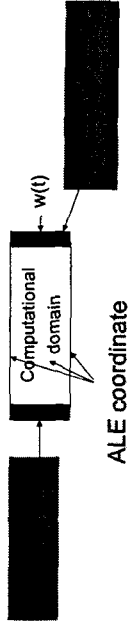


## Introduction to ADINA

- 1986년 MIT 교수인 K.J. Bathe를 주축으로 개발됨
- 구조, 열 전달 및 유체에 대한 유한 해석 프로그램 (FEM/FVM)
- 구조와 유동체 흐름과의 상호 연성 작용에 대한 비선형 해석 지원 (FSI Module)
- Moving Mesh : Arbitrary Lagrangian-Eulerian (ALE) Method



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## ADINA-FSI (Fluid-Structure Interaction)를 이용한 Aortic Valve Analysis

발표자: 심 정연

ableMAX

<http://www.ablemax.co.kr>

## Aortic Valve

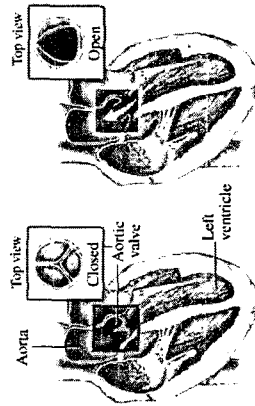
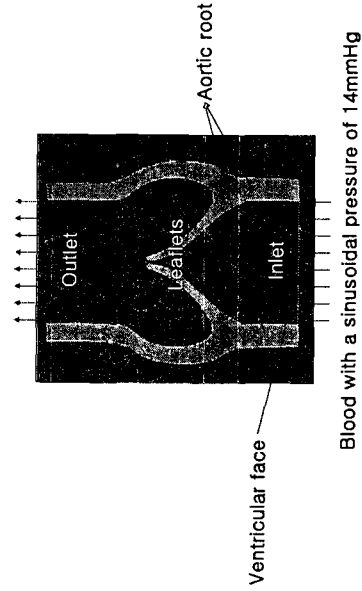


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## Modeling

### Schematic of Aortic Valve



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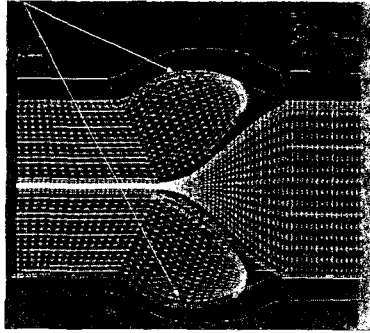
## Modeling

1. Solid: Leaflets & Aortic Root
  - Isotropic Neo-Hookean Large-deformation solids with a constant of 50kPa
  - 2D Plane Strain Mesh
  - Material: Mooney-Rivlin (Rubber)
    - ✓  $\rho = 10^{-6} \text{ g/mm}^3$
    - ✓  $E = 24000 \text{ Pa}$
2. Fluid: Blood
  - Slightly compressible Newtonian fluid
    - ✓  $\mu = 4.6 \text{ centipoise}$
    - ✓  $\rho = 10^{-6} \text{ g/mm}^3$

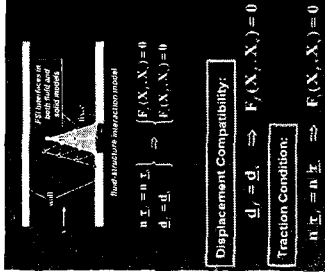
7. Abaqus/CAE

## Modeling

### Fluid Model: Boundary Condition & Mesh



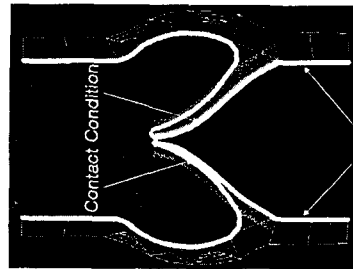
Fluid-structure interface



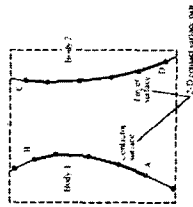
7. Abaqus/CAE

## Modeling

### Solid Model: Contact Condition & Mesh



Fluid-structure interface



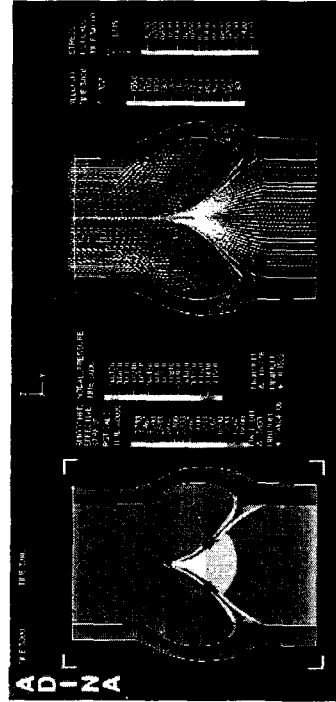
Assumption  
 Frictionless contact ( $\mu = 0$ )  
 Coulumb friction ( $\mu > 0$ )  
 $\mu$  : Coefficient of friction

### Contact Algorithm

- Constraint-function method
  - Use constraint function to enforce all contact conditions
- Segment method
  - Use Lagrange multiplier to enforce the contact conditions
  - Kinematic conditions on contactor nodes
  - Frictional condition on contact segments
- Rigid target method
  - Use when one of the contact bodies is rigid

7. Abaqus/CAE

## Results



7. Abaqus/CAE

## Results

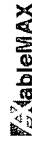
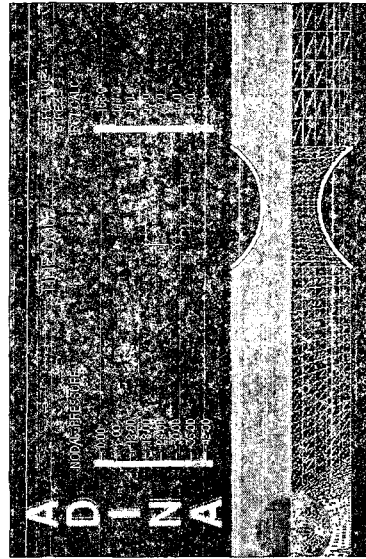
Problem size	3660 nodes 7440 elements
Time to solve	~ 2.6hr 2280 physical time steps
Required RAM	6.5 MB without Sparse Solver 10 MB total (with Sparse Solver)
Result-File size	360 MB (300 time step results)

(Pentium 4 2.4GHz 2GB Ram)



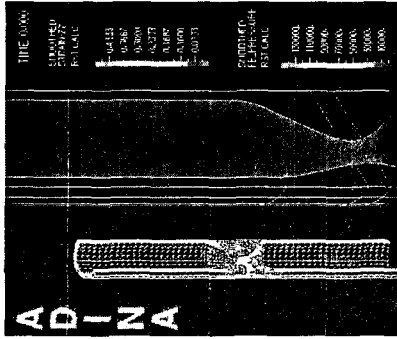
ADINA-FSI를 이용한 BIO 적용사례

## Simulation of Neutrophil (Cell) Passing through a Capillary



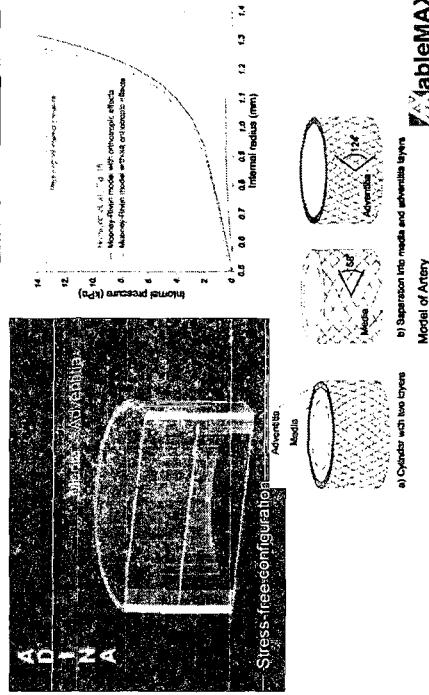
ADINA-FSI를 이용한 BIO 적용사례

## Blood Vessel Simulation



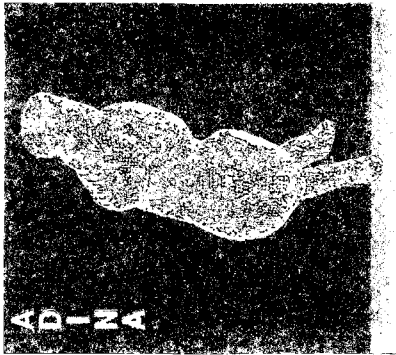
ADINA-FSI를 이용한 BIO 적용사례

## Analysis of an Artery using the ADINA Orthotropic Rubber Model



ADINA-FSI를 이용한 BIO 적용사례

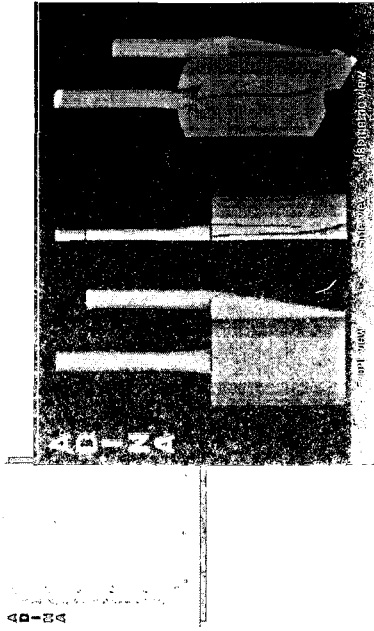
### Simulation of Blood Flow through an Aneurysm



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ADINA-FSI를 이용한 BIO 적용사례

### Artificial Lung Analysis



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