ANSYS

Advanced FSI
using ANSYS CFX

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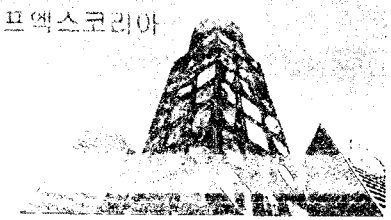

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- Two-Way FSI 해석 절차 사례
  - Fluid-damped Oscillation
  - Flexible Elbow (Blood Vessel)

Direct Coupled

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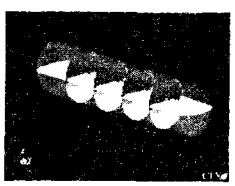
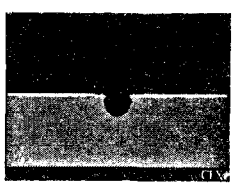
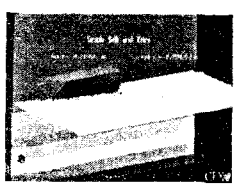


Fuel tank with porous baffles

Ball valve



Sink and Trim



Sink and Trim

Direct: Prescribed 3-D Motion

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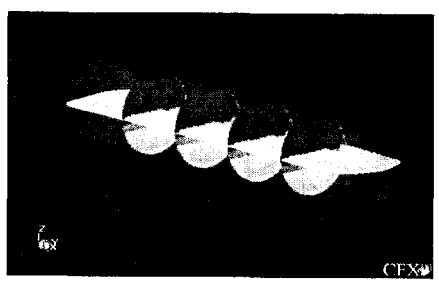
- Prescribed periodic motion about 2 axes
- Porous baffles, implicit fluid motion
- Fluid forces -> solid stresses



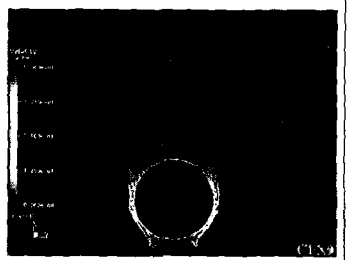
Fuel tank with porous baffles

Direct: Implicit Integration

$$F = m\ddot{x} + kx$$

Solve with CFX, simple integration (explicit):

```
CEL:
  EXPRESSIONS:
    tStep = 5.0e-5 [s]
    tTotal = 7.5e-3 [s]
    kSpring = 300 [N m^-1]
    denBall = 7800 [kg m^-3]
    volBall = pi * (2.0 [mm])^2 * 1e-4 [m]
    mBall = denBall * volBall
    FFlow = force_y()@Ball
    FGrav = mBall * 9.81 [m s^-2]
    velBall = areaAve(Mesh Velocity v)@Ball
    dBall = areaAve(Total Mesh Displacement y)@Ball
    dBallNuser = FFlow - FGrav + mBall*velBall/tStep + M
                 mBall*dBall/tStep^2
    dBallDenom = kSpring+mBall/tStep^2
    dBallNew = dBallNuser/dBallDenom
  END
END
```



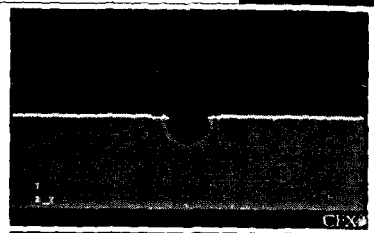
Ball valve

- Assumes body is rigid and does not deform

Direct Coupled: Fluid-Structure Motion

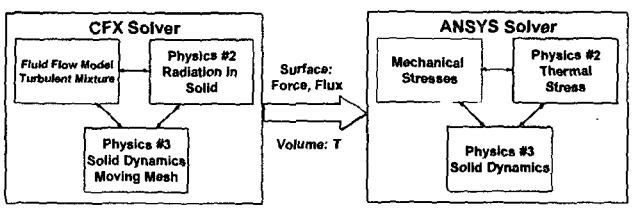
- Air and water fluids
- Inhomogeneous
- Buoy motion implicit result of simulation
- Mesh morphs around moving solid
- Direct coupled fluid-structure interaction within the CFD solver

```
SUBROUTINE: buoyvib
  Location = SUB
  MESH MOTION:
    Displacement X Component = 0 [m]
    Displacement Y Component = dyBuoy
    Displacement Z Component = 0 [m]
    Option = Specified Displacement
  END
END
```

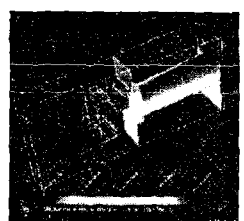


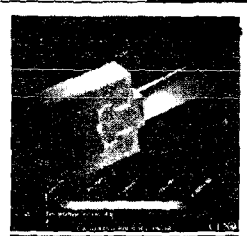
One-Way Coupled

- **Two solvers run sequentially, multiple physics models**
- ***Practical coupling between physics, users, groups***
- CFX and ANSYS write/read files directly



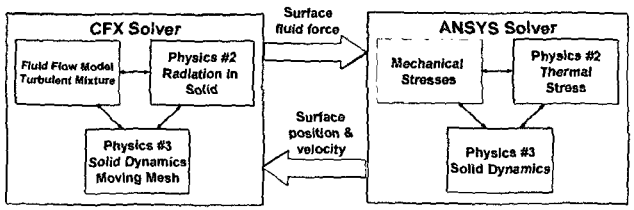
One-Way Coupled





Two-Way Coupled

- **Two solvers run simultaneously, multiple physics models**
- Implicit coupling via **ANSYS-CFX *native*** IPC library
- Integration preserves established solver integrity
- Each solver writes results in solver-native format

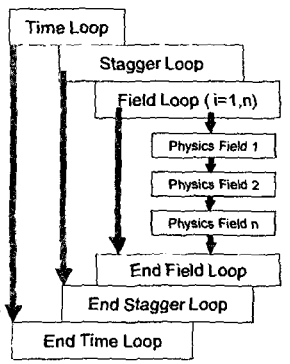


Multi-field Solver Implementation

Time loop:
- For transient analysis, refers to solution *in time*
- For static analysis, refers to each load step

Stagger loop:
- Implicit coupling of various fields *in time loop*
- Number *of* stagger iterations determined by convergence of load transfer or max. stagger iterations

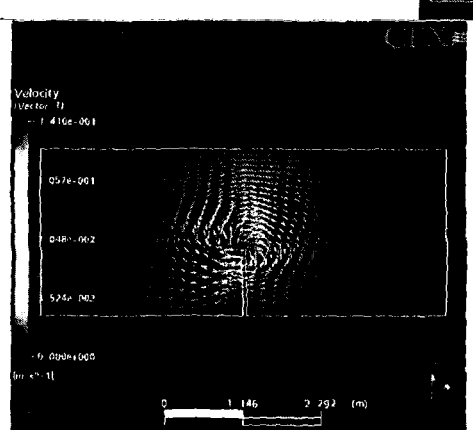
Field loop:
- Field solution with specific solution options
- Load transfer to a particular field occurs before solution *of the field*
- Dissimilar mesh across surface/ volume *interface* between fields

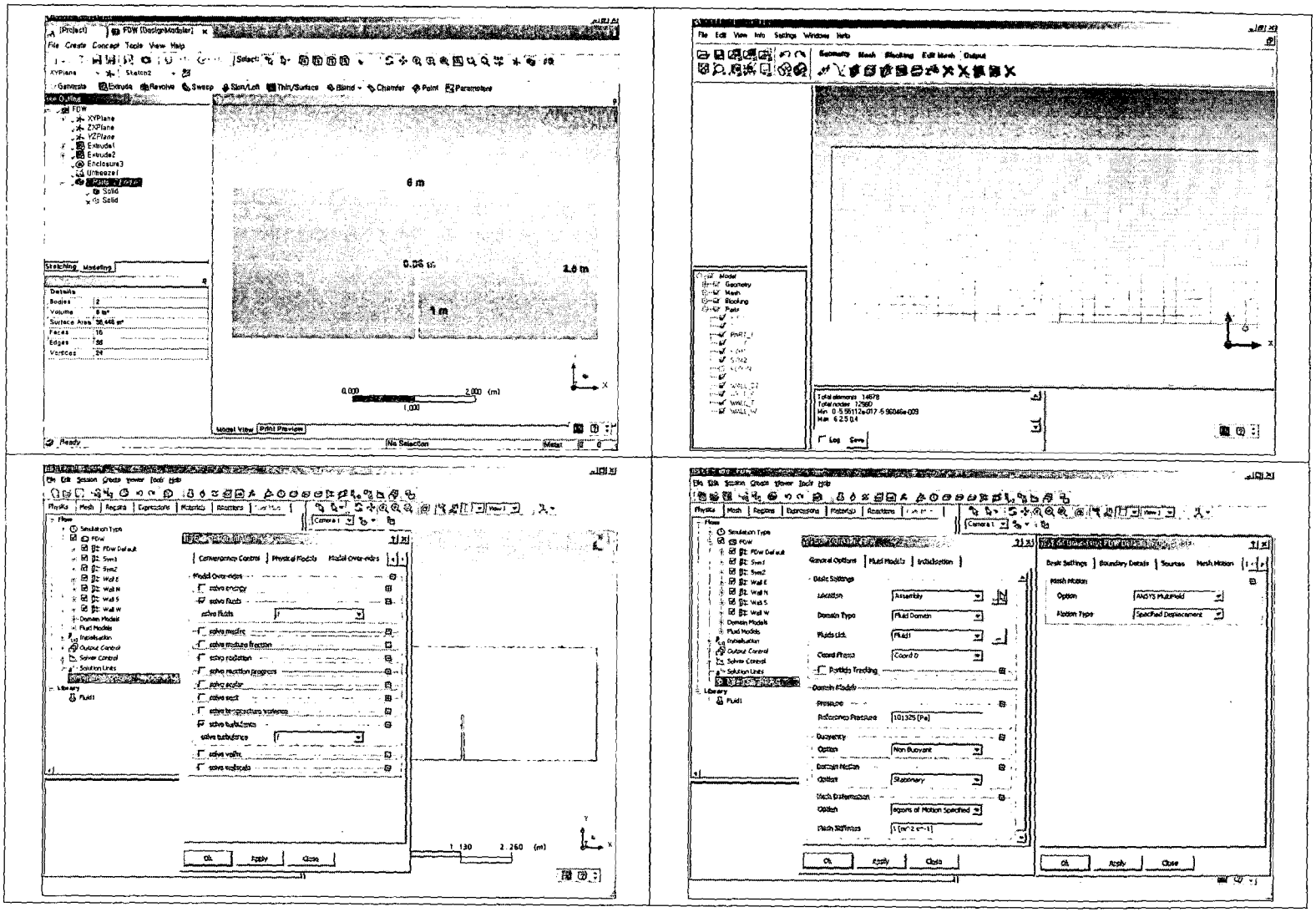


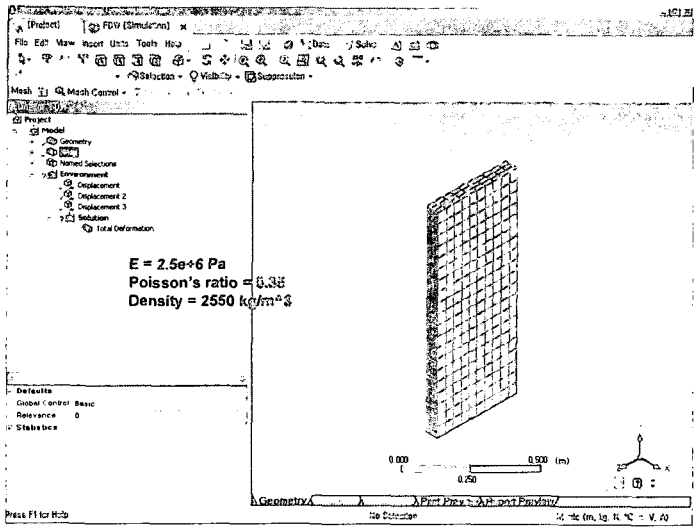
Two-Way FSI Application Example

- Fluid-damped Wall Oscillation
- Flexible Elbow (Blood Vessel)

Fluid-damped Wall Oscillation




6 m
0.05 m
2.0 m
1 m
0.000
2.000 (m)
1.000
1.130
2.260 (m)



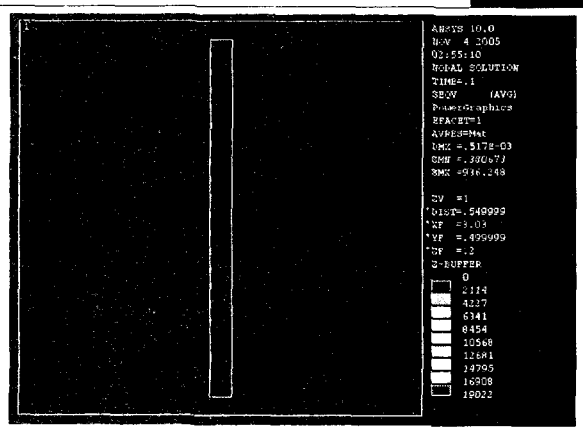
External Load

- MFAN,ON
- MFTI, 0.500000000
- MFDT, 0.100000000 , 0.100000000 , 0.100000000 ,OFF
- MFIT, 10, 1, 5
- MFCO,UX , 1.000000000E-03
- MFCO,UY , 1.000000000E-03
- MFCO,UZ , 1.000000000E-03
- MFCO,FX , 1.000000000E-03
- MFCO,FY , 1.000000000E-03
- MFCO,FZ , 1.000000000E-03
- MFRE,DISP, 0.750000000 ,RELX
- MFRE,FORC, 0.750000000 ,RELX
- MFRS, 0.00000000
- MFPS,group1,ANSYS,
- MFPS,group2,CFX,
- MFSO,group1,group2,
- MFLC, SURF,ANSYS,1,DISP,CFX,(Default),Mesh Displacement,NONC
- MFLC, SURF,CFX,(Default),Total Force Density,ANSYS,1,FORC,NONC

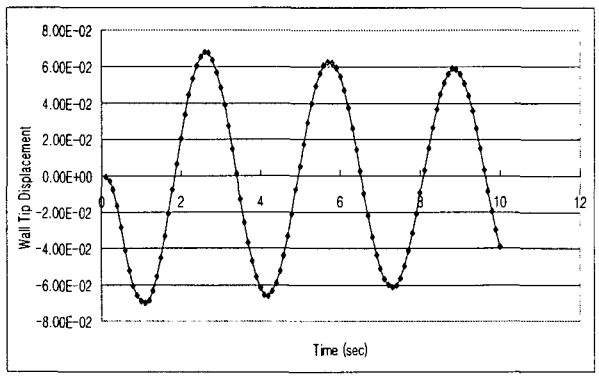
No External Load

- /batch,list
- resume,file,db
- /solu
- mfrs,0.5
- mfti,10
- MFLC, SURF,ANSYS,1,DISP,CFX,(Default),Mesh Displacement,NONC
- MFLC, SURF,CFX,(Default),Total Force Density,ANSYS,1,FORC,NONC
- solve
- save

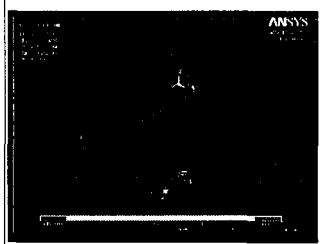
Result 1 (Deformation, Stress)

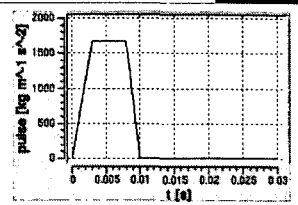


Result 2 (Wall Tip Displacement History)

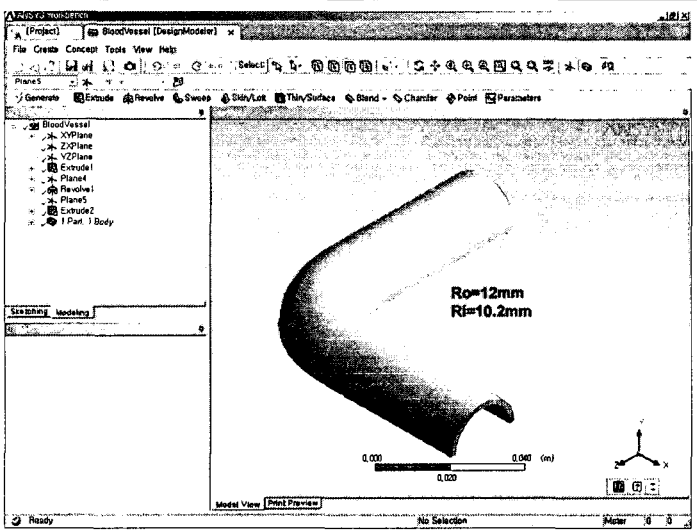


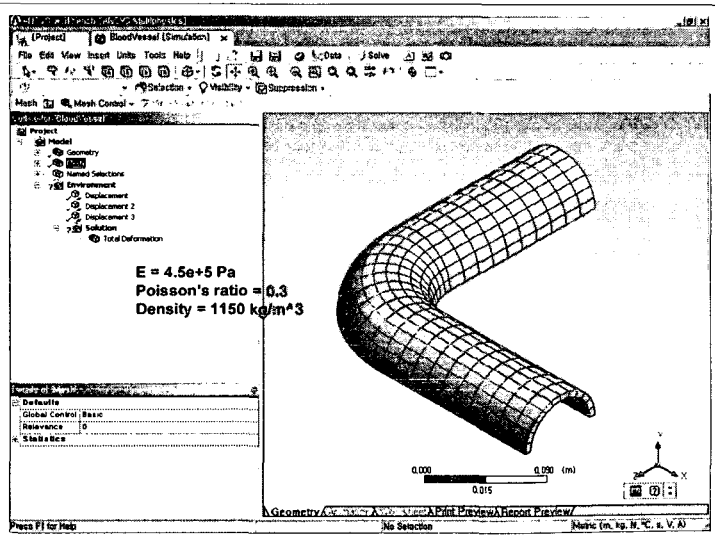
Flexible Elbow (Blood Vessel)

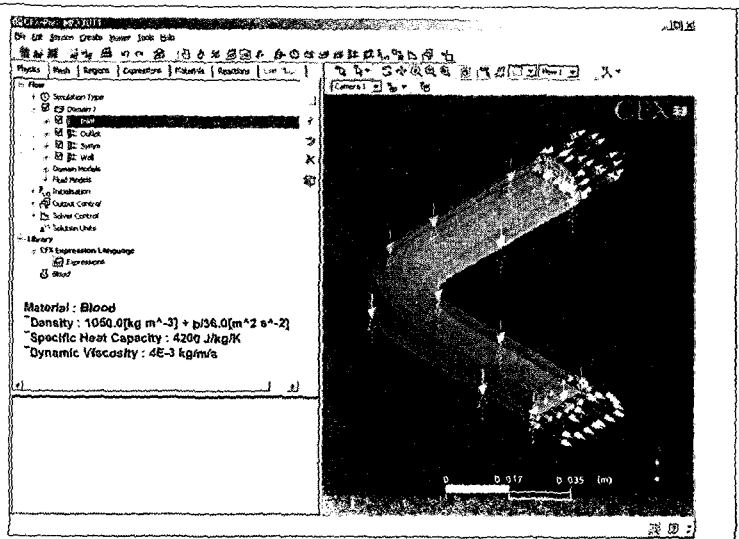


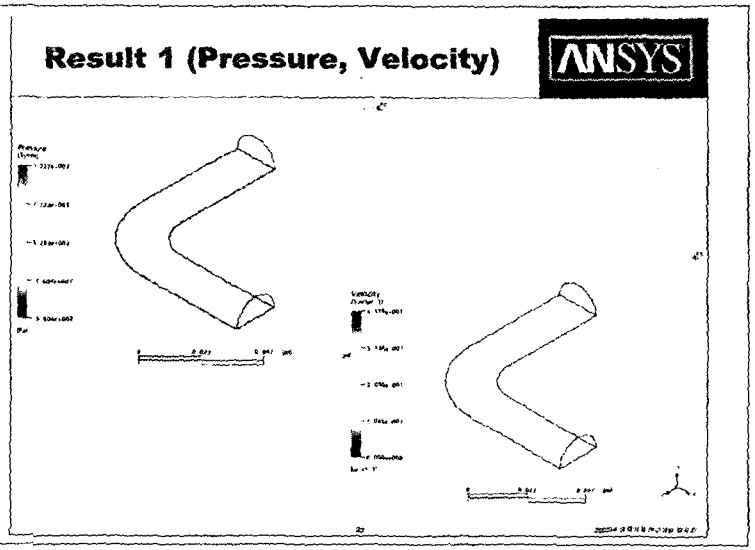


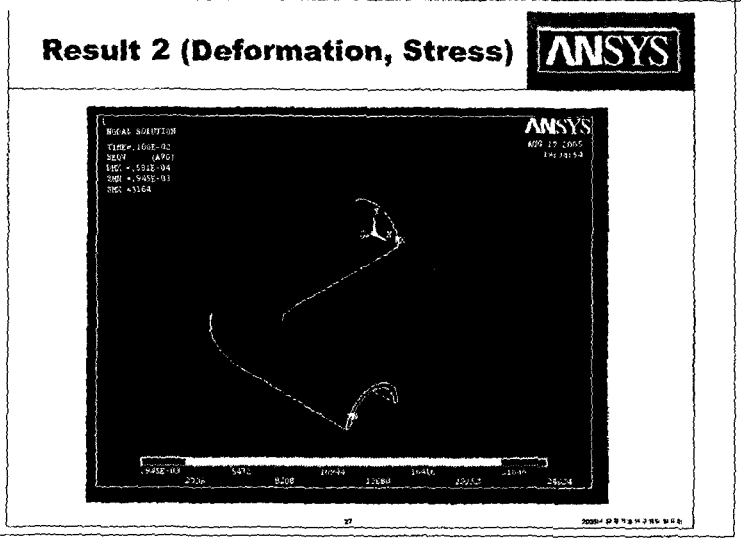

```
LIBRARY:
 CEL:
  EXPRESSIONS:
    Bulk Comp = 36.0 [m^2 s^-2]
    den = 1050.0 [kg m^-3] + (pabs-1.0 [atm])/Bulk Comp
    pmax = 1666.0 [Pa]
    stepup = step((0.003 [s] - t)/1.0 [s])
    steptop = step((t - 0.003 [s])/1.0 [s])*step((0.008 [s] - t)/1.0 [s])
    stepdown = step((0.01 [s]-t)/1.0 [s])*step((t - 0.008 [s])/1.0 [s])
    pulseup = (pmax*t/0.003 [s])*stepup
    pulsetop = pmax * steptop
    pulsedown = (pmax-pmax*(t-0.008[s])/(0.002[s]))*stepdown
    pulse = pulseup + pulsetop + pulsedown
  END
 END
END
```






Material : Blood
Density : 1050.0[kg m^-3] + p/36.0[m^2 s^-2]
Specific Heat Capacity : 4200 J/kg/K
Dynamic Viscosity : 4E-3 kg/m/s


Result 1 (Pressure, Velocity)
ANSYS


Result 2 (Deformation, Stress)
ANSYS