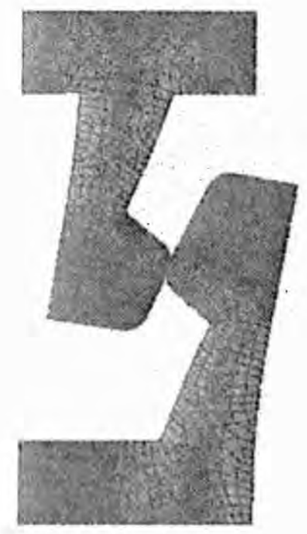
Section 13.4

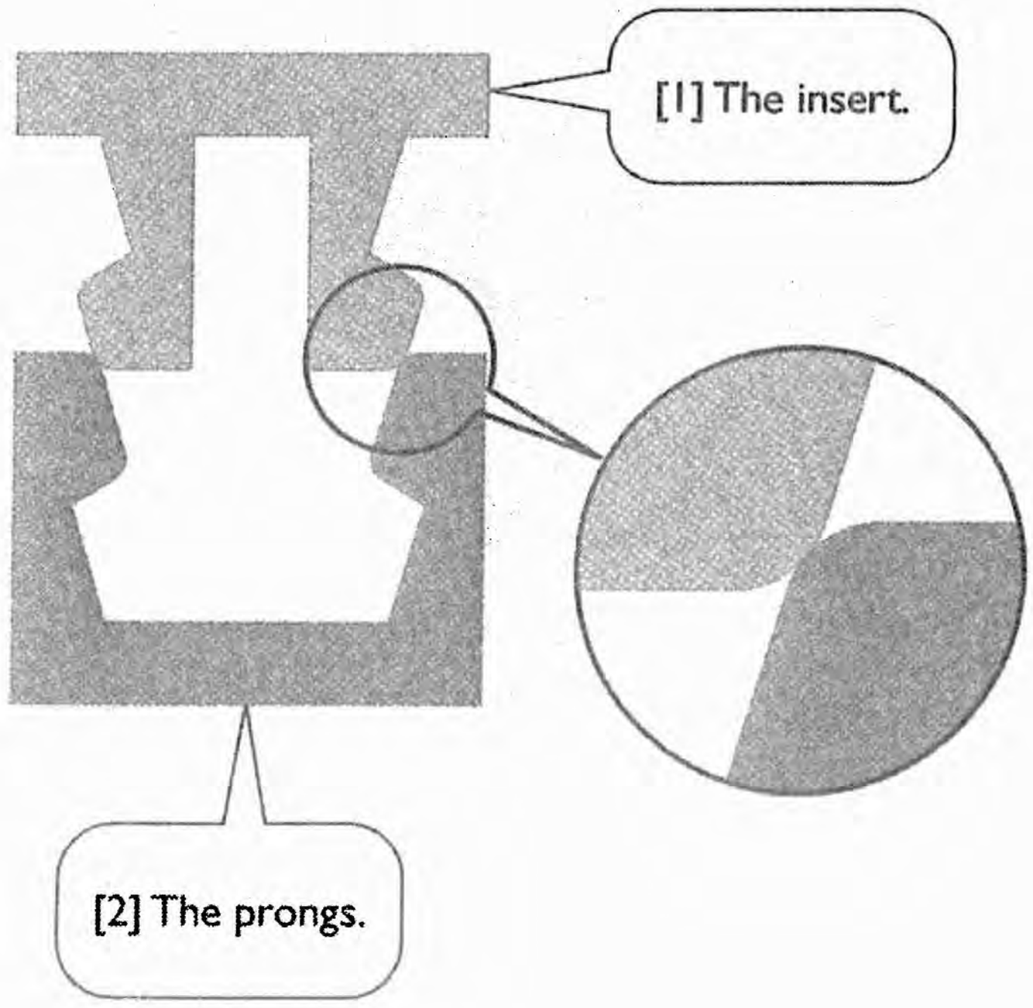
Exercise: Snap Lock

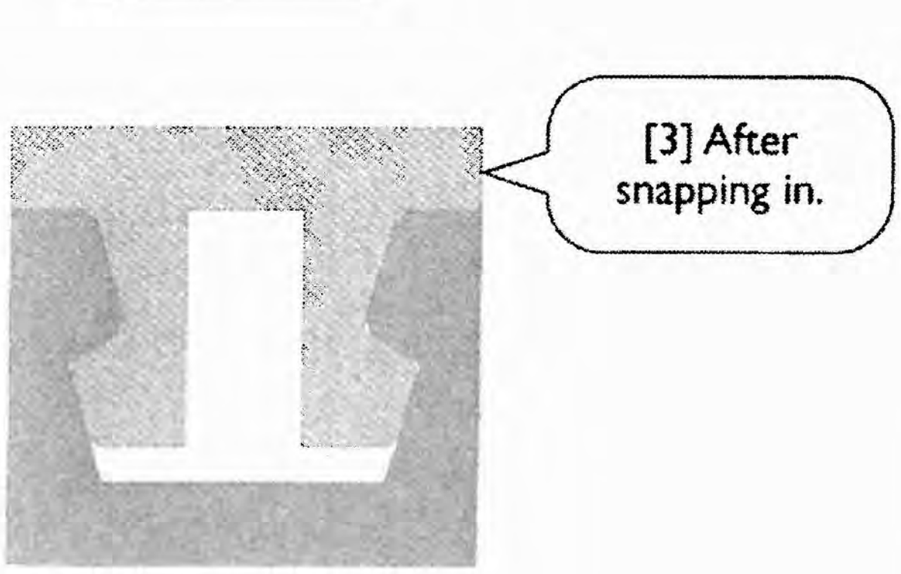


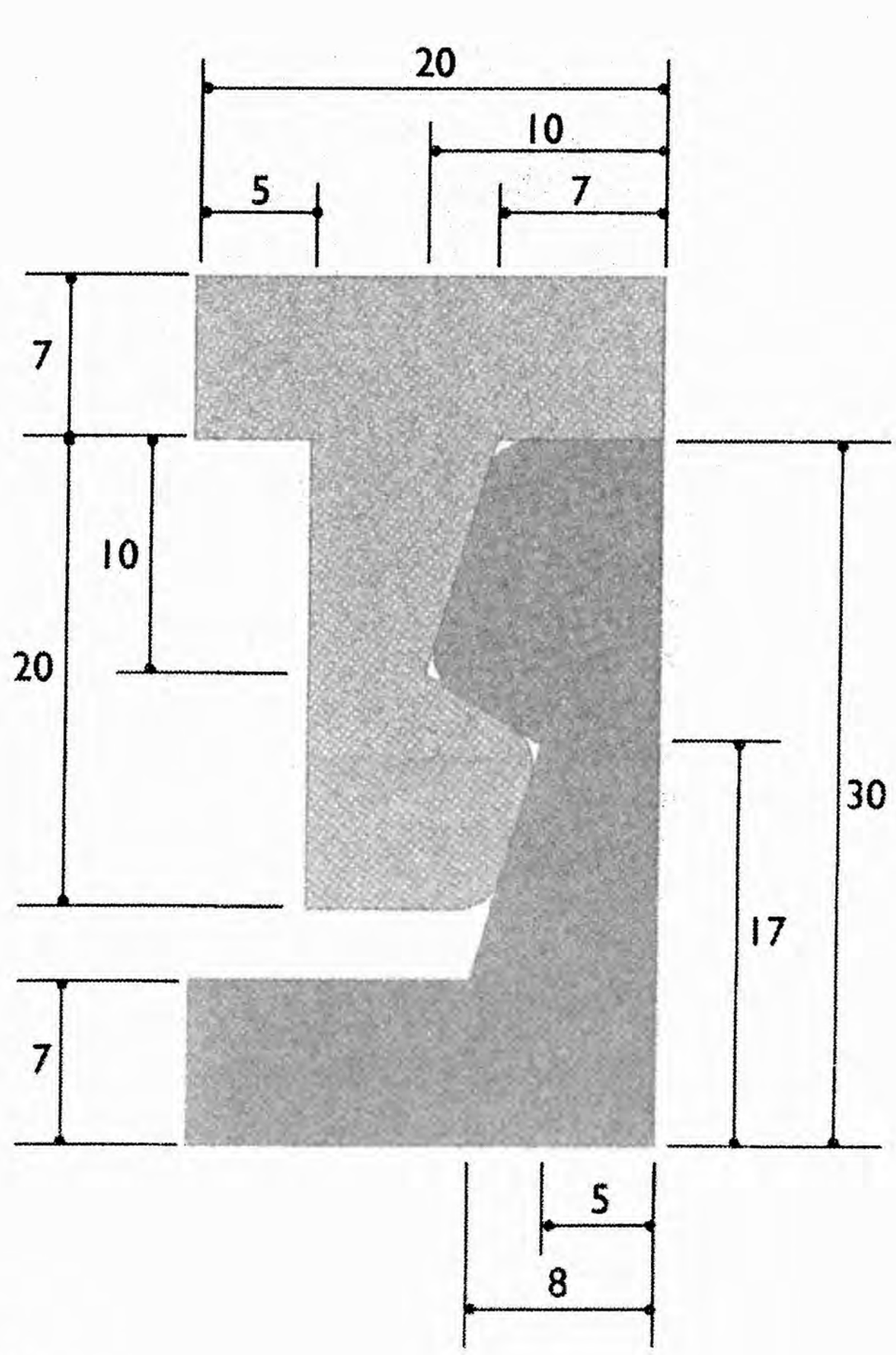
13.4-1 About the Snap Lock

The snap lock consists of two parts: the insert [1] and the prongs [2]; it is fastened when pushed into position [3]. The snap lock has a thickness of 5 mm and is made of a plastic material with a Young's modulus of 2.8 GPa and a Poisson's ratio of 0.35. The coefficient of friction between the materials is 0.2. The purpose of the simulation is to find out the force required to push the insert into the position and the force required to pull it out.

We will model the problem as a plane stress problem. Due to the symmetry, only one half of the model is used in the simulation.





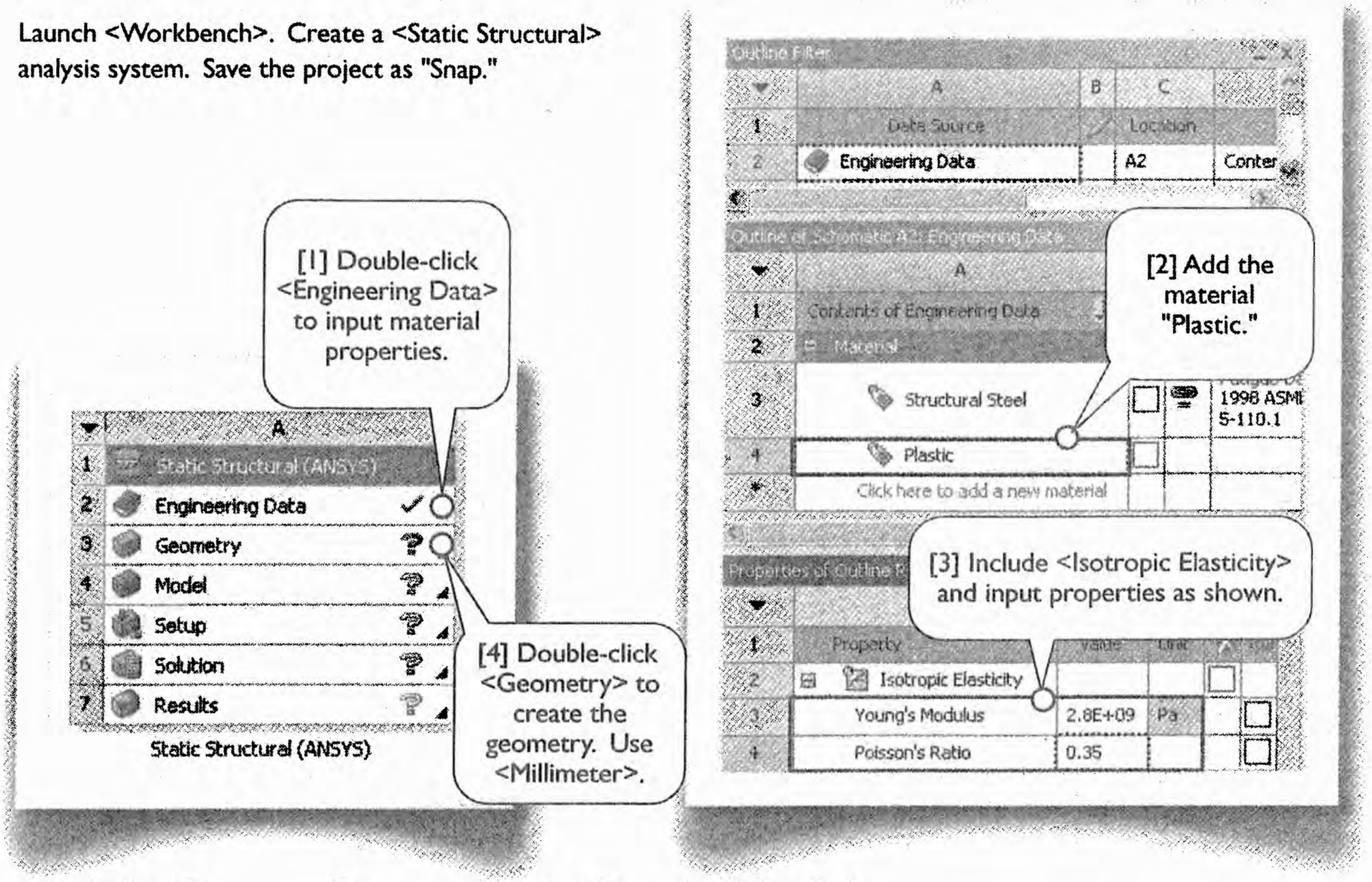


Unit: mm.

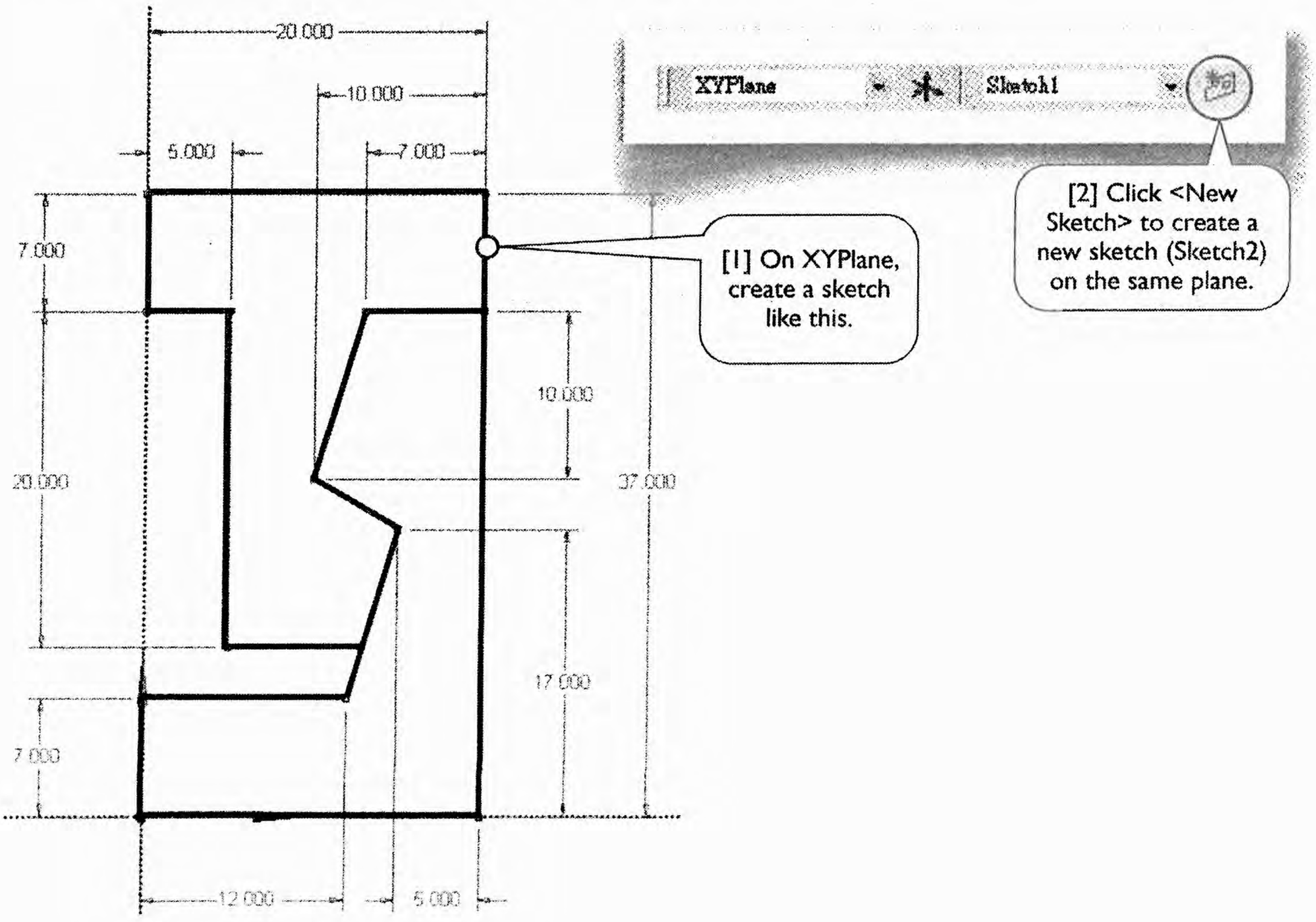
All fillets has radius of 2 mm.

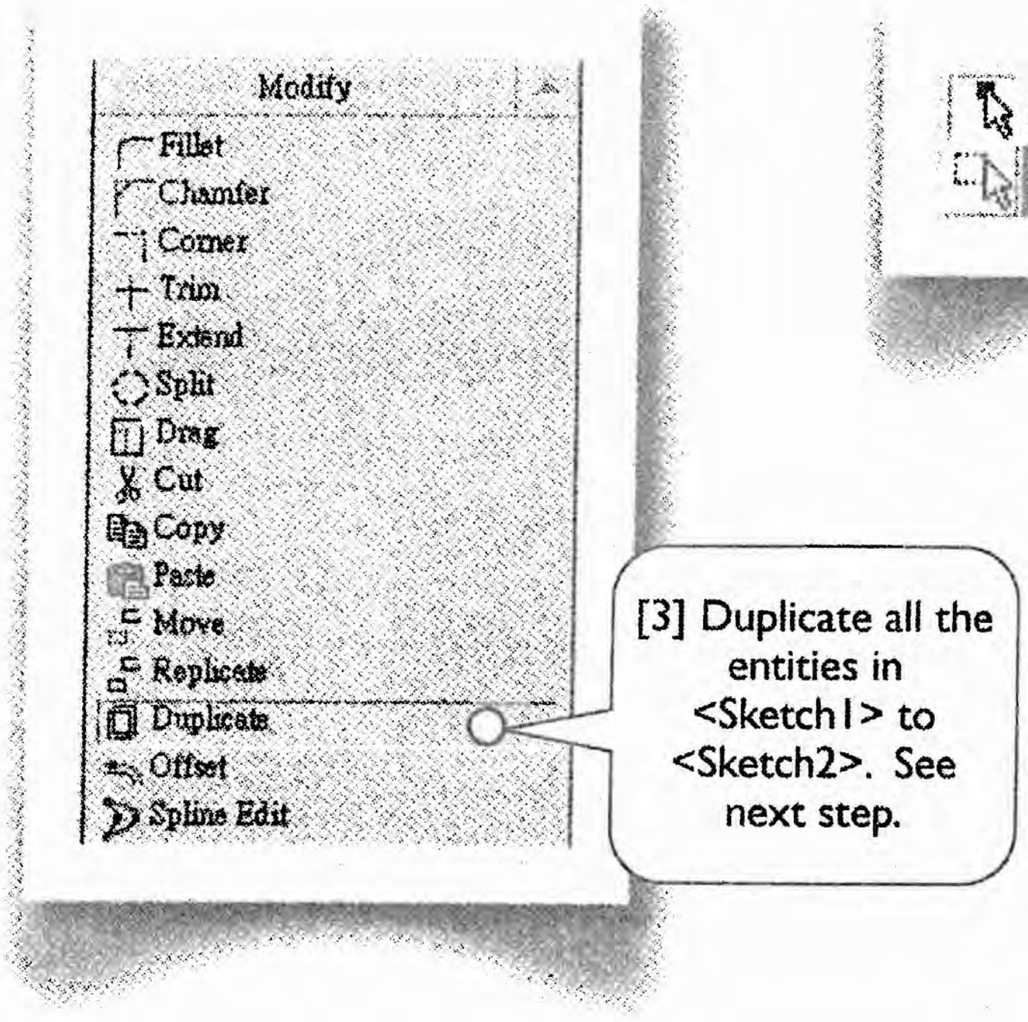
13.4-2 Start Up

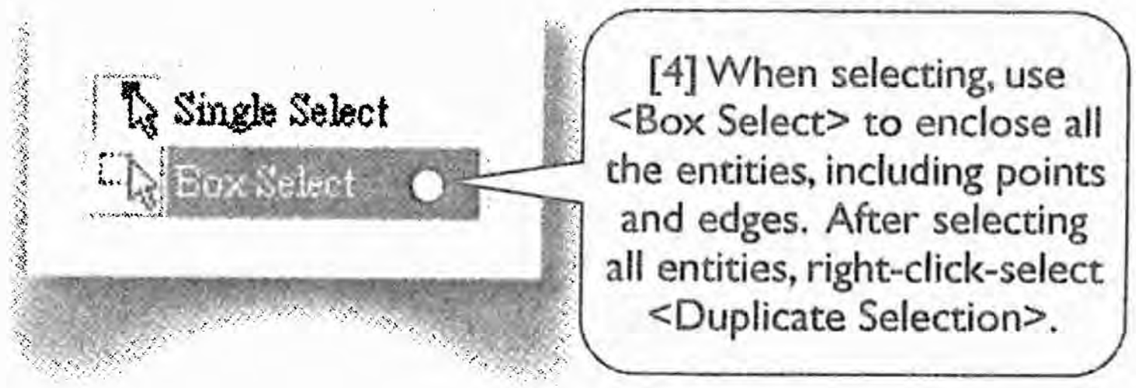
Launch <Workbench>. Create a <Static Structural> analysis system. Save the project as "Snap."

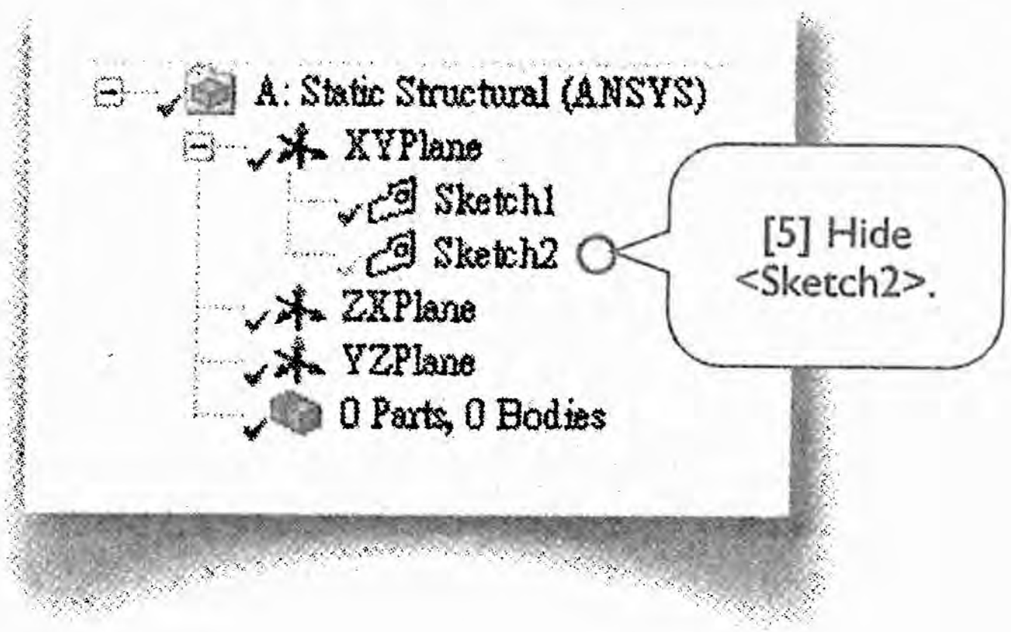


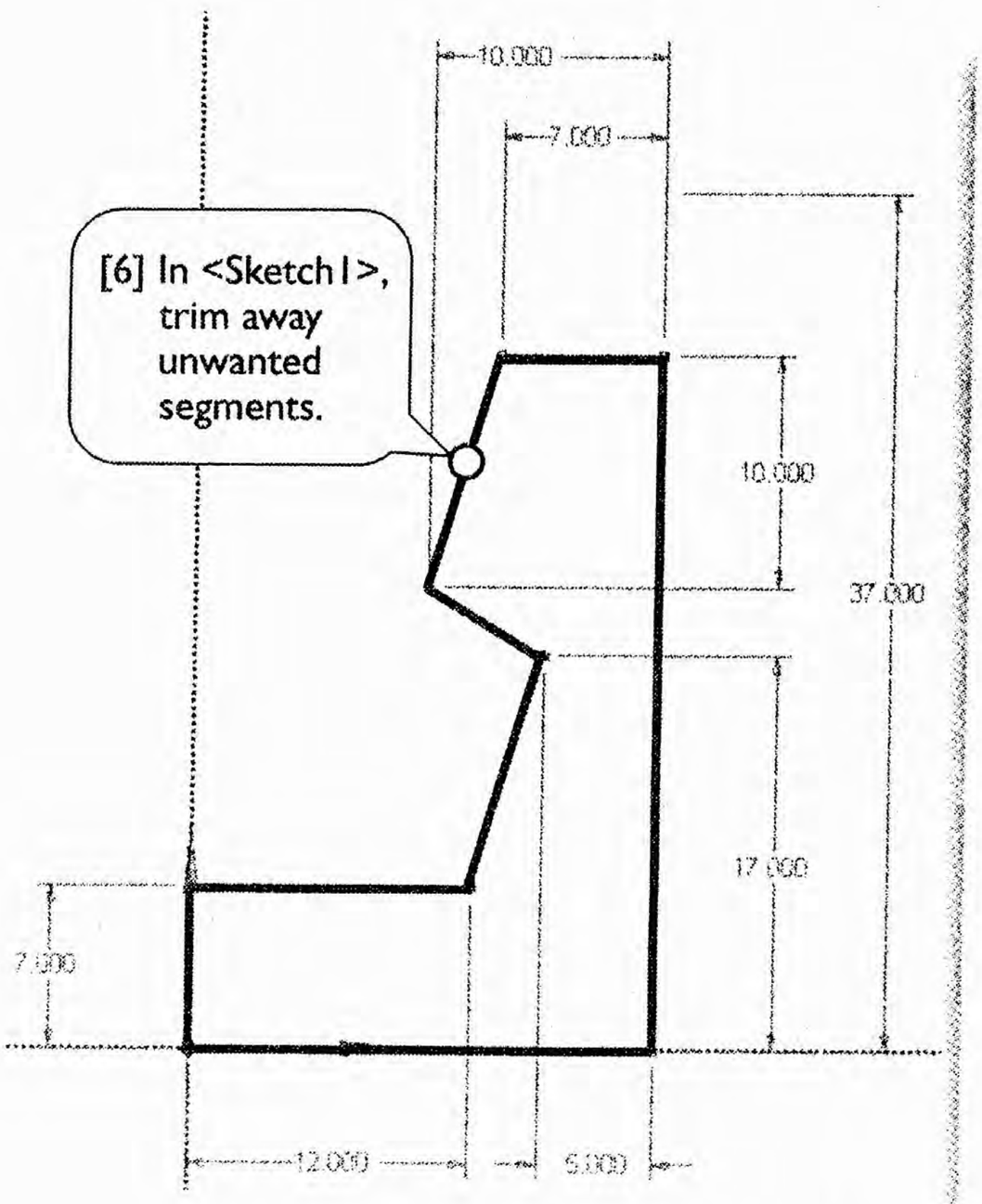
13.4-3 Create Geometry in DesignModeler

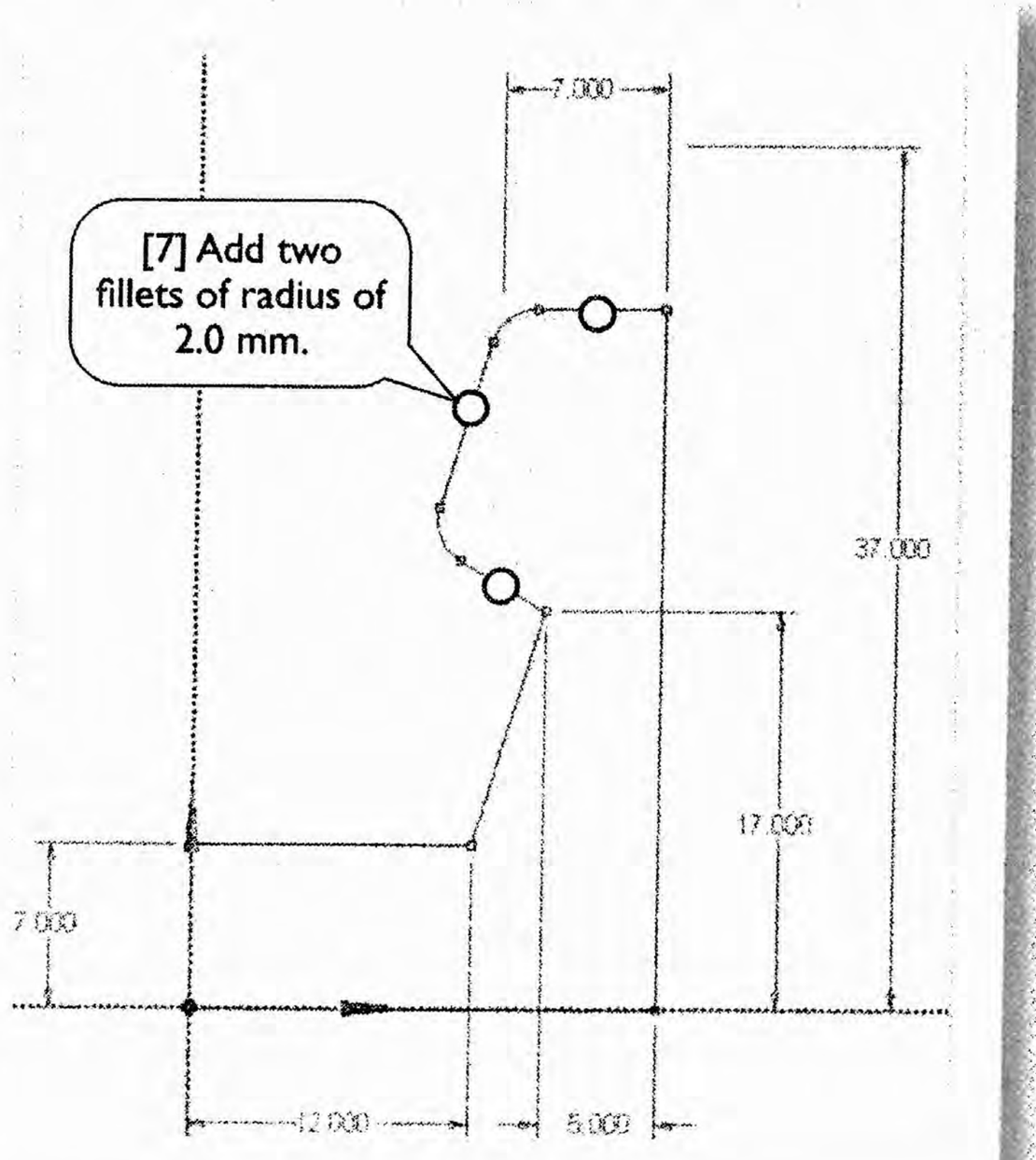


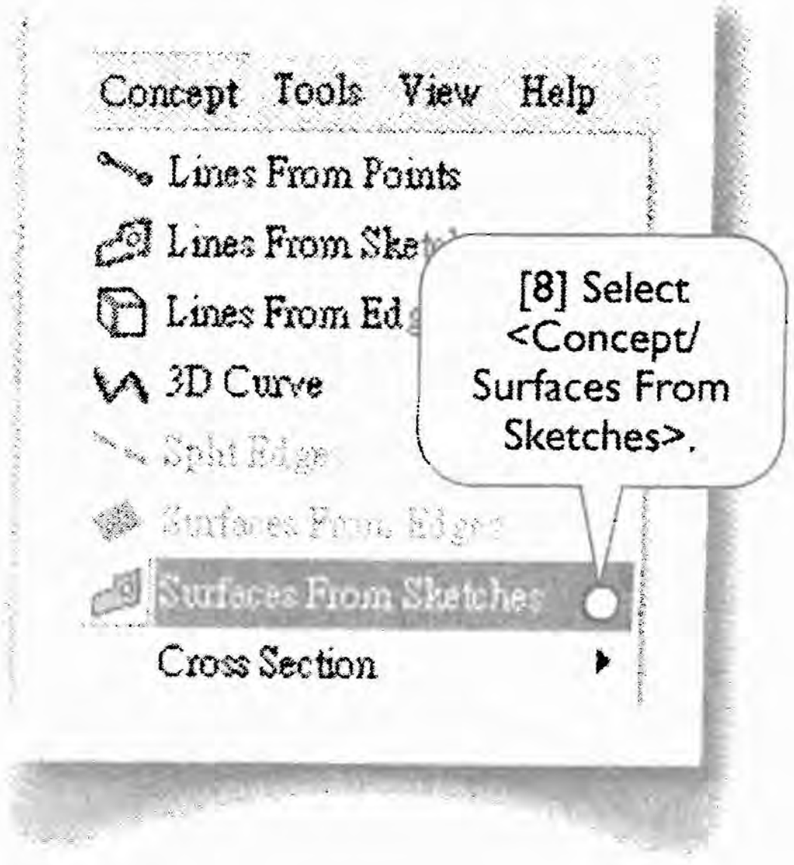

Modify
Fillet
Chamfer
Corner
Trim
Extend
Split
Drag
Cut
Copy
Paste
Move
Replicate
Duplicate
Offset
Spline Edit
[3] Duplicate all the entities in <Sketch1> to <Sketch2>. See next step.


Single Select
Box Select
[4] When selecting, use <Box Select> to enclose all the entities, including points and edges. After selecting all entities, right-click-select <Duplicate Selection>.

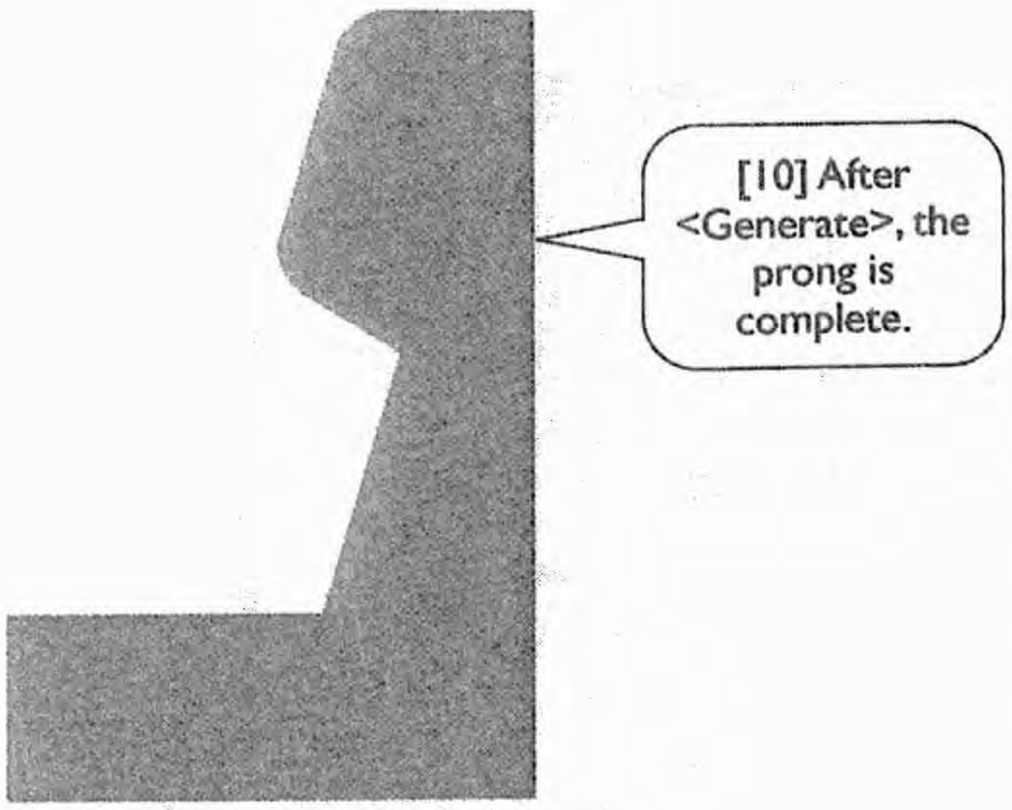

A: Static Structural (ANSYS)
XYPlane
Sketch1
Sketch2
ZXPlane
YZPlane
0 Parts, 0 Bodies
[5] Hide <Sketch2>.

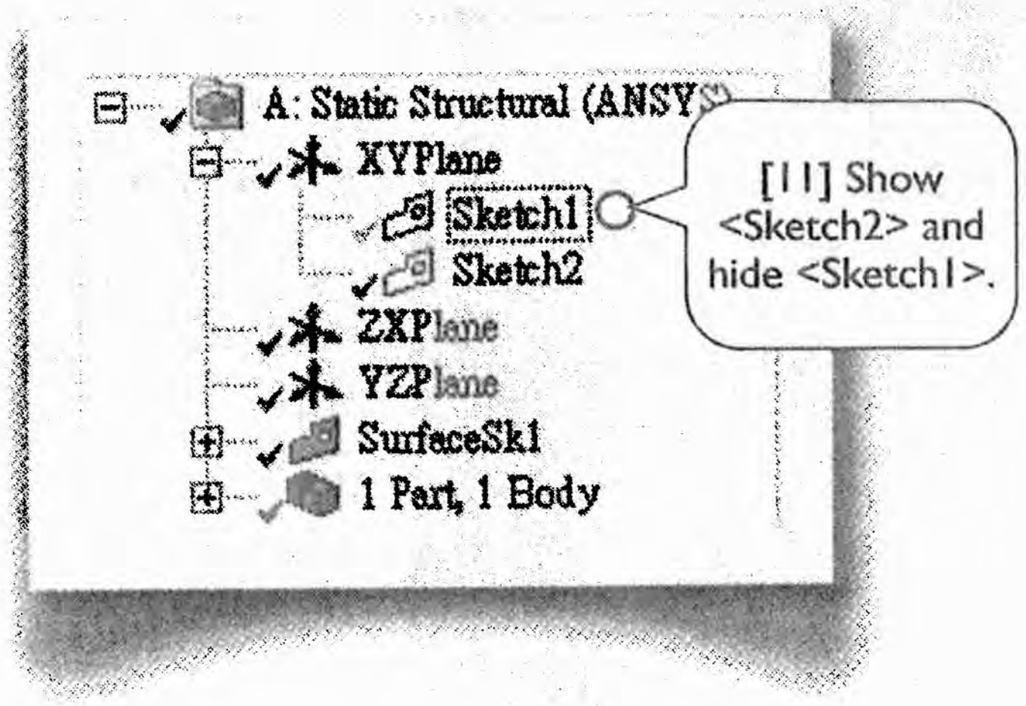

[6] In <Sketch1>, trim away unwanted segments.
10.000
7.000
10.000
37.000
17.000
7.000
12.000
5.000

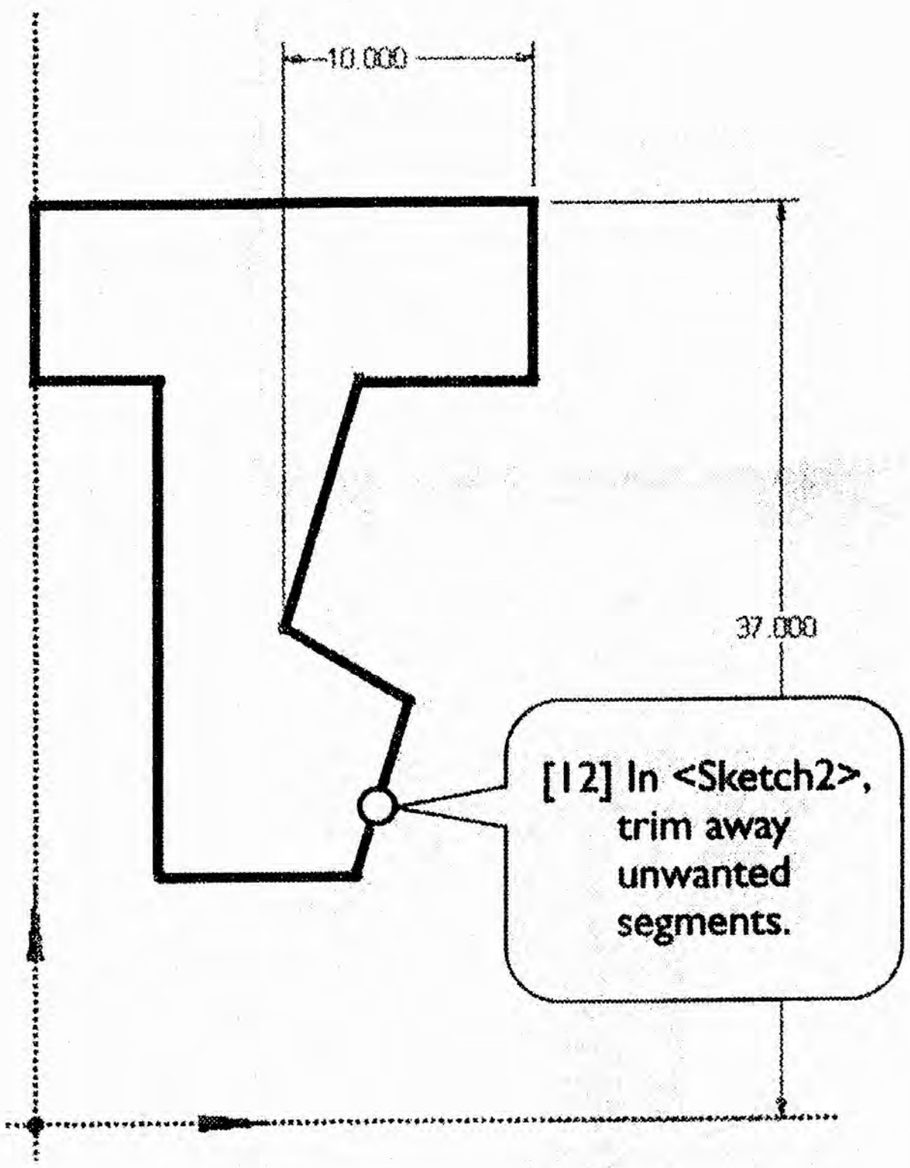

[7] Add two fillets of radius of 2.0 mm.
7.000
37.000
17.000
7.000
12.000
5.000

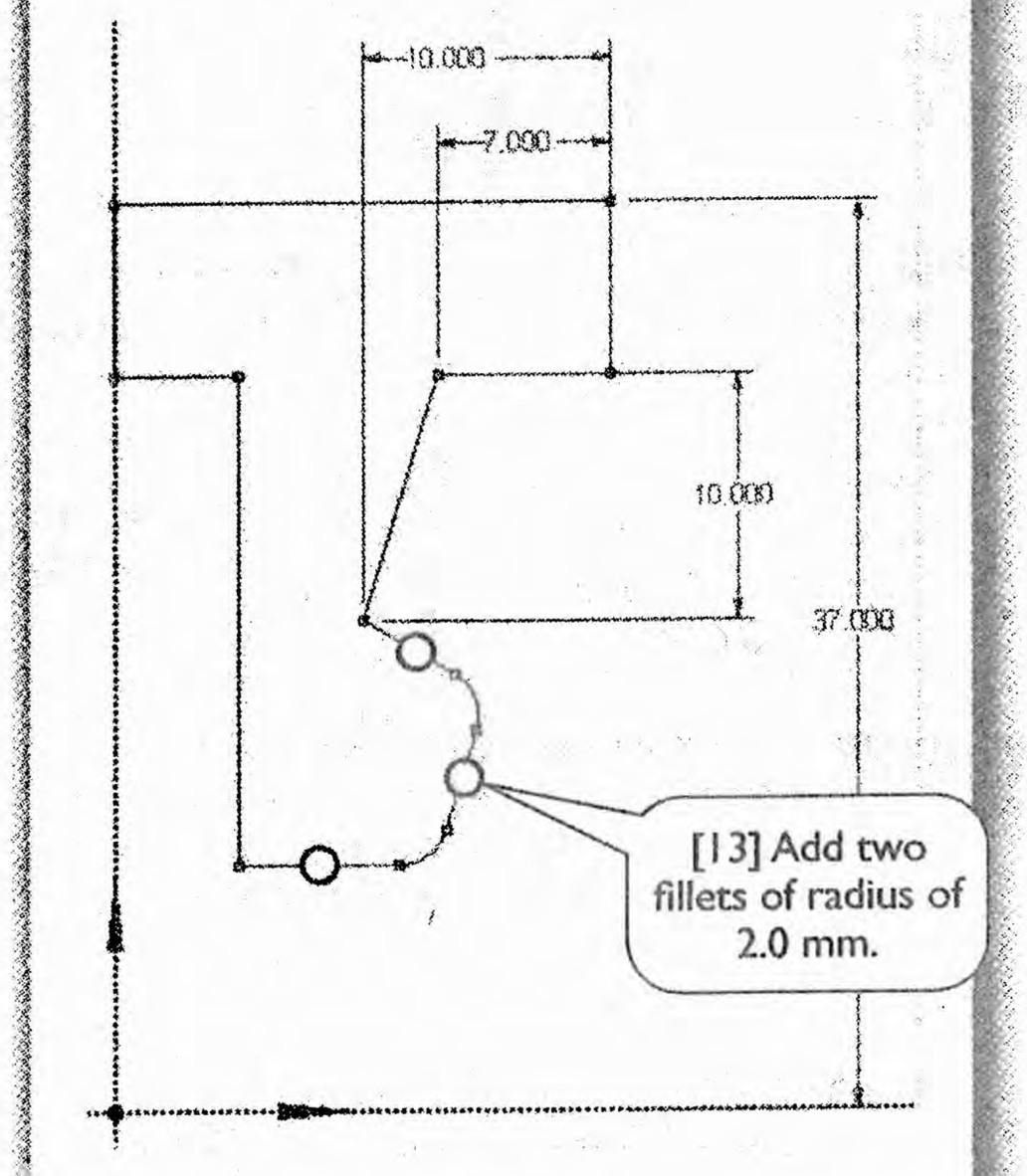

Concept Tools View Help
Lines From Points
Lines From Sketches
Lines From Edges
3D Curve
Split Edges
Surfaces From Edges
Surfaces From Sketches
Cross Section
[8] Select <Concept/ Surfaces From Sketches>.

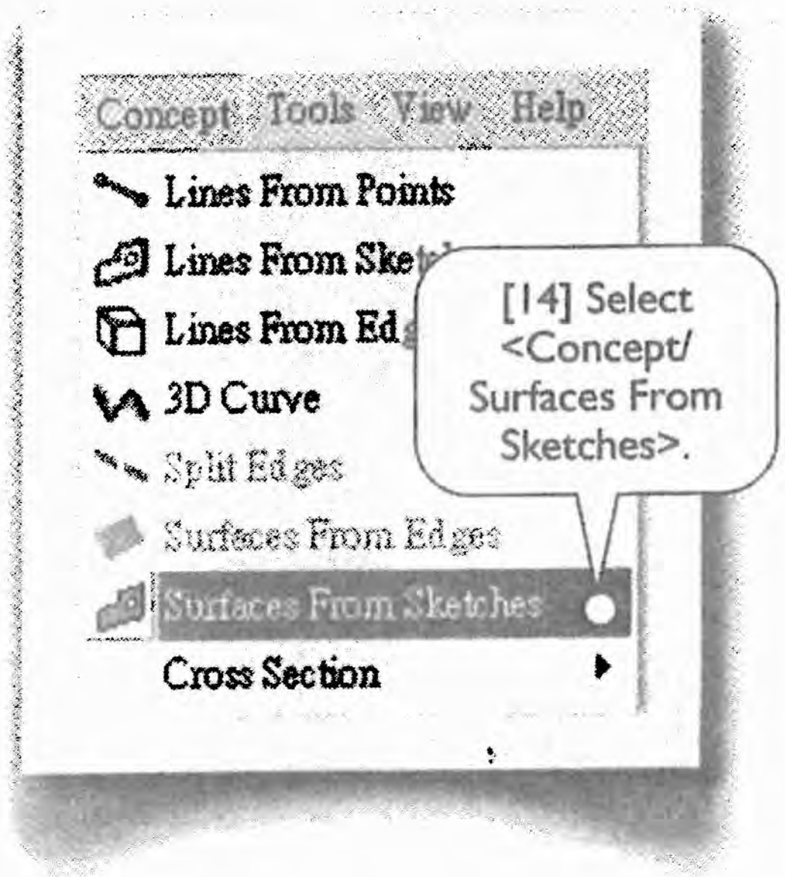
[9] Select <Sketch1>.
Details View
Details of SurfaceSk1
Surface From Sketches
SurfaceSk1
Base Objects
1 Sketch
Operation
Add Material
Orient With Plane Normal?
Yes
Thickness (>=0)
5 mm


[10] After <Generate>, the prong is complete.

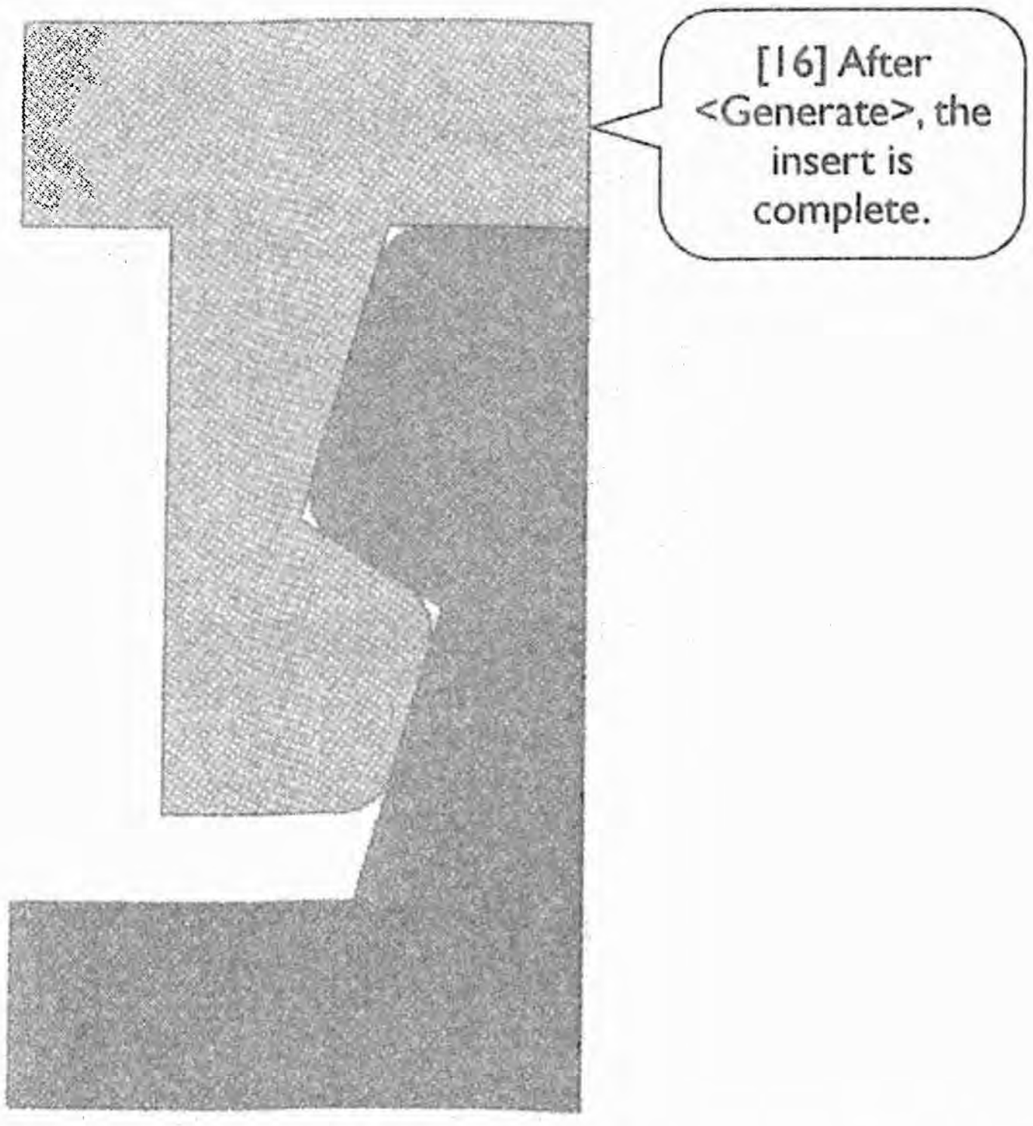

A: Static Structural (ANSYS)
XYPlane
Sketch1
Sketch2
ZXPlane
YZPlane
SurfaceSk1
1 Part, 1 Body
[11] Show <Sketch2> and hide <Sketch1>.

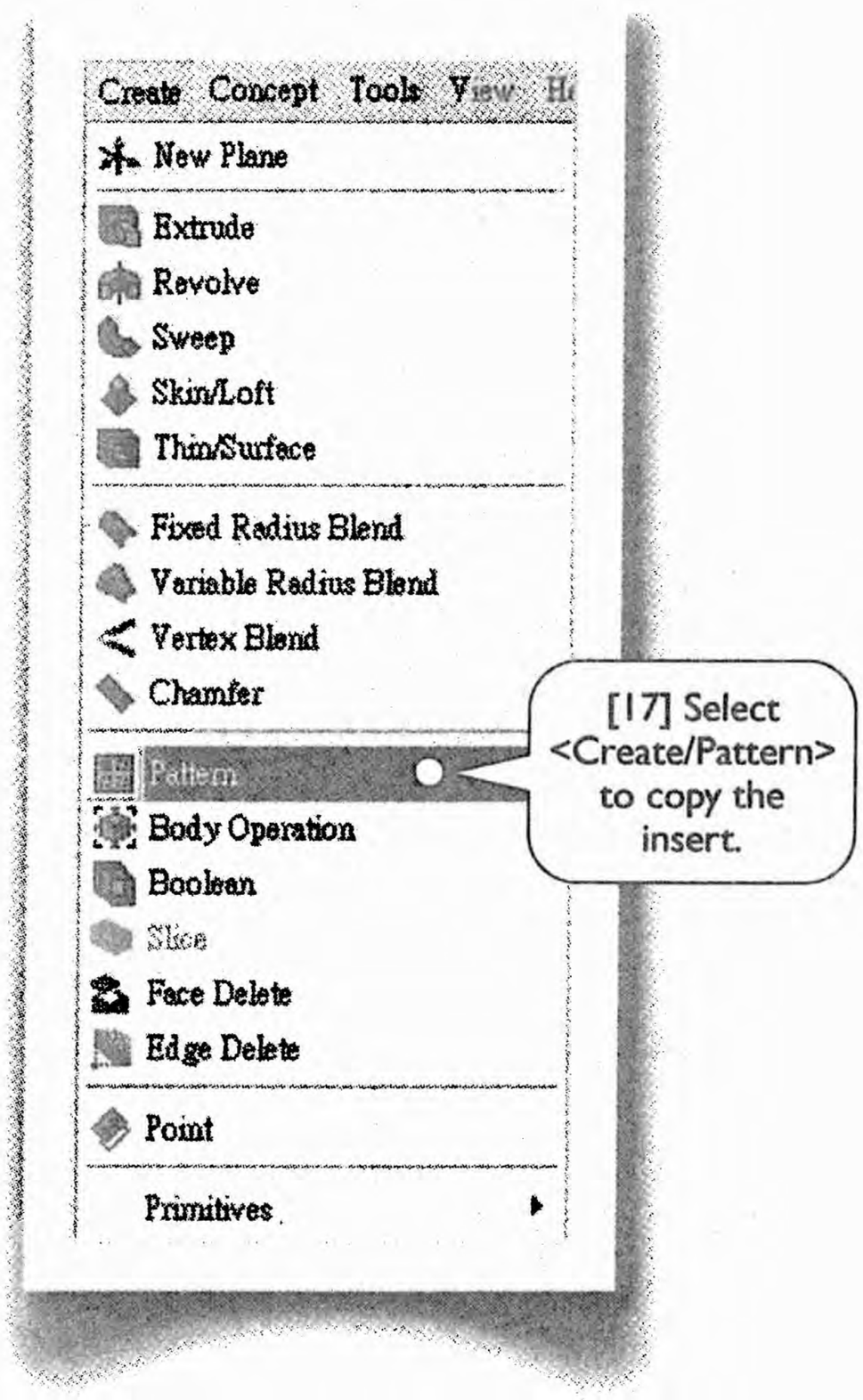

10.000
37.000
[12] In <Sketch2>, trim away unwanted segments.

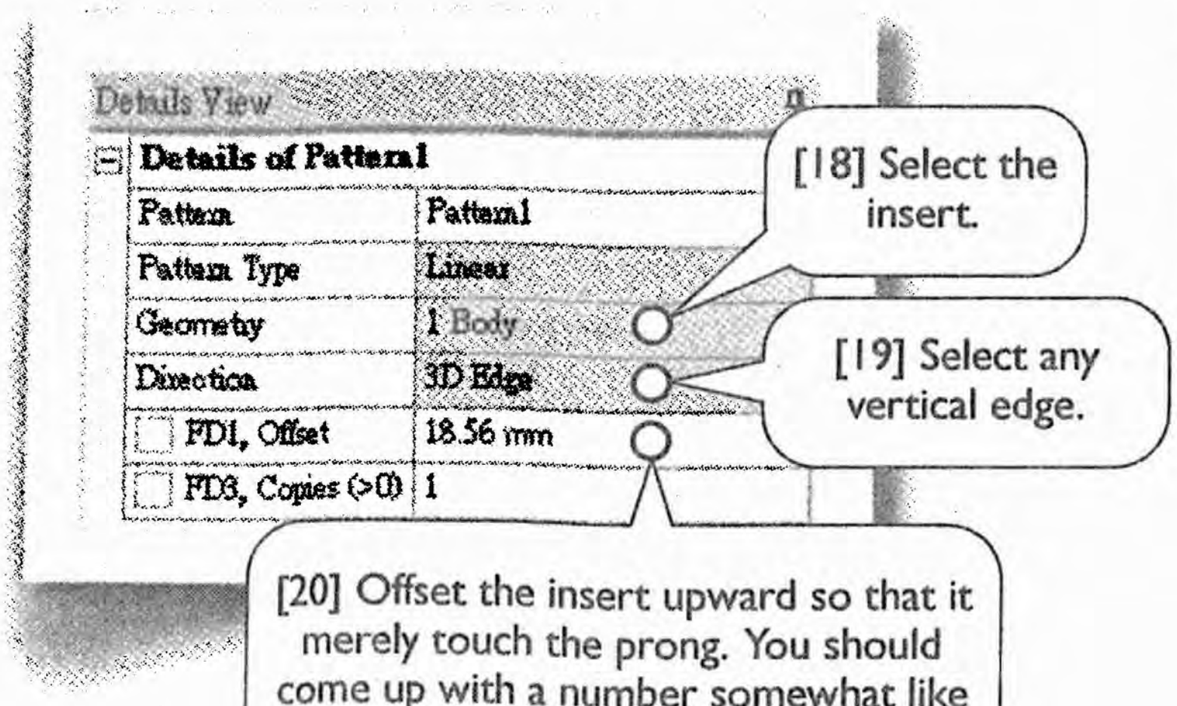

10.000
7.000
10.000
37.000
[13] Add two fillets of radius of 2.0 mm.

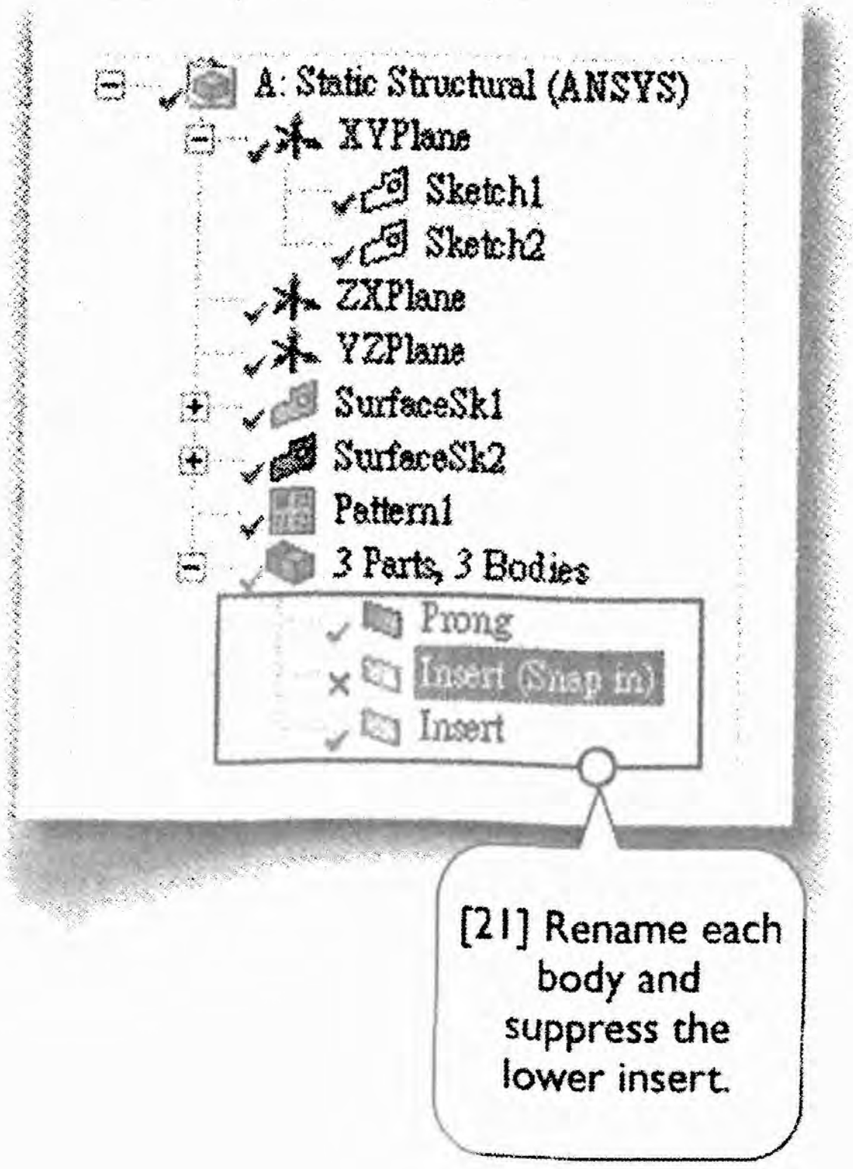

Concept
Tools
View
Help
Lines From Points
Lines From Sketches
Lines From Edges
3D Curve
Split Edges
Surfaces From Edges
Surfaces From Sketches
Cross Section
[14] Select <Concept/ Surfaces From Sketches>.

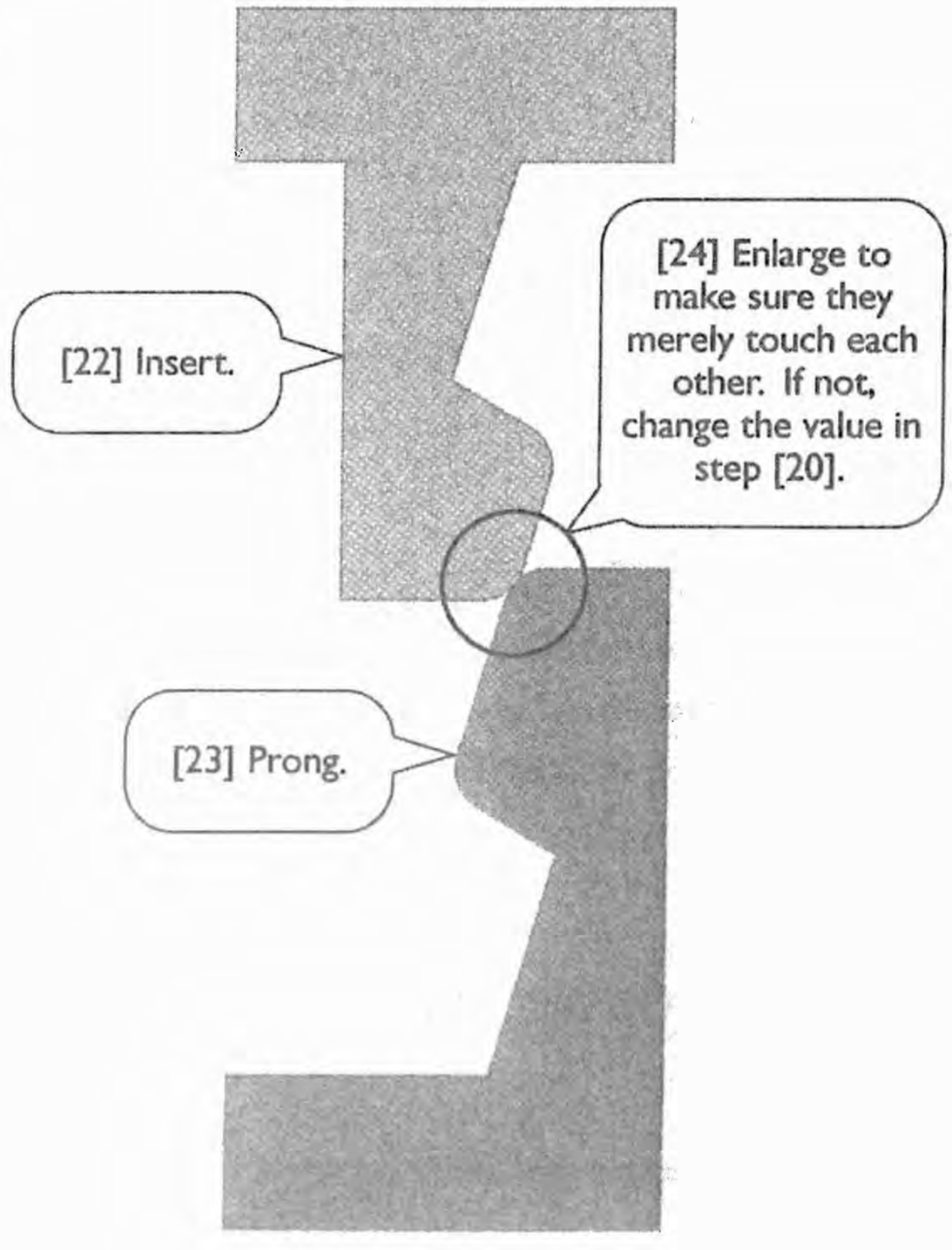
[15] Select <Sketch2>.
Details View
Details of SurfaceSk2
Surface From Sketches
SurfaceSk2
Base Objects
1 Sketch
Operation
Add Frozen
Orient With Plane Normal?
Yes
Thickness (>=0)
5 mm


[16] After <Generate>, the insert is complete.


Create
Concept
Tools
New Plane
Extrude
Revolve
Sweep
Skin/Loft
Thin/Surface
Fixed Radius Blend
Variable Radius Blend
Vertex Blend
Chamfer
Pattern
Body Operation
Boolean
Slice
Face Delete
Edge Delete
Point
Primitives
[17] Select <Create/Pattern> to copy the insert.


Details View
Details of Pattern1
Pattern
Pattern1
Pattern Type
Linear
Geometry
1 Body
Direction
3D Edge
FD1, Offset
18.56 mm
FD3, Copies (>0)
1
[18] Select the insert.
[19] Select any vertical edge.
[20] Offset the insert upward so that it merely touch the prong. You should come up with a number somewhat like this by trials. Click <Generate>.


A: Static Structural (ANSYS)
XYPlane
Sketch1
Sketch2
ZXPlane
YZPlane
SurfaceSk1
SurfaceSk2
Pattern1
3 Parts, 3 Bodies
Prong
Insert (Snap in)
Insert
[21] Rename each body and suppress the lower insert.


[22] Insert.
[23] Prong.
[24] Enlarge to make sure they merely touch each other. If not, change the value in step [20].

Properties of Schematic A3: Geometry

	A	B
1	Property	Value
2	General	
4	Geometry Source	
7	Basic Geometry Options	
16	Advanced Geometry Options	
17	Analysis Type	2D
18	Use Associativity	☑
19	Import Coordinate Systems	☐
20	Import Work Points	☐
21	Reader Mode Saves Updated File	☐
22	Import Using Instances	☑
23	Smart CAD Update	☐
24	Enclosure and Symmetry Processing	☑
25	Mixed Import Resolution	None

[25] Before attaching the geometry to <Mechanical>, remember to select <2D> option (3.1-4[7]).

13.4-4 Set Up Model

Details of "Geometry"

Definition	
Source	C:\Documents and Settings\PC\Lo...
Type	DesignModeler
Length Unit	Millimeters
Element Control	Program Controlled
2D Behavior	Plane Stress
Display Style	Part Color
Bounding Box	
Properties	
Statistics	
Preferences	

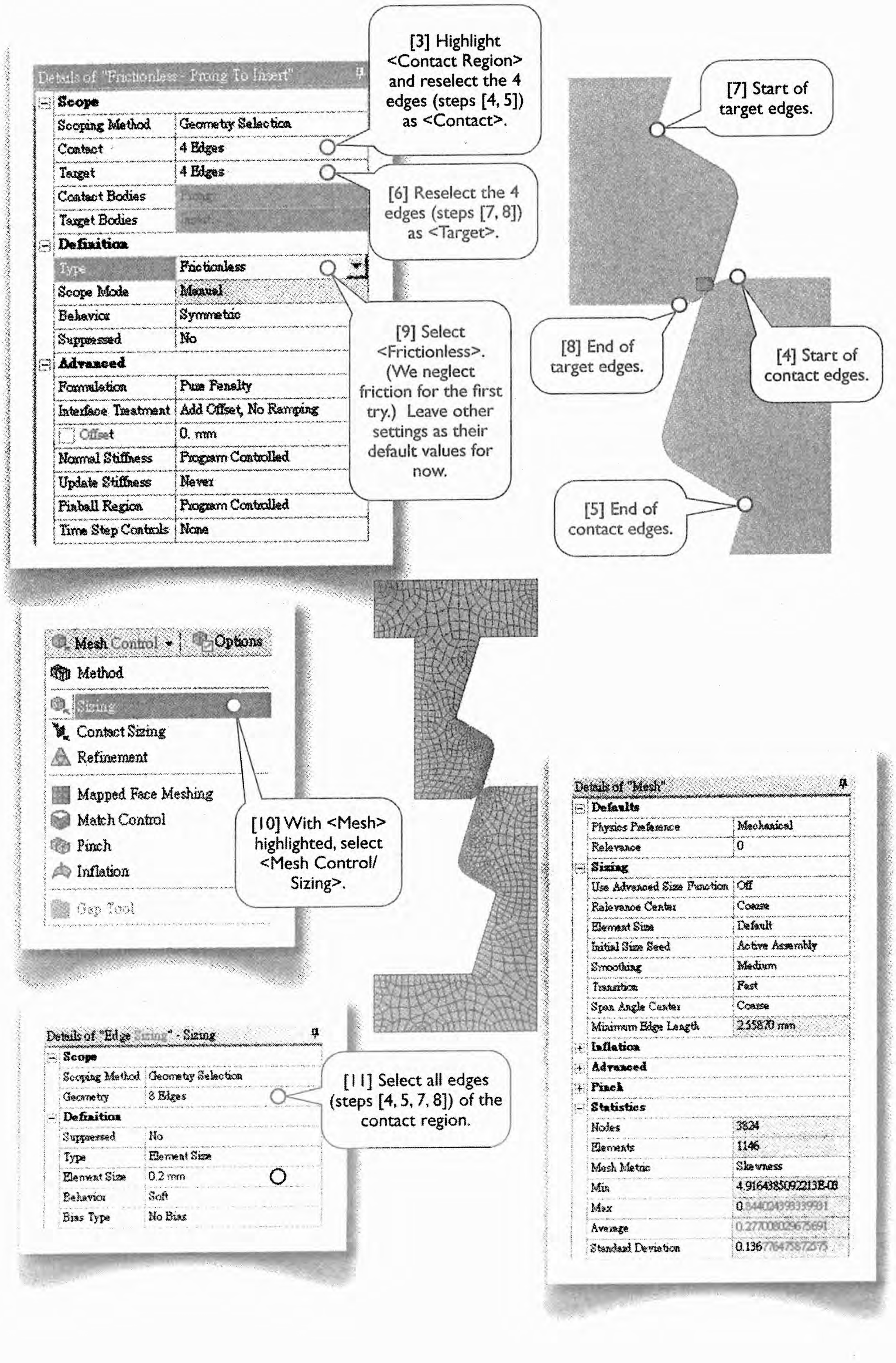
[1] Highlight <Geometry>, make sure <Plane Stress> is selected.

Project
- Model (A4)
  - Geometry
    - Prong
    - Insert
  - Coordinate Systems
  - Connections
    - Contact Region
  - Mesh
  - Static Structural (A5)
    - Analysis Settings
    - Solution (A6)
      - Solution Information

Details of "Multiple Selection"

Graphics Properties	
Definition	
Suppressed	No
Stiffness Behavior	Flexible
Coordinate System	Default Coordinate System
Reference Temperature	By Environment
Thickness	5. mm
Thickness Mode	Refresh on Update
Material	
Assignment	Plastic
Nonlinear Effects	Yes
Thermal Strain Effects	Yes
Bounding Box	
Properties	
Statistics	

[2] Highlight <Prong> and <Insert>, assign <Plastic> to two bodies.



Details of "Frictionless - Prong To Insert"

Scope	
Scoping Method	Geometry Selection
Contact	4 Edges
Target	4 Edges
Contact Bodies	
Target Bodies	
Definition	
Type	Frictionless
Scope Mode	Manual
Behavior	Symmetric
Suppressed	No
Advanced	
Formulation	Pure Penalty
Interface Treatment	Add Offset, No Ramping
Offset	0. mm
Normal Stiffness	Program Controlled
Update Stiffness	Never
Pinball Region	Program Controlled
Time Step Controls	None

Mesh Control | Options

Method

Sizing

Contact Sizing

Refinement

Mapped Face Meshing

Match Control

Pinch

Inflation

Gap Tool

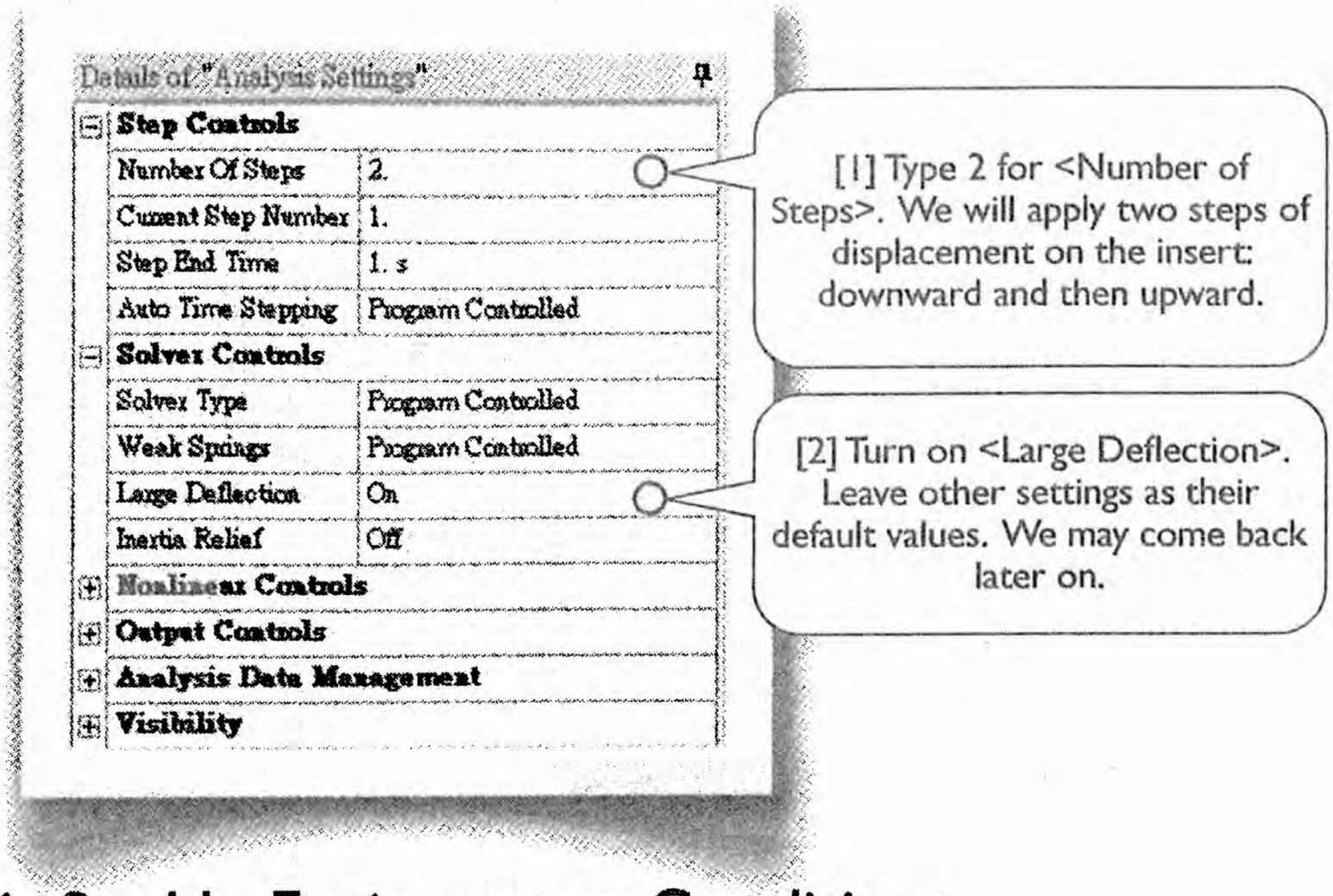
Details of "Edge Sizing" - Sizing

Scope	
Scoping Method	Geometry Selection
Geometry	8 Edges
Definition	
Suppressed	No
Type	Element Size
Element Size	0.2 mm
Behavior	Soft
Bias Type	No Bias

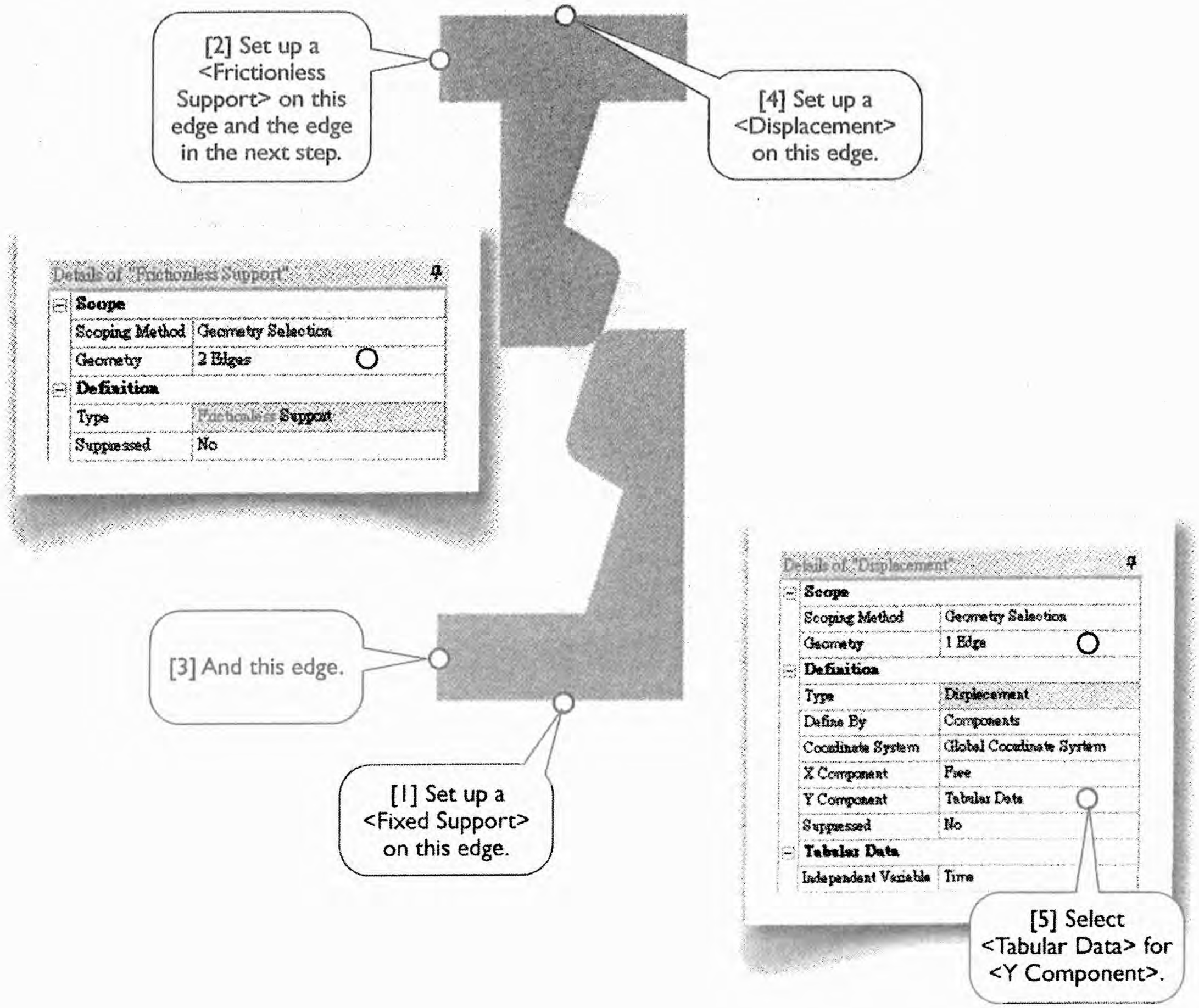
Details of "Mesh"

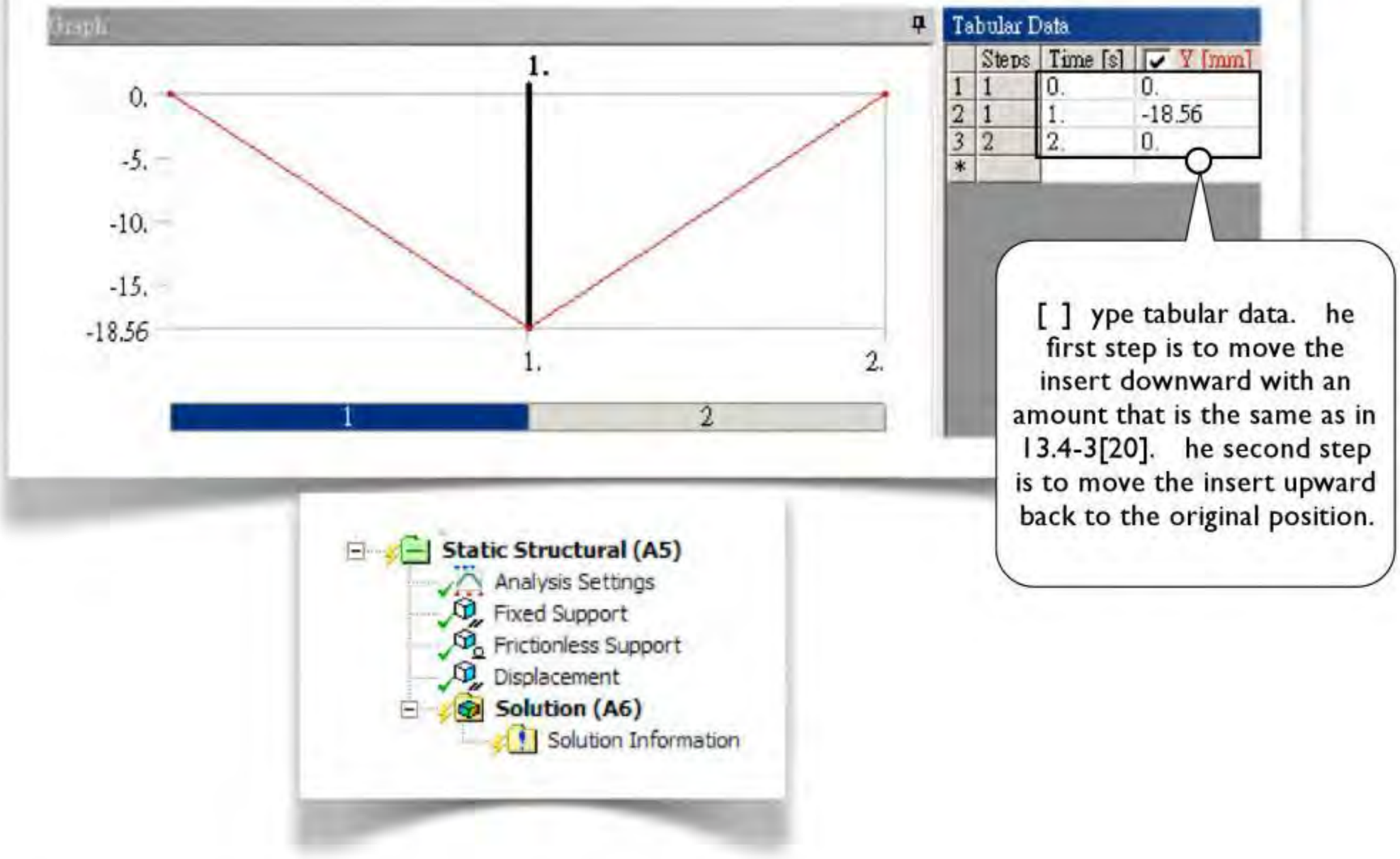
Defaults	
Physics Preference	Mechanical
Relevance	0
Sizing	
Use Advanced Size Function	Off
Relevance Center	Coarse
Element Size	Default
Initial Size Seed	Active Assembly
Smoothing	Medium
Transition	Fast
Span Angle Center	Coarse
Minimum Edge Length	2.3587E-10 mm
Inflation	
Advanced	
Pinch	
Statistics	
Nodes	3824
Elements	1146
Mesh Metric	Skewness
Min	4.9164385092213E-08
Max	0.84402439833991
Average	0.27700802967569[illegible]
Standard Deviation	0.136[illegible]

13.4-5 Set Up Analysis Settings

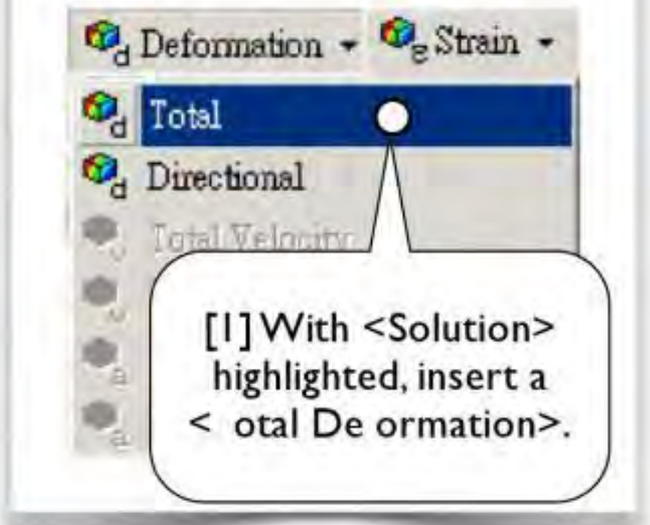


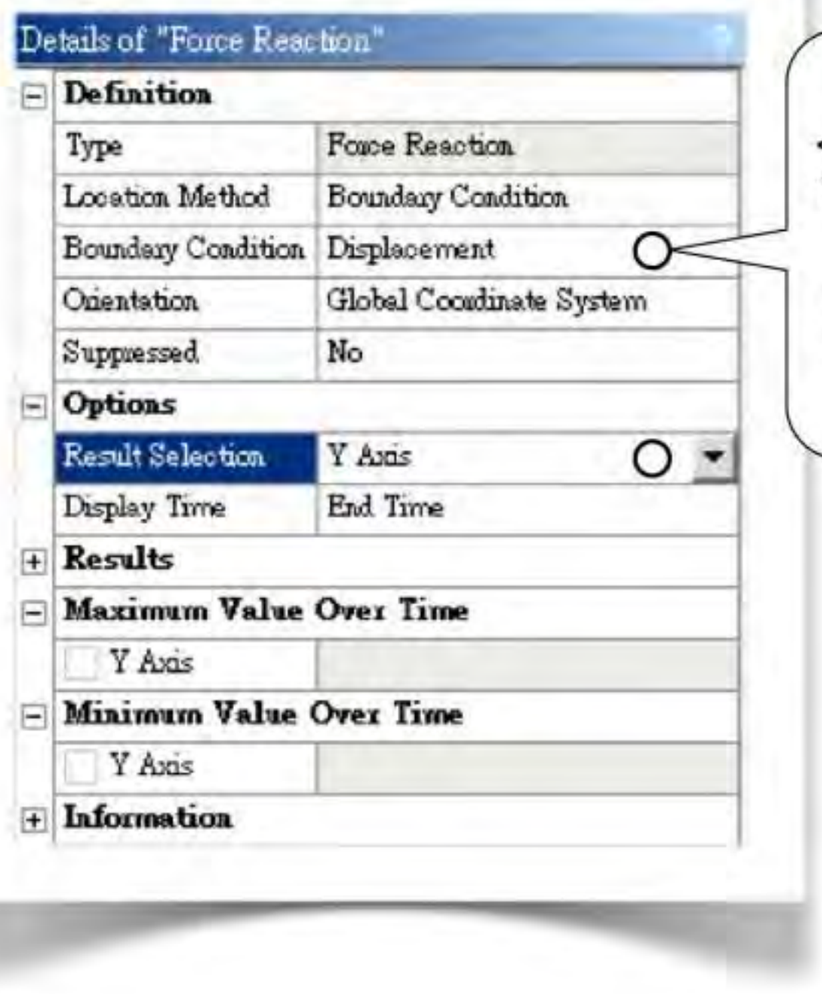
13.4-6 Set Up Environment Conditions

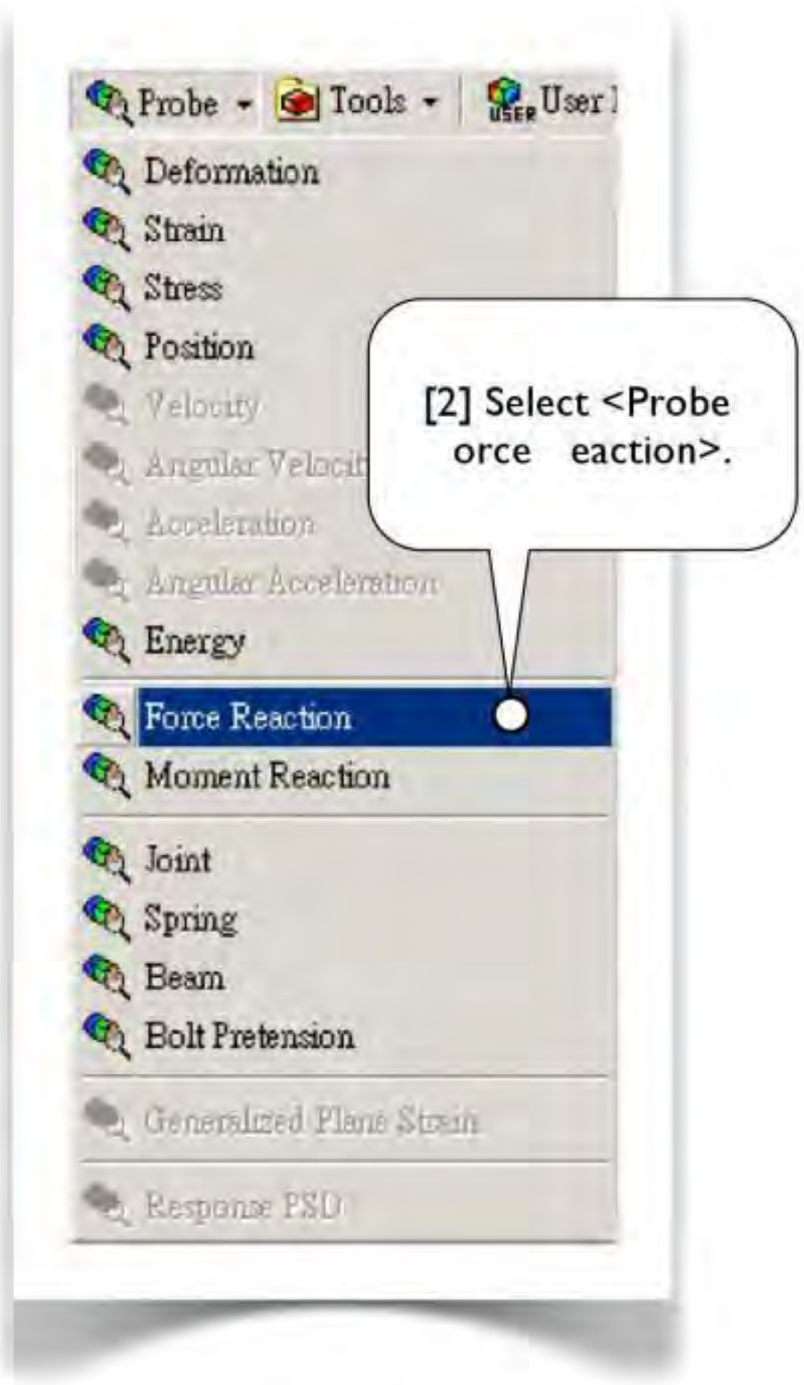




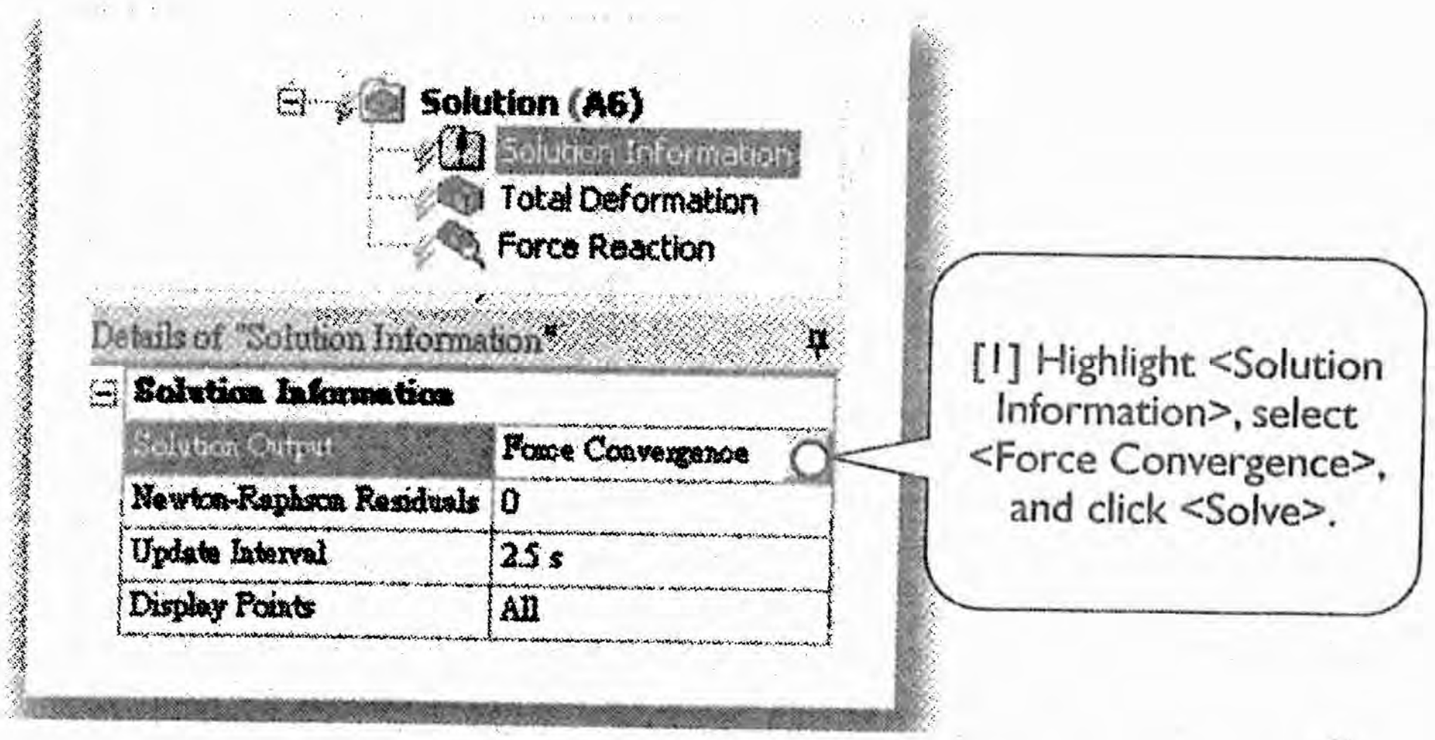
13.4- Set Up esult Objects

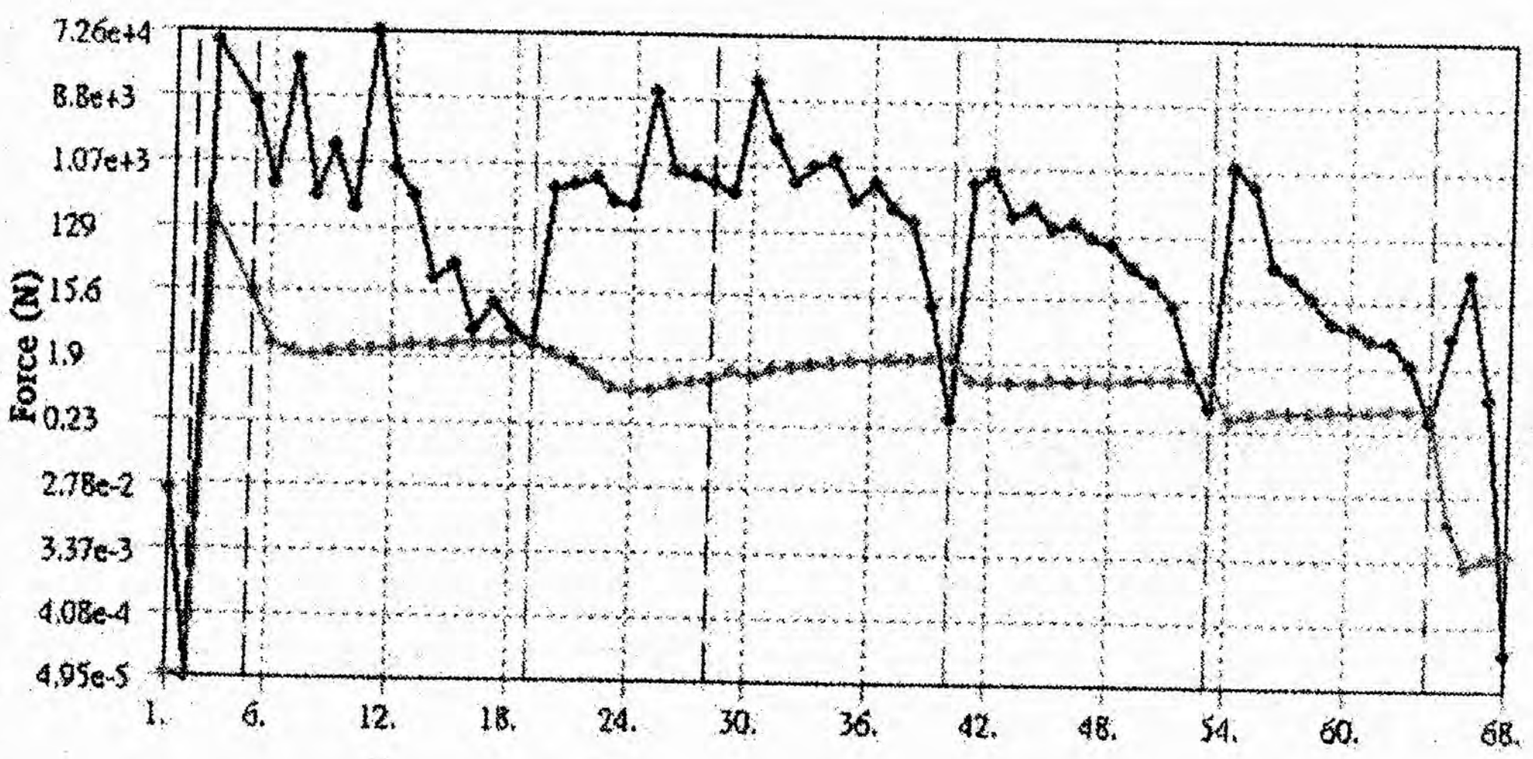


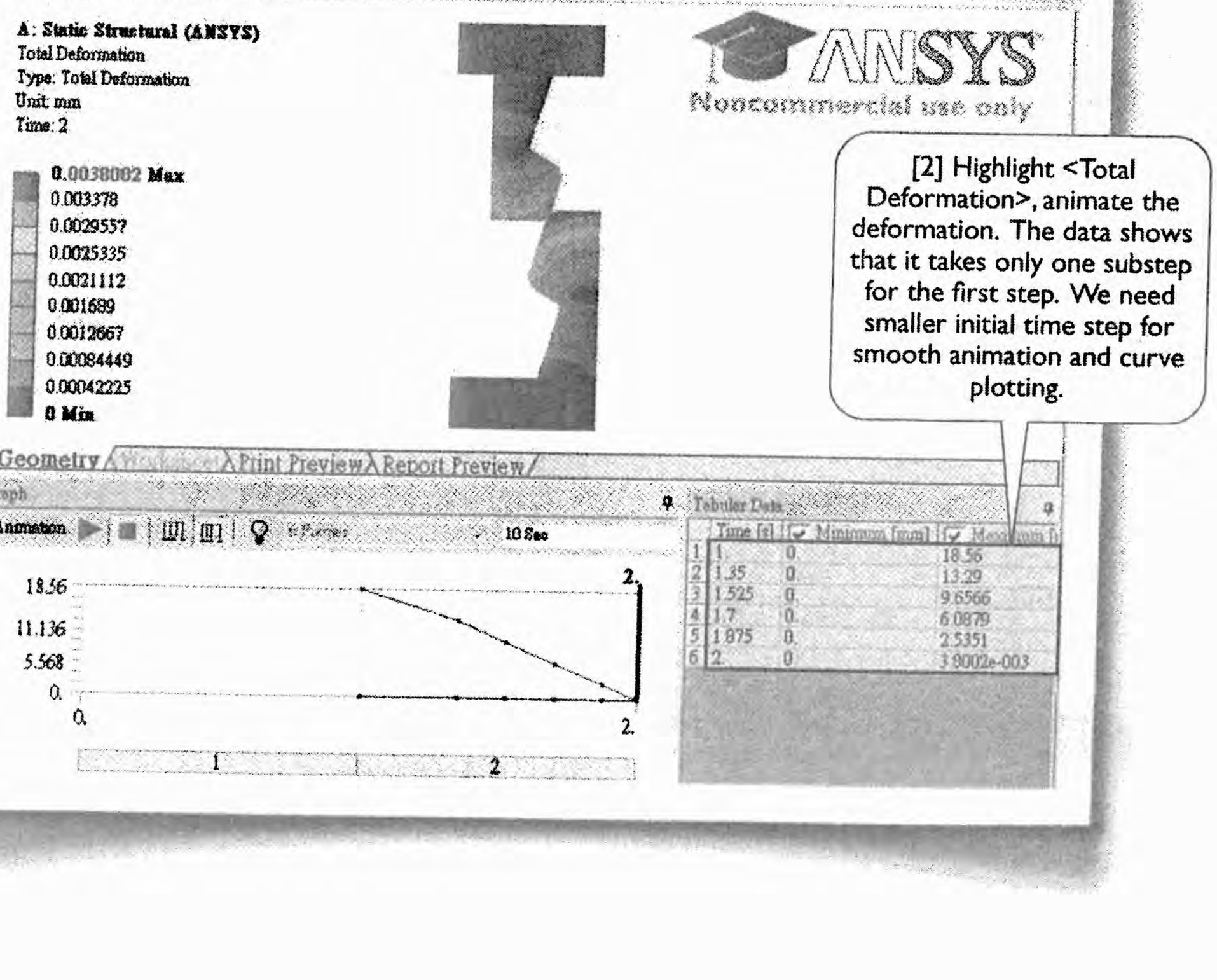




13.4-8 Solve the Model and View the Results







[1] Set up <Analysis Settings> for the first step.

[2] Set up <Analysis Settings> for the second step.

[3] Turning on <Carry Over Time Step> is to use the time step value of the last substep of the first load step as the initial time step value for this step.

Details of "Analysis Settings"

Step Controls		
Number Of Steps	2.	
Current Step Number	1.	
Step End Time	1. s	
Auto Time Stepping	On	
Define By	Time	
Initial Time Step	0.1 s	
Minimum Time Step	1.e-002 s	
Maximum Time Step	0.1 s	
Solver Controls		
Solver Type	Program Controlled	
Weak Springs	Program Controlled	
Large Deflection	On	
Inertia Relief	Off	
Nonlinear Controls		
Output Controls		
Analysis Data Management		
Visibility		

Details of "Analysis Settings"

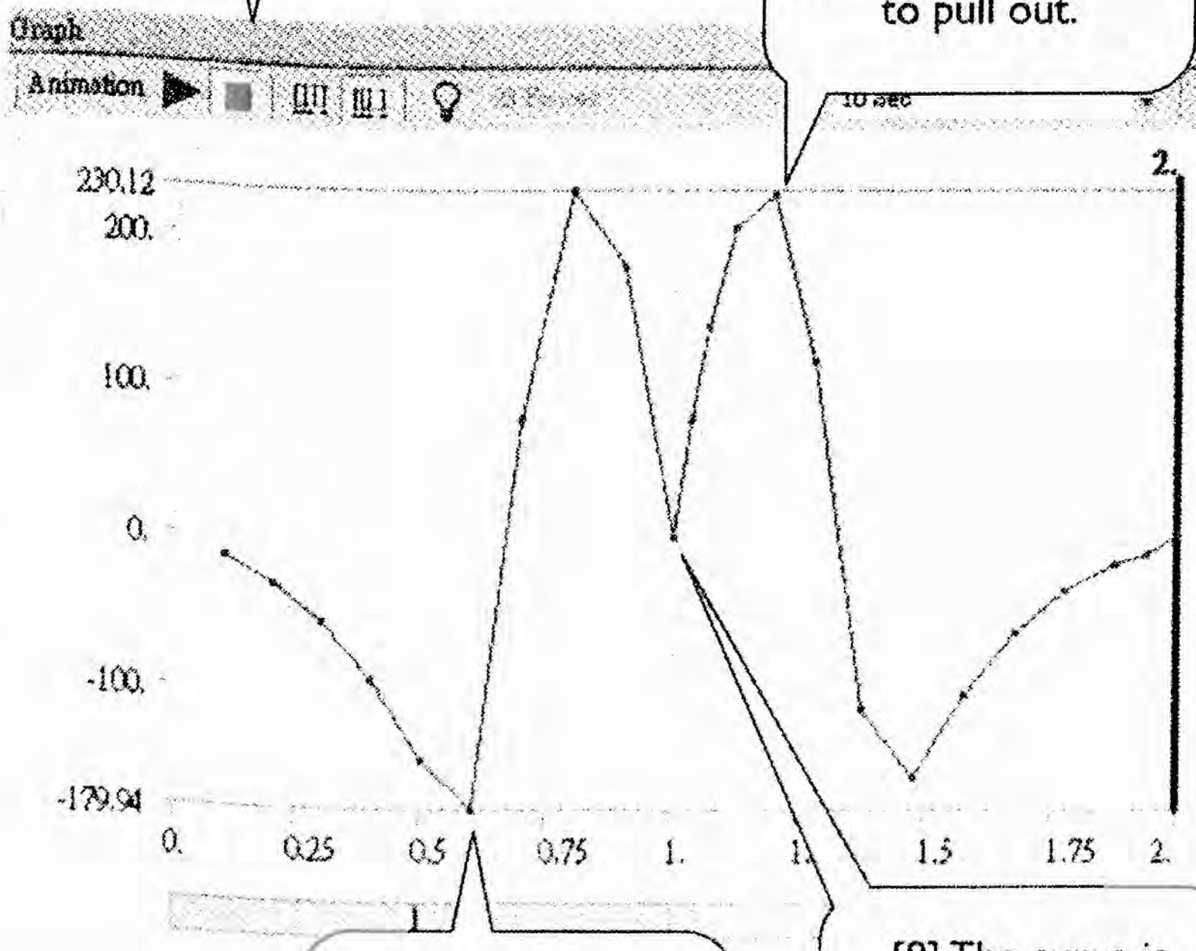
Step Controls		
Number Of Steps	2.	
Current Step Number	2.	
Step End Time	2. s	
Auto Time Stepping	On	
Define By	Time	
Carry Over Time Step	On	
Minimum Time Step	1.e-002 s	
Maximum Time Step	0.1 s	
Solver Controls		
Solver Type	Program Controlled	
Weak Springs	Program Controlled	
Large Deflection	On	
Inertia Relief	Off	
Nonlinear Controls		
Output Controls		
Analysis Data Management		
Visibility		

Solve

[4] Solve.

[5] Highlight <Force Reaction> to view the required forces.

[7] It requires 230 N to pull out.



Tabular Data

	Time [s]	Force Reaction (Y) [N]
1	0.1	-15.334
2	0.2	-32.008
3	0.3	-57.293
4	0.4	-94.737
5	0.5	-147.37
6	0.6	-179.94
7	0.7	78.567
8	0.8	230.12
9	0.9	180.13
10	1	-2.8357e-004
11	1.035	77.555
12	1.07	138.77
13	1.1225	205.43
14	1.2012	227.23
15	1.28	116.12
16	1.38	-113.82
17	1.48	-159.32
18	1.58	-103.61
19	1.68	-63.691
20	1.78	-36.345
21	1.88	-18.196
22	1.94	-11.202
23	2.	-1.0371e-009

[6] It requires 180 N to snap in.

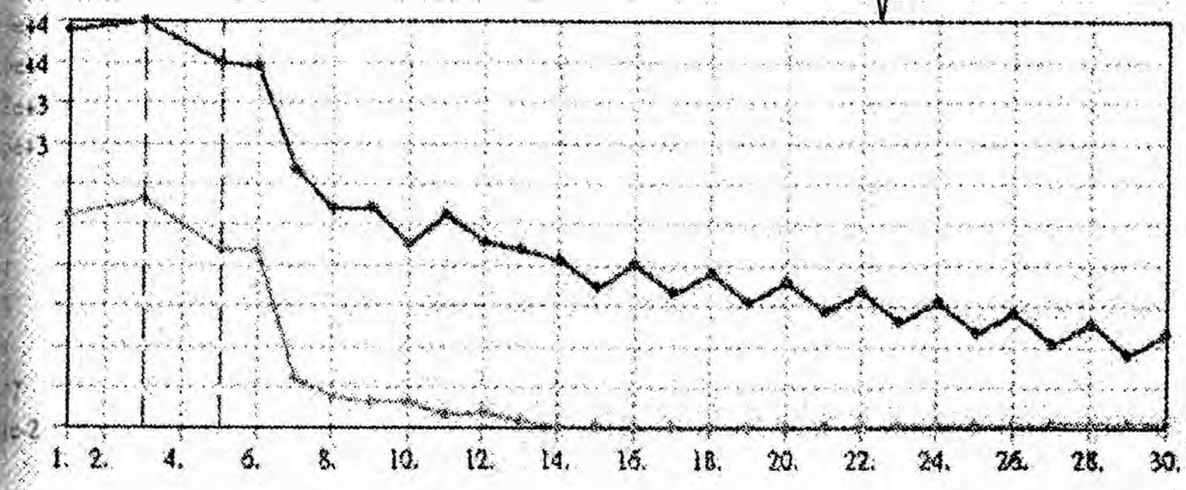
[8] The curve is symmetric. Remember that we didn't take the friction into account.

Details of "Frictional - Prong To Insert"

Scope	
Scoping Method	Geometry Selection
Contact	4 Edges
Target	4 Edges
Contact Bodies	
Target Bodies	
Definition	
Type	Frictional
Friction Coefficient	0.2
Scope Mode	Manual
Behavior	Symmetric
Suppressed	No
Advanced	
Formulation	Pure Penalty
Interface Treatment	Add Offset, No Ramping
Offset	0. mm
Normal Stiffness	Program Controlled
Update Stiffness	Never
Pinball Region	Program Controlled
Time Step Controls	None

[9] Highlight <Frictionless - Prong To Insert>, change the <Type> to <Frictional>, and type 0.2 for <Friction Coefficient>

[10] Solve again. It fails after a few iterations, because of too many bisections.



Details of "Analysis Settings"

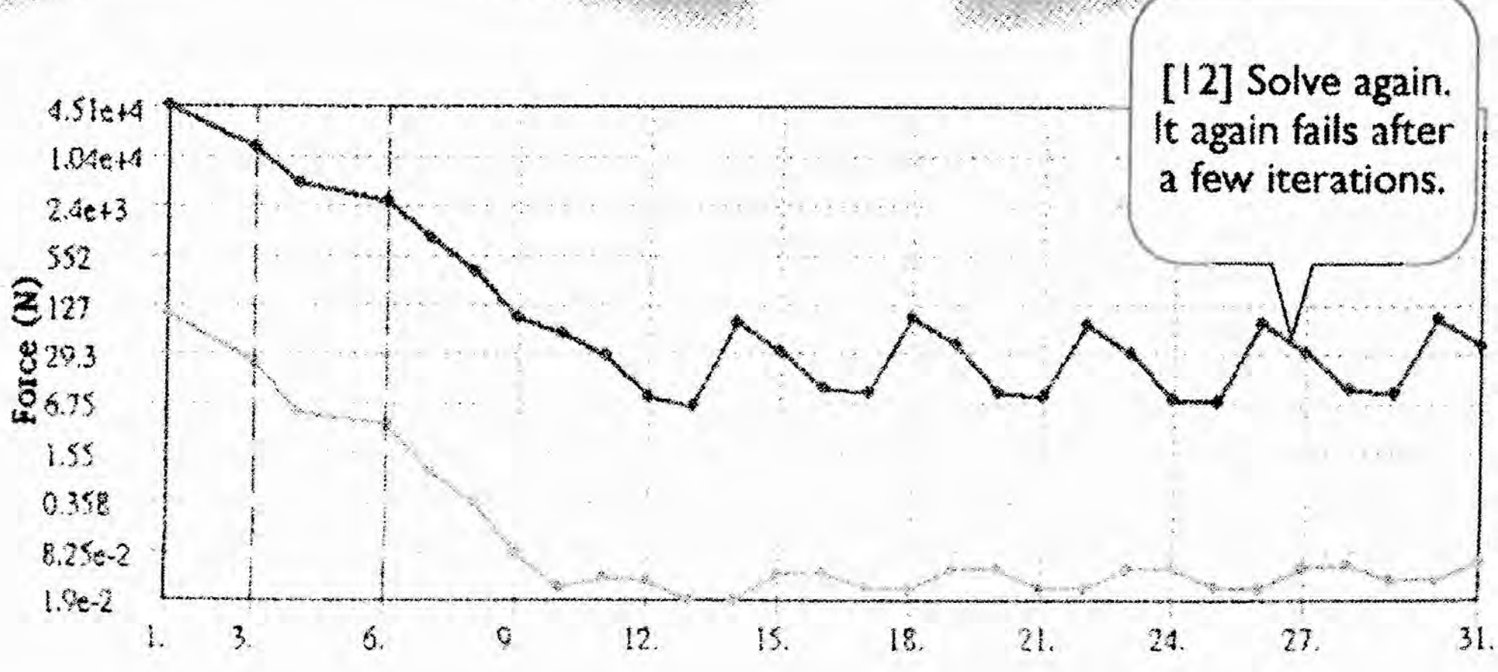
Step Controls	
Number Of Steps	2.
Current Step Number	1.
Step End Time	1. s
Auto Time Stepping	On
Define By	Time
Initial Time Step	2.e-002 s
Minimum Time Step	2.e-003 s
Maximum Time Step	0.1 s
Solver Controls	
Solver Type	Program Controlled
Weak Springs	Program Controlled
Large Deflection	On
Inertia Relief	Off

[11] Reduce the initial time step to 0.02 s.

Details of "Analysis Settings"

Step Controls	
Number Of Steps	2.
Current Step Number	2.
Step End Time	2. s
Auto Time Stepping	On
Define By	Time
Carry Over Time Step	On
Minimum Time Step	2.e-003 s
Maximum Time Step	0.1 s
Solver Controls	
Solver Type	Program Controlled
Weak Springs	Program Controlled
Large Deflection	On
Inertia Relief	Off

[12] Solve again. It again fails after a few iterations.

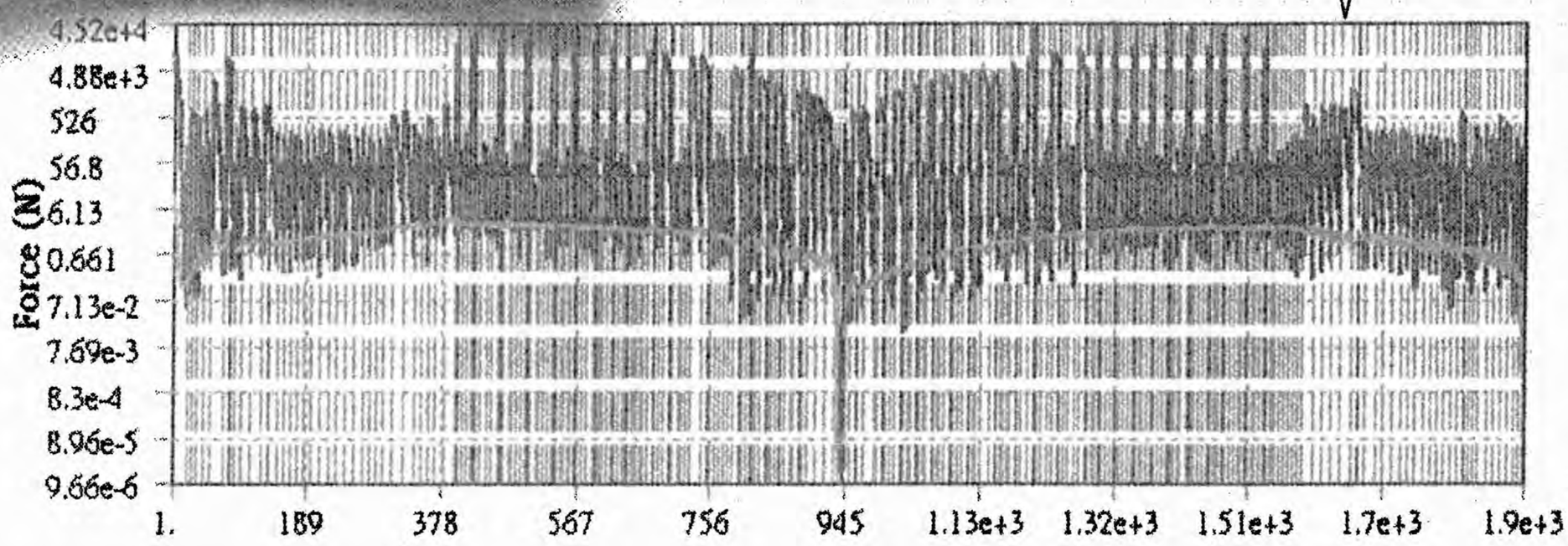


Details of "Frictional - Prong To Insert"

Scope	
Scoping Method	Geometry Selection
Contact	4 Edges
Target	4 Edges
Contact Bodies	
Target Bodies	
Definition	
Type	Frictional
Friction Coefficient	0.2
Scope Mode	Manual
Behavior	Symmetric
Suppressed	No
Advanced	
Formulation	Pure Penalty
Interface Treatment	Add Offset, No Ramping
Offset	0. mm
Normal Stiffness	Program Controlled
Update Stiffness	Each Equilibrium Iteration
Pinball Region	Program Controlled
Time Step Controls	None

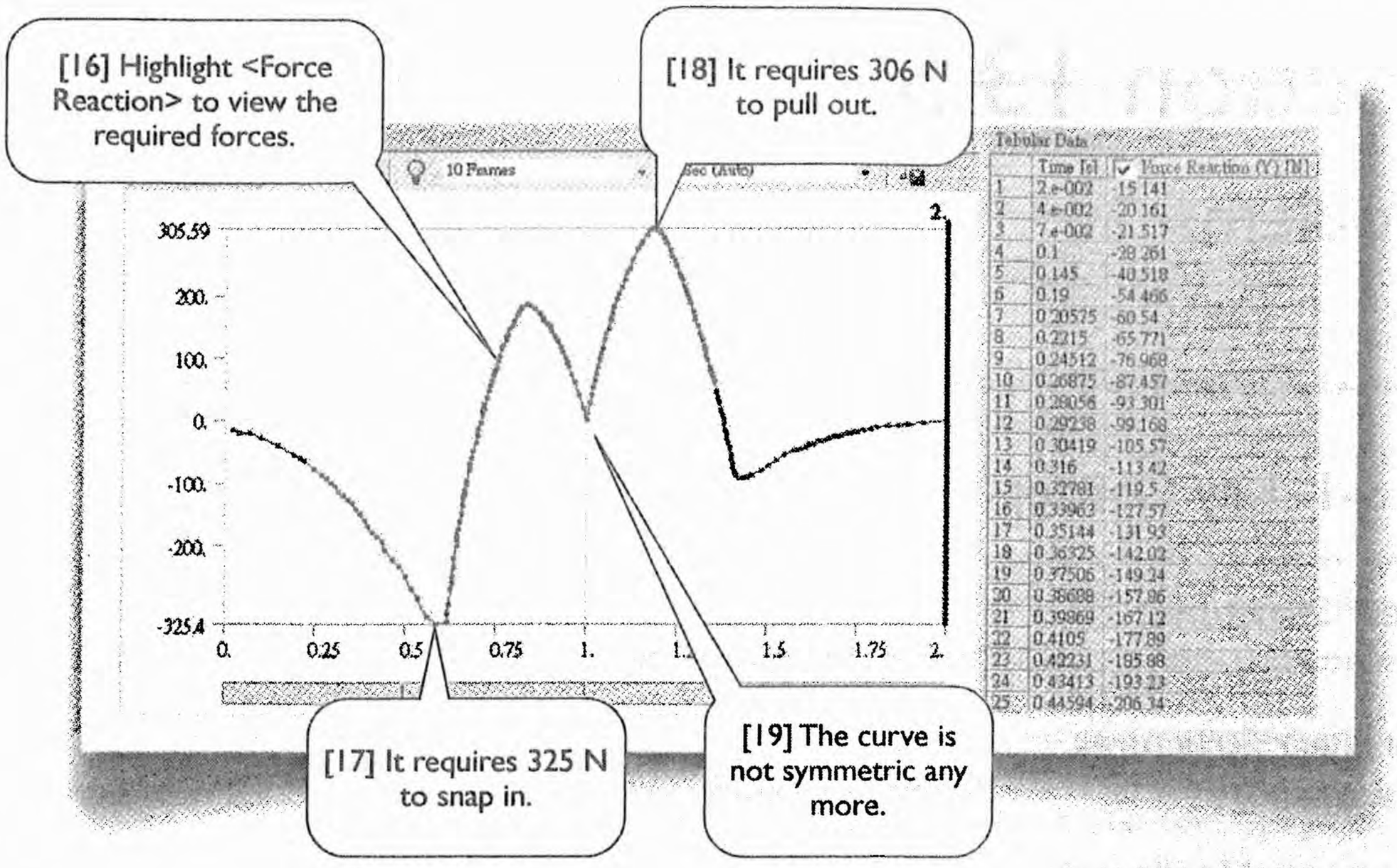
[13] Highlight <Frictional - Prong To Insert>, select <Each Equilibrium Iteration> for <Update Stiffness>. This usually helps convergence.

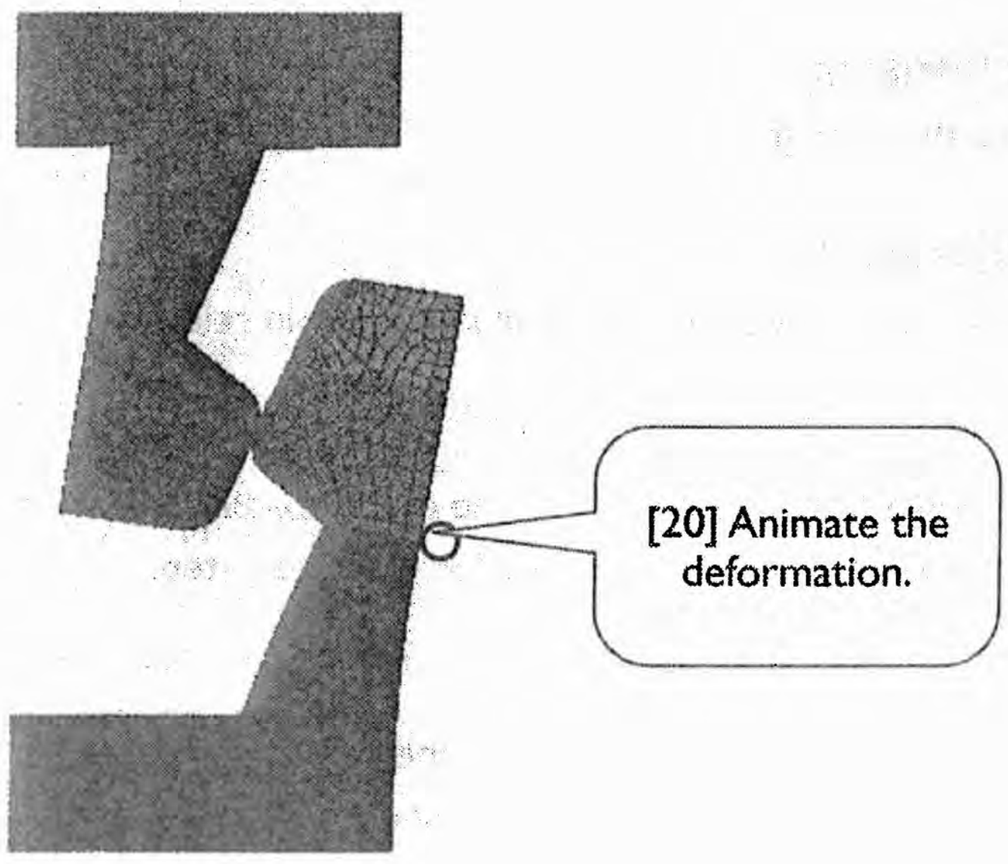
[14] Solve again. It takes a while (about 25 minutes in my computer) to complete the solution.




```
 FORCE CONVERGENCE VALUE  =  327.2      CRITERION= 0.2962
EQUIL ITER   1 COMPLETED.  NEW TRIANG MATRIX.  MAX DOF INC= -0.1956
 LINE SEARCH PARAMETER =  0.5779     SCALED MAX DOF INC = -0.1131
 FORCE CONVERGENCE VALUE  =  179.4      CRITERION= 0.2133
EQUIL ITER   2 COMPLETED.  NEW TRIANG MATRIX.  MAX DOF INC=  0.1267E-01
 LINE SEARCH PARAMETER =   1.000     SCALED MAX DOF INC =  0.1267E-01
 FORCE CONVERGENCE VALUE  =  34.92      CRITERION= 0.2253
EQUIL ITER   3 COMPLETED.  NEW TRIANG MATRIX.  MAX DOF INC=  0.1004
 LINE SEARCH PARAMETER =  0.6958     SCALED MAX DOF INC =  0.6985E-01
 FORCE CONVERGENCE VALUE  =  30.58      CRITERION= 0.2916
EQUIL ITER   4 COMPLETED.  NEW TRIANG MATRIX.  MAX DOF INC=  0.1047E-01
 LINE SEARCH PARAMETER =   1.000     SCALED MAX DOF INC =  0.1047E-01
 FORCE CONVERGENCE VALUE  =  5.867      CRITERION= 0.3076
EQUIL ITER   5 COMPLETED.  NEW TRIANG MATRIX.  MAX DOF INC=  0.1734E-01
 LINE SEARCH PARAMETER =  0.8577     SCALED MAX DOF INC =  0.1487E-01
 FORCE CONVERGENCE VALUE  =  2.724      CRITERION= 0.3313
EQUIL ITER   6 COMPLETED.  NEW TRIANG MATRIX.  MAX DOF INC=  0.3472E-0
 LINE SEARCH PARAMETER =   1.000     SCALED MAX DOF INC =  0.3472E-03
 FORCE CONVERGENCE VALUE  = 0.2257      CRITERION= 0.3382     <<< CONV
>>> SOLUTION CONVERGED AFTER EQUILIBRIUM ITERATION   6
*** LOAD STEP     2   SUBSTEP   114  COMPLETED.    CUM ITER =   1889
*** TIME =   1.89395          TIME INC =  0.288325E-01
*** AUTO TIME STEP:  NEXT TIME INC = 0.43249E-01  INCREASED (FACTOR = 1.5000)
```

[15] Many of line search take place.





Wrap Up

Save the project and exit Workbench.