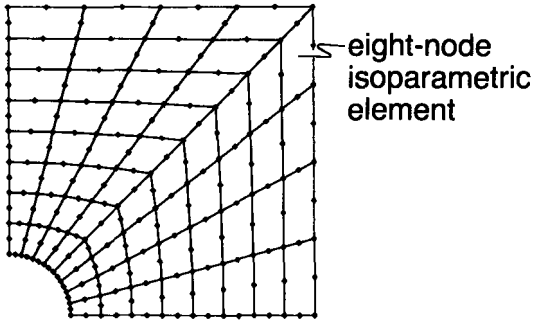

MATERIAL 1 PLASTIC E=207000 NU=0.3 ET=2070 YIELD=740
MATERIAL 1 PLASTIC E=207000 NU=0.3 ET=2070 YIELD=740
DELETE EQUILIBRIUM-ITERATIONS
DELETE EQUILIBRIUM-ITERATIONS
ADINA
ADINA
```

ADINA Demonstration 22-1
Input data

Transparency 22-10
(Repeat 21-25)

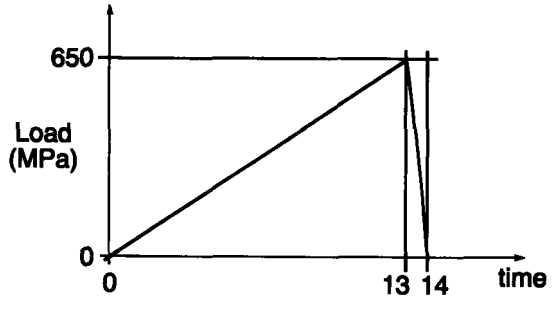
Finite element mesh to be generated using ADINA-IN:

- Mesh contains 64 elements, 288 nodes.



Transparency 22-11

Load history:



- Load is increased 50 MPa per load step.
- Load is released in one load step.
- The BFGS method is employed for each load step.

Convergence criteria:

Energy:

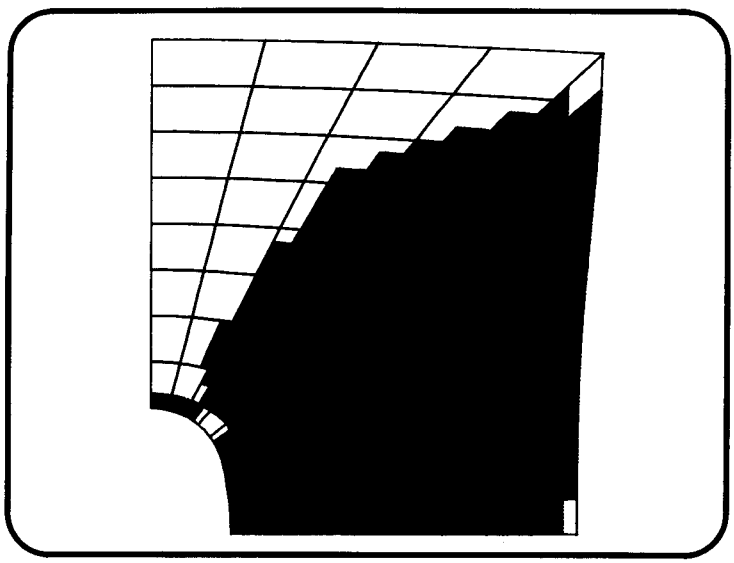
$$\frac{\Delta \underline{U}^{(i)T}\left[{}^{t+\Delta t}\underline{R} - {}^{t+\Delta t}\underline{F}^{(i-1)}\right]}{\Delta \underline{U}^{(1)T}\left[{}^{t+\Delta t}\underline{R} - {}^{t}\underline{F}\right]} \leq \text{ETOL} = 0.001$$

Force:

$$\frac{\left\| {}^{t+\Delta t}\underline{R} - {}^{t+\Delta t}\underline{F}^{(i-1)} \right\|_2}{\text{RNORM}} \leq \text{RTOL} = 0.01$$

$$(\text{RNORM} = \underbrace{100\ \text{MPa}}_{\substack{\text{nominal}\\ \text{applied}\\ \text{load}}} \times \underbrace{0.05\ \text{m}}_{\text{width}} \times \underbrace{0.01\ \text{m}}_{\text{thickness}})$$

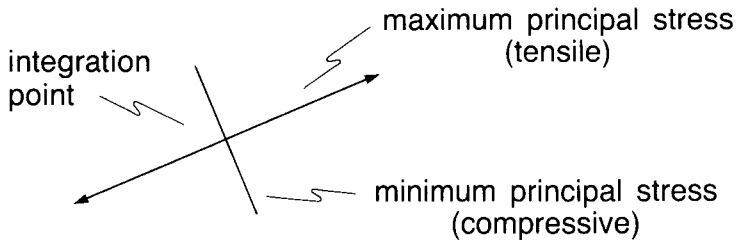
Transparency 22-12



ADINA Demonstration 22-2
Plot of plasticity in plate with hole

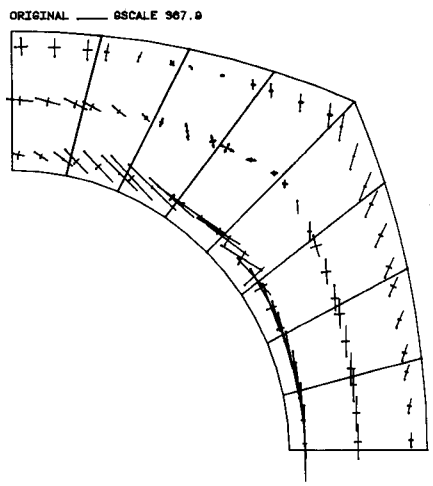
Transparency 22-13

Stress vector output: Example



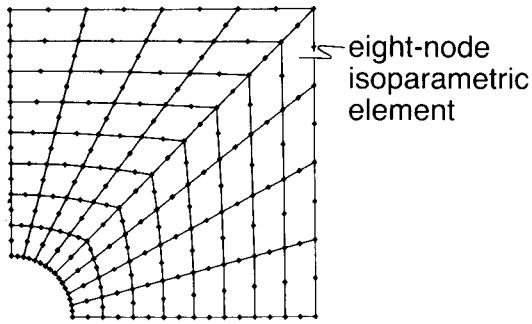
The length of the line is proportional to the magnitude of the stress.

ADINA Demonstration 22-3
Close-up of stress vectors around hole



Finite element mesh to be generated using ADINA-IN:

- Mesh contains 64 elements, 288 nodes.



Transparency 22-14
(Repeat 21-25)

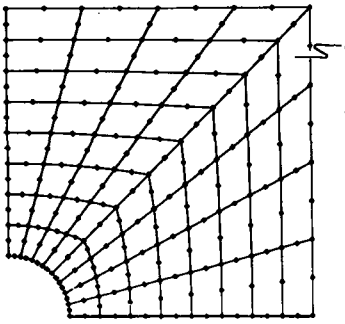
M.N.O.	Materially-Nonlinear-Only analysis
T.L.	Total Lagrangian formulation
U.L.	Updated Lagrangian formulation

Transparency 22-15

Transparency 22-16
(Repeat 21-25)

Finite element mesh to be generated using ADINA-IN:

- Mesh contains 64 elements, 288 nodes.



ADINA Demonstration 22-4
Elasto-plastic load displacement response

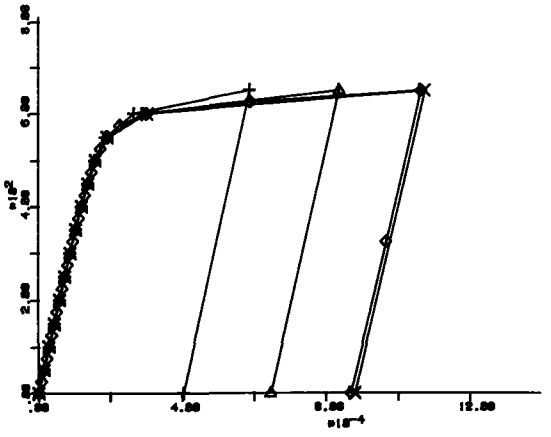
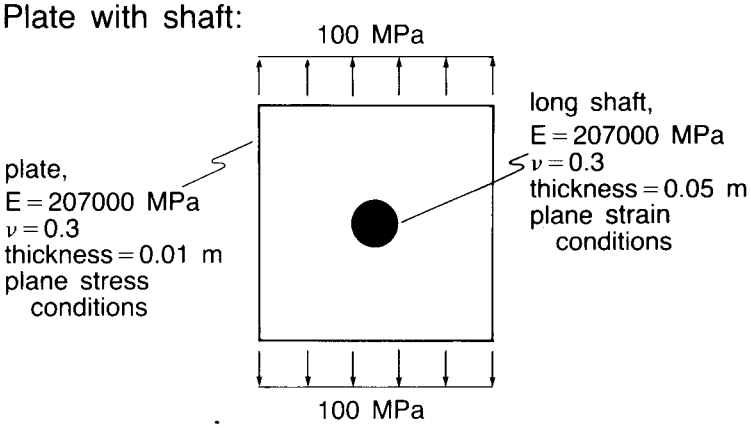


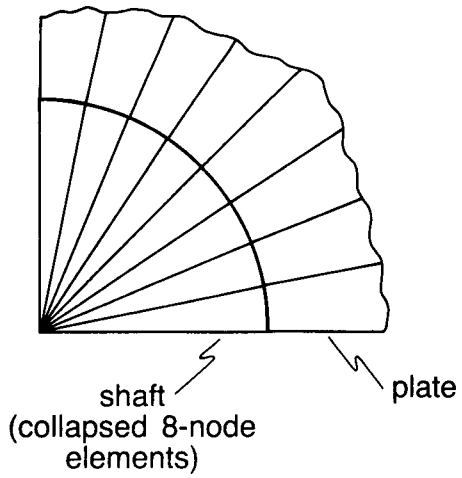
Plate with shaft:



- The shaft is initially flush with the hole.
- We assume no friction between the shaft and the hole.

Transparency 22-17

Detail of shaft:



Transparency 22-18

Transparency 22-19

Solution procedure: Full Newton iterations without line searches

Convergence criteria:

Energy: ETOL = 0.001

Force: RTOL = 0.01 , RNORM = 0.05 N

Incremental contact force:

$$\frac{\|\Delta \underline{R}^{(i-1)} - \Delta \underline{R}^{(i-2)}\|_2}{\|\Delta \underline{R}^{(i-1)}\|_2} \leq \text{RCTOL} = 0.05$$

ADINA Demonstration 22-5
Deformed mesh

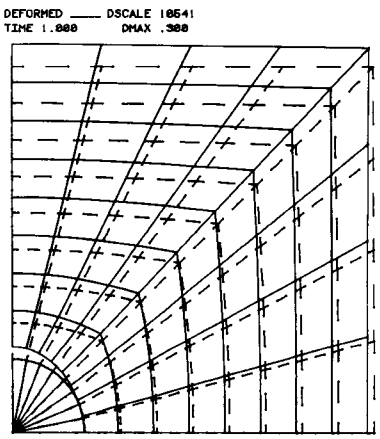
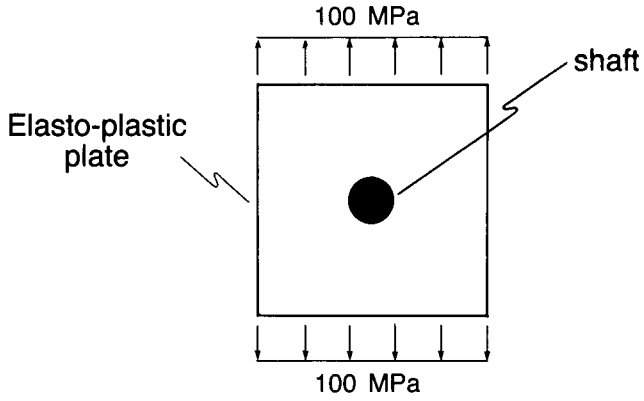
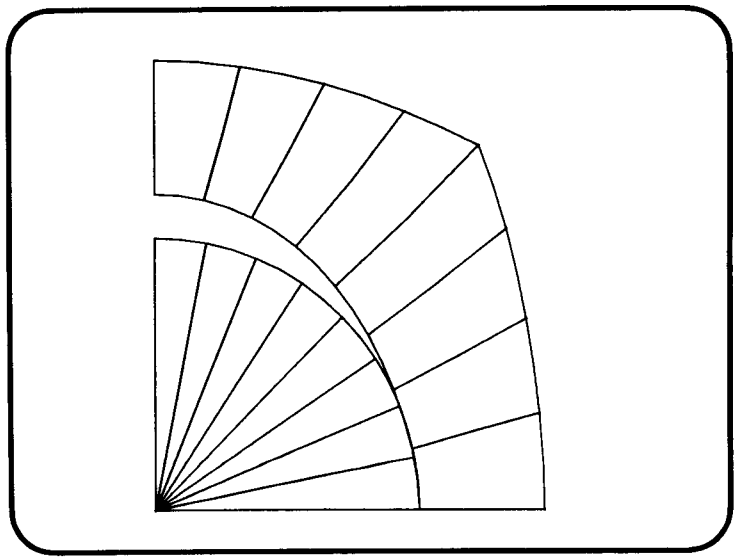


Plate with expanding shaft:



- The shaft now uniformly expands.

Transparency 22-20



ADINA Demonstration 22-6
Close-up of deformations at contact

Resource: Finite Element Procedures for Solids and Structures
Klaus-Jürgen Bathe