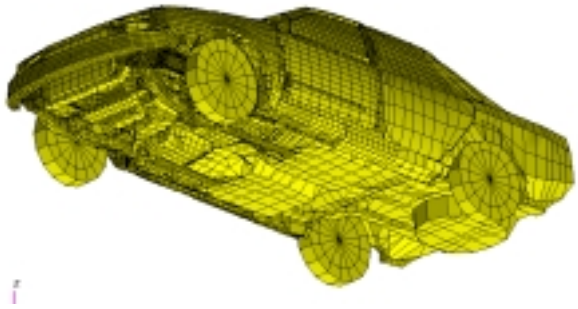
FEM in Automotive Body Structures



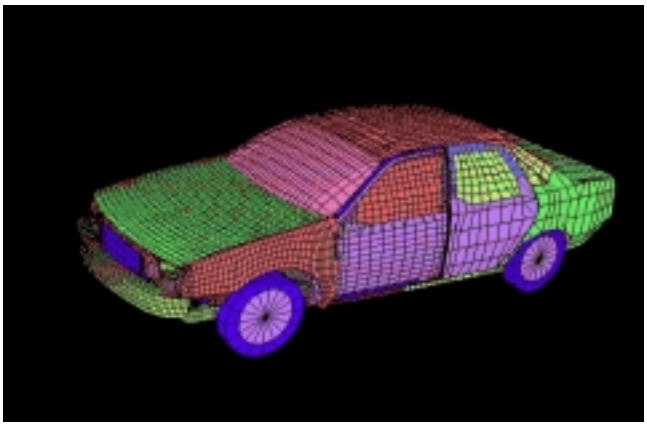
FEM Applications

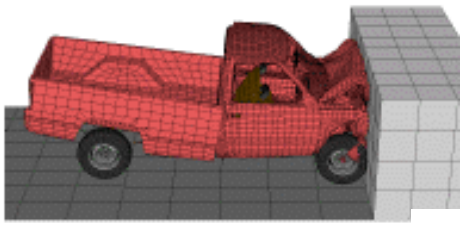
- Around 1982, FEM application becomes popular in Automotive Industry
  - 60s and 70s : Beam/Frame Models (First Order Analysis Type)
  - 80s : MSC/NASTRAN (1983 MacNeal's QUAD4 element , and its Improvement) made shell description of automotive bodies
  - 80s : DYNA made tremendous success in crash simulation
  - 90s : LS/DYNA and PAM/Stamp make quite success in sheet metal forming simulation

Livermore Software

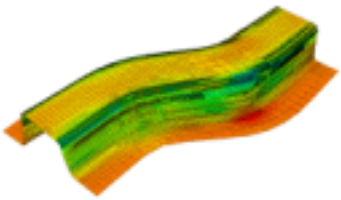
Technology Corporation

http://www.lsdyna.com/

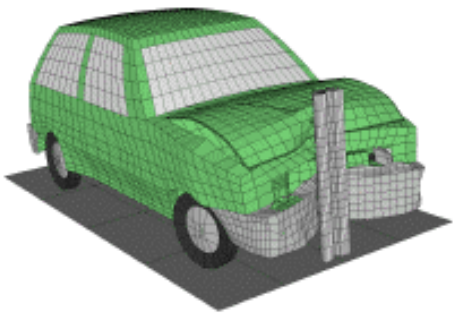




NCAC Chevy C-2500 Model



NUMI Sheet Benchmark



Three Aspects

- Stiffness/Strength
  - MSC/NASTRAN or ABAQUS
  - Strength for Spot Welding Portion
- Noise & Vibration
  - MSC/NASTRAN
  - Acoustics Analysis (BEM)
- Crashworthiness
  - LS/DYNA or PAM/Crash by ESI Group

Analysis Involved

- Static
  - Stiffness and Strength
- Normal Modes Analysis
  - Construct modal mass and stiffness matrices
- Transient Response Analysis
- Frequency Response Analysis
- Impact/Crash Analysis

Finite Elements

- Bar/Beam Elements
- Plate/Shell Elements
  - **QUAD4** is the most popular element
- Solid Elements
  - HEXA and **TETRA**, PENTA
- Spring Element
- Contact Element
- Non-Structural Mass Element

Modeling Issue

still now meshing is a big problem

- CAE Models for three are different !
  - Stiffness : <=20Hz
  - Vibration : 20Hz ~ 60Hz
  - Noise : 200 Hz ~ 300 Hz

Finite Element Mesh Size (Recommended)

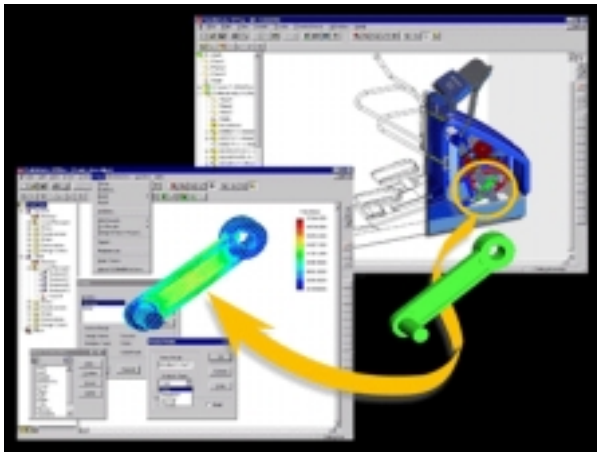
$$\Delta x = \frac{L}{mf} \quad , \quad f = \text{frequecy} \ \ \& \ \ m = 6 \sim 12$$

⇒ F=20Hz, m=8 implies 0.00625m

CAD/CAE Integration

http://www.cosmosm.com/works.htm

http://www.solidworks.com/



PC Window NT Environment

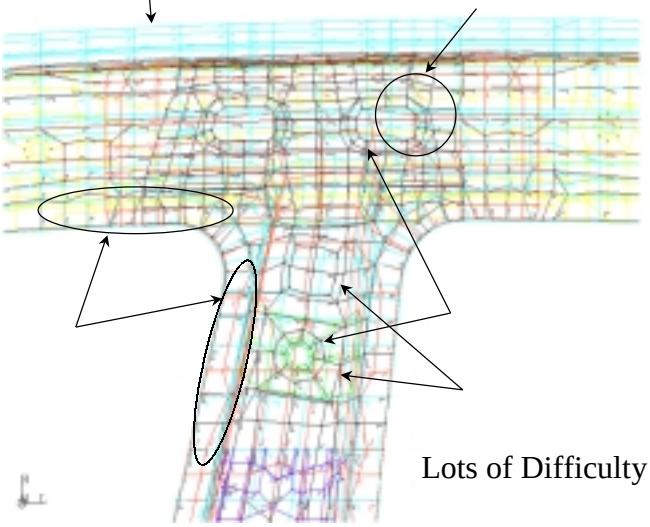
CAD : SolidWorks
CAE : Cosmos

COSMOS/Works

Practical References

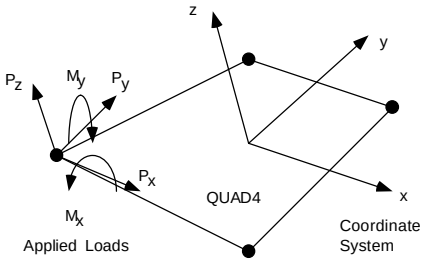
- R.D. Cook, Concepts and Applications of Finite Element Analysis, 2nd Edition, John Wiley & Sons, 1981
- K.H. Huebner, E.A. Thornton, and T.G. Bryrom, The Finite Element Method for Engineers, 3rd Edition, John Wiley & Sons, 1995

Difficulty Involved In FEM Modeling of Automotive Body



Lots of Difficulty in FEA

QUAD4 in Auto-Body



4 Node Quadrilateral Element

5 Degrees of Freedom

$$\begin{Bmatrix} u \\ v \\ w \\ \theta_x \\ \theta_y \end{Bmatrix}$$

$u = inplane\ displacement$

$v = inplane\ displacement$

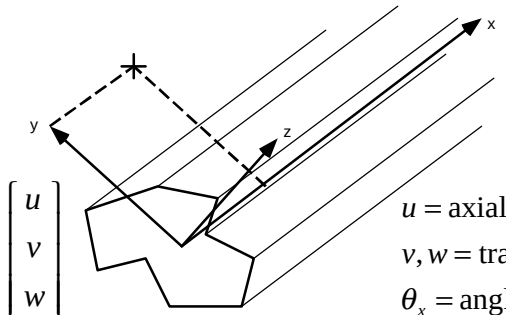
$w = transverse\ displacement$

$\theta_x = rotation\ about\ x\ axis$

$\theta_y = rotation\ about\ y axis$

BEAM(BAR) Element

See Note in Web



6 Degrees of Freedom

$$\begin{Bmatrix} u \\ v \\ w \\ \theta_x \\ \theta_y \\ \theta_z \end{Bmatrix}$$

u = axial displacement(axial)

v, w = transverse deflections(bending)

θ_x = angle of twist

θ_y, θ_z = slopes of transverse deflections

Section Properties can be computed by **AISI/CARS98**

Element Stiffness Matrix of BEAM Ekement

$$\boldsymbol{k} = \begin{bmatrix}
\frac{EA}{L} & & & & & & & & & & & \\
0 & \frac{12}{1+\Phi_y}\frac{EI_z}{L^3} & & & & & & & & & & \text{symmetric} \\
0 & 0 & \frac{12}{1+\Phi_z}\frac{EI_y}{L^3} & & & & & & & & & \\
0 & 0 & 0 & \frac{GJ}{L} & & & & & & & & \\
0 & 0 & -\frac{6}{1+\Phi_z}\frac{EI_y}{L^2} & 0 & \frac{4+\Phi_z}{1+\Phi_z}\frac{EI_y}{L} & & & & & & & \\
0 & \frac{6}{1+\Phi_y}\frac{EI_z}{L^2} & 0 & 0 & 0 & \frac{4+\Phi_y}{1+\Phi_y}\frac{EI_z}{L} & & & & & & \\
-\frac{EA}{L} & 0 & 0 & 0 & 0 & 0 & \frac{EA}{L} & & & & & \\
0 & -\frac{12}{1+\Phi_y}\frac{EI_z}{L^3} & 0 & 0 & 0 & -\frac{6}{1+\Phi_y}\frac{EI_z}{L^2} & 0 & \frac{12}{1+\Phi_y}\frac{EI_z}{L^3} & & & & \\
0 & 0 & -\frac{12}{1+\Phi_z}\frac{EI_y}{L^3} & 0 & \frac{6}{1+\Phi_z}\frac{EI_y}{L^2} & 0 & 0 & 0 & \frac{12}{1+\Phi_z}\frac{EI_y}{L^3} & & & \\
0 & 0 & 0 & -\frac{GJ}{L} & 0 & 0 & 0 & 0 & 0 & \frac{GJ}{L} & & \\
0 & 0 & -\frac{6}{1+\Phi_z}\frac{EI_y}{L^2} & 0 & \frac{2-\Phi_z}{1+\Phi_z}\frac{EI_y}{L} & 0 & 0 & 0 & \frac{6}{1+\Phi_z}\frac{EI_y}{L^3} & 0 & \frac{4+\Phi_z}{1+\Phi_z}\frac{EI_y}{L} & \\
0 & \frac{6}{1+\Phi_y}\frac{EI_z}{L^2} & 0 & 0 & 0 & \frac{2-\Phi_y}{1+\Phi_y}\frac{EI_z}{L} & 0 & -\frac{6}{1+\Phi_y}\frac{EI_z}{L^3} & 0 & 0 & 0 & \frac{4+\Phi_y}{1+\Phi_y}\frac{EI_z}{L}
\end{bmatrix}$$