Load control versus Displacement control

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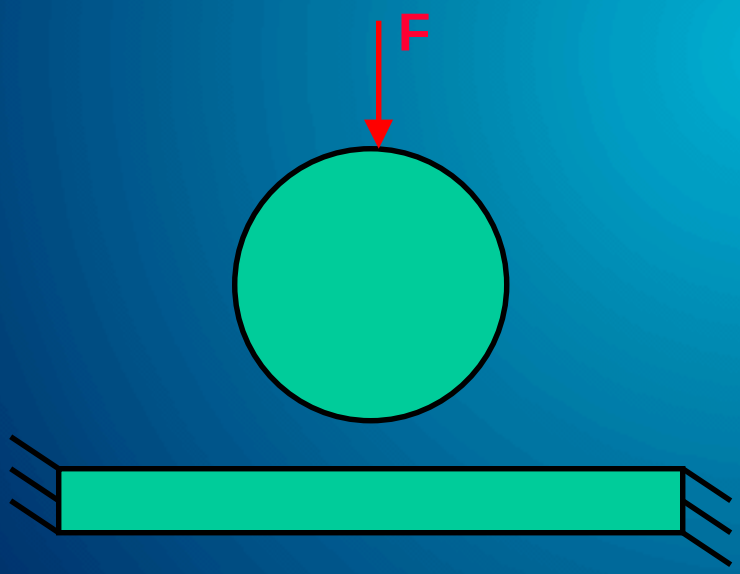
February 2000

Load vs. Displacement Control

- Load Control
  - Forces
  - Pressures
  - Gravity Loads
- Displacement Control
  - Non-zero Displacement Constraints

Load vs. Displacement Control

In a static analysis of two (or more) bodies that are initially unconnected, a rigid body motion can result before contact is established.



In this force controlled example, the cylinder has no applied displacement constraints.

Constraints on the cylinder are established by contact between the cylinder and the plate.

Load vs. Displacement Control

Problem:

If at any point in the solution two bodies are disconnected, the stiffness matrix becomes singular and unsolvable. ANSYS issues a *negative pivot warning message*.

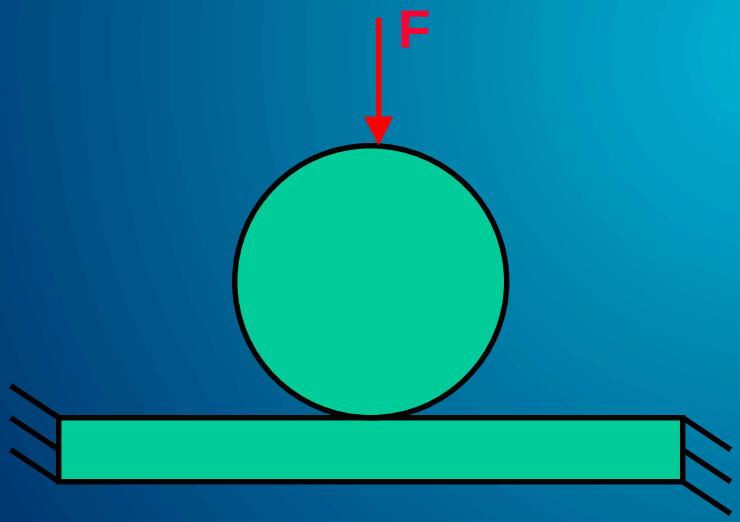
How to overcome Rigid Body Modes?

- **Build the geometry in the "Just-Touching" Position**
- **Dynamics**
- **Weak Springs**
- **Displacement Control**

Load vs. Displacement Control

1) "Just Touching"

Requirement: The "just touching" position has to be known. This can be difficult if the surfaces are curved or irregular.



Small gaps or penetrations can exist between the bodies due to numerical round-off in the finite element meshes, which can cause non-convergence or breaking away of the bodies in contact.

Load vs. Displacement Control

2) Dynamics

In a dynamic analysis, inertial effects prevent rigid body motion. The addition of *mass* and *damping* converts the solution from a static to a dynamic solution.

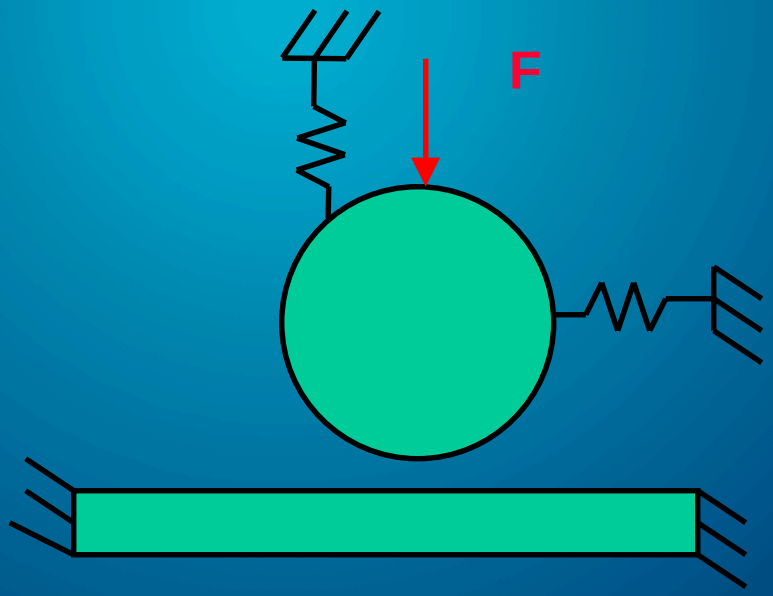
Remark:

It is not always easy to damp out unwanted dynamic effects in a "static" model.

Load vs. Displacement Control

3) Weak Springs

Weak springs are used to ground one body in order to prevent the rigid body motion. The spring stiffness should be negligible compared to the stiffness of the system.



Load vs. Displacement Control

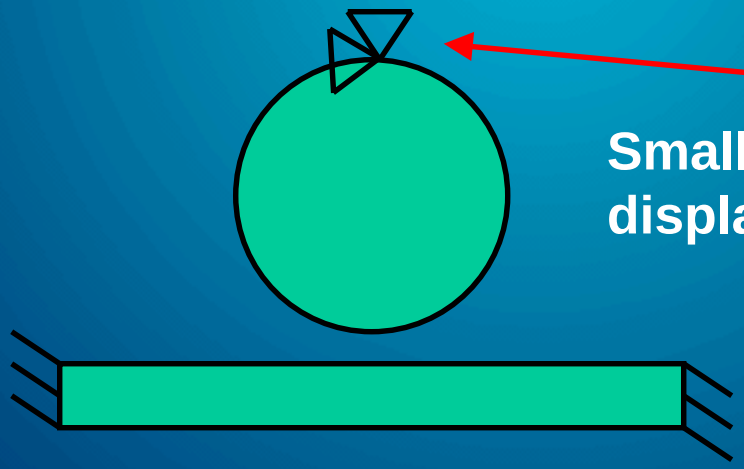
3) Weak Springs

- **The initial load has to cause a deflection on the springs such that contact between the 2 bodies is established. This requires some experimentation as to not "pass through" the contact surfaces.**
- **The reactions at the grounded nodes have to be compared to the total reaction forces to ensure that the springs have no effect on the solution.**

Load vs. Displacement Control

4) Displacement Control

An imposed displacement is applied in order to move the two bodies into contact (*displacement control).* The solution can then be switched back to *force control* through the use of a null load step.



Small imposed non-zero displacement.

Load vs. Displacement Control

4) Displacement Control

Load Step 1

Apply an initial non-zero displacement to initialize contact

Load Step 2

Switch from Displacement Control to Force Control: delete the non-zero displacements, apply the reaction forces (LDREAD) and solve in one substep.

Load Step 3

Continue with the load history.

Load vs. Displacement Control

4) Displacement Control

For the new contact elements (169 to 174), ANSYS provides a feature to have contact established *automatically* through the setting of parameters ICONT or PMIN/PMAX in the real constant set of the contact pair.

Load vs. Displacement Control

4) Displacement Control

ICONT

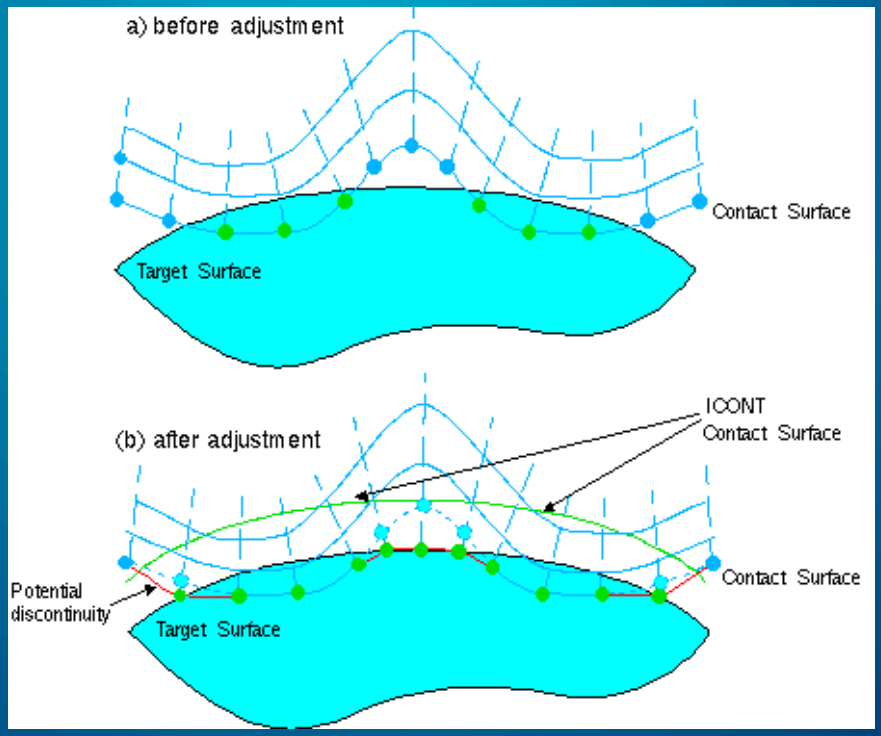
ICONT specifies an "adjustment band" around the target surface. The nodes on the contact surface within the adjustment band are moved to the target surface to establish contact.

If ICONT is not specified, ANSYS provides a default value of 0.01 (relative number).

Load vs. Displacement Control

ICONT

Contact surface adjustment, shown before and after adjustment:



Load vs. Displacement Control

4) Displacement Control

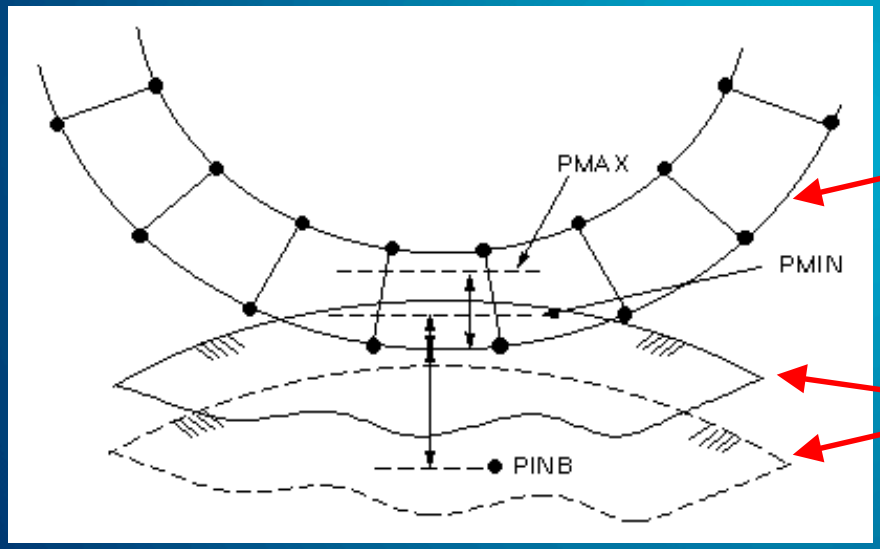
PMIN, PMAX

To establish contact between 2 originally unconnected bodies, ANSYS moves the deformable target surface (and attached body) into the contact body within the range of penetration of [PMIN,PMAX].

If neither PMAX nor PMIN are explicitly specified, then ANSYS does not adjust the initial contact. If a value for either PMIN or PMAX (but not both) is specified, then ANSYS assigns a value to the other real constant, such that PMAX = 2*PMIN.

Load vs. Displacement Control

PMIN, PMAX



Contact Surface

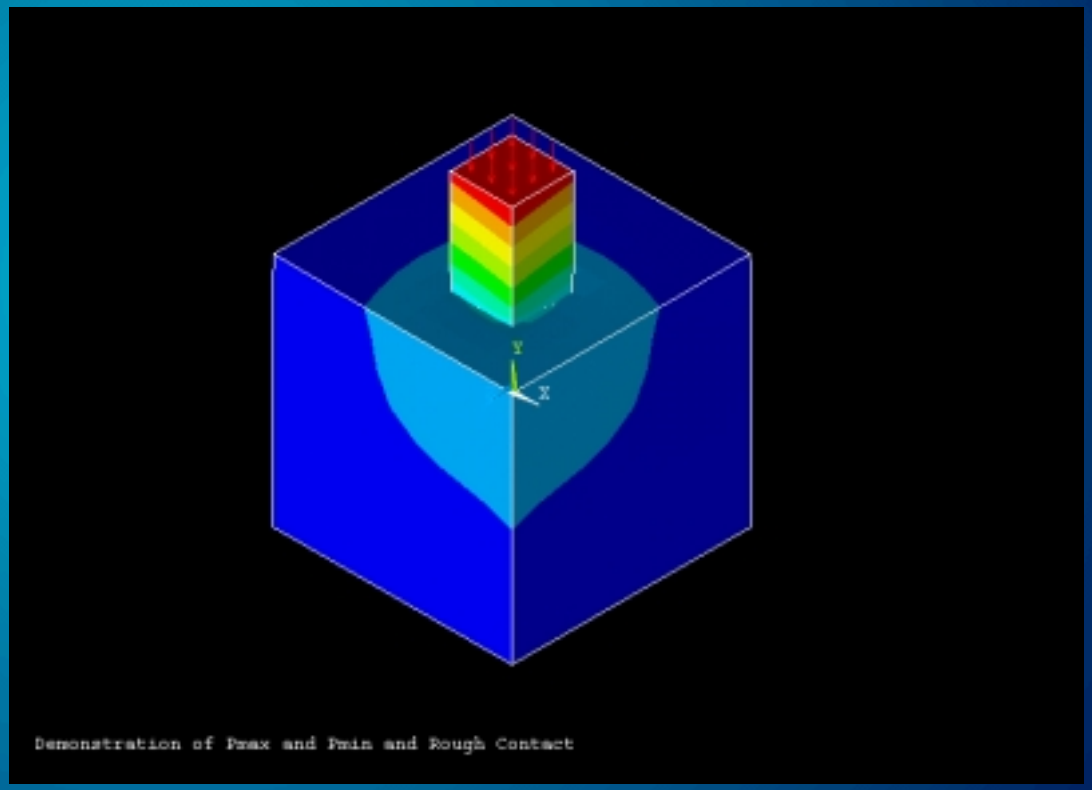
Target Surface before and after adjustment

Load vs. Displacement Control

```
/TITLE, Pmax, Pmin and Rough Contact
!ANSYS 5.6

FINI
/CLEAR
/PREP7
/VIEW, 1 ,1,1,1
/ANG, 1
/REP,FAST
BLOCK,0,1,0,1,0,1,
KWPAVE,3,8
BLOCK,0,.25,0,.5,0,.25,

ET,1,45
ET,2,170
ET,3,174
KEYOPT,3,7,1
KEYOPT,3,12,1
```



Load vs. Displacement Control

```
R,2,0,0,1,0.1,0,0,
RMORE,-0.0002,-0.0001,1e+20,0,1,0,
UIMP,1,EX,,,10e6
UIMP,1,NUXY,,,,.3
UIMP,1,MU,,,,.3

ESIZE,.1,0,
MSHAPE,0,3D
MSHKEY,1
VMESH,all

TYPE,2
REAl,2
ASEL,S,,,9
NSLA,S,1
ESLN,R,0
ESURF,all
ALLSEL,all

TYPE,3
ASEL,S,,,4
NSLA,S,1
ESLN,R,0
ESURF,ALL
ALLSEL
FINISH

/SOLU
DA,3,ALL,
SFA,10,1,PRES,30000
SOLCONTROL,ON,1
TIME,1
AUTOTS,-1
NSUBST,,,,1
KBC,0
OUTRES,BASIC,ALL,
SOLVE
FINISH
```

Load vs. Displacement Control

HOW TO PREVENT 2 CONNECTED BODIES FROM LOOSING CONTACT, ONCE CONTACT IS ESTABLISHED?

This can be done through an appropriate setting of KEYOPT(12) for the elements CONT169,170,171,172:

- *"No separation" contact* : The target and contact surfaces are tied (although sliding is permitted) for the remainder of the analysis once contact is established.

- *"Bonded" contact*: The target and contact surfaces are bonded in all directions (once contact is established) for the remainder of the analysis.