Boundary Element Analysis at Caterpillar

Ling Pan
Caterpillar Inc.

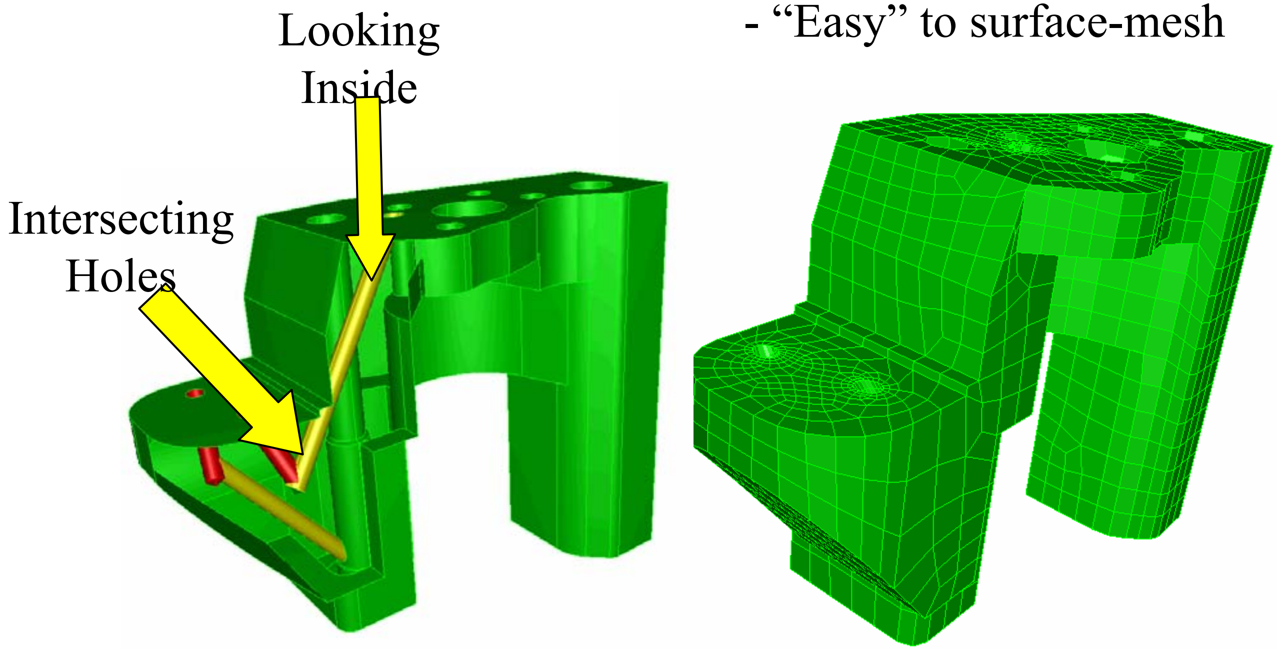
EZBEA

- ***Easy* Boundary Element Analysis**
- Originated from ‘70’s code at Kentucky State
  - Owned & enhanced significantly by Caterpillar
- Model external boundary only
  - Meshing is much easier, especially with details & small holes
  - Accurate with coarse triangles, quads

Strength

- Excels on Geometry with Complicated Details

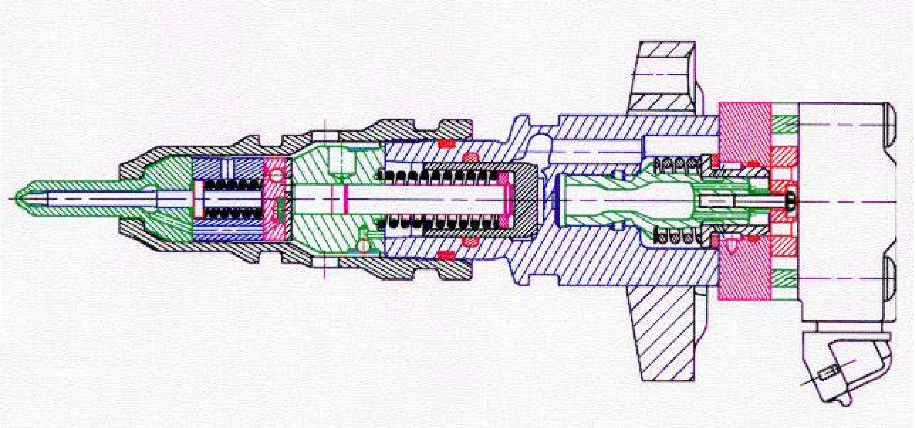
  - Still difficult to tet-mesh
  - "Easy" to surface-mesh

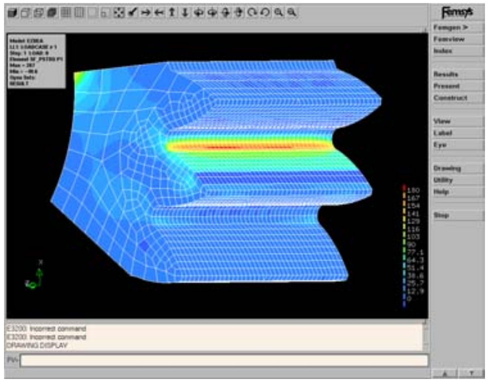


Brake Stand for C9 Engine

Applications

- Engine components
  - Fuel injector
  - Crankshaft





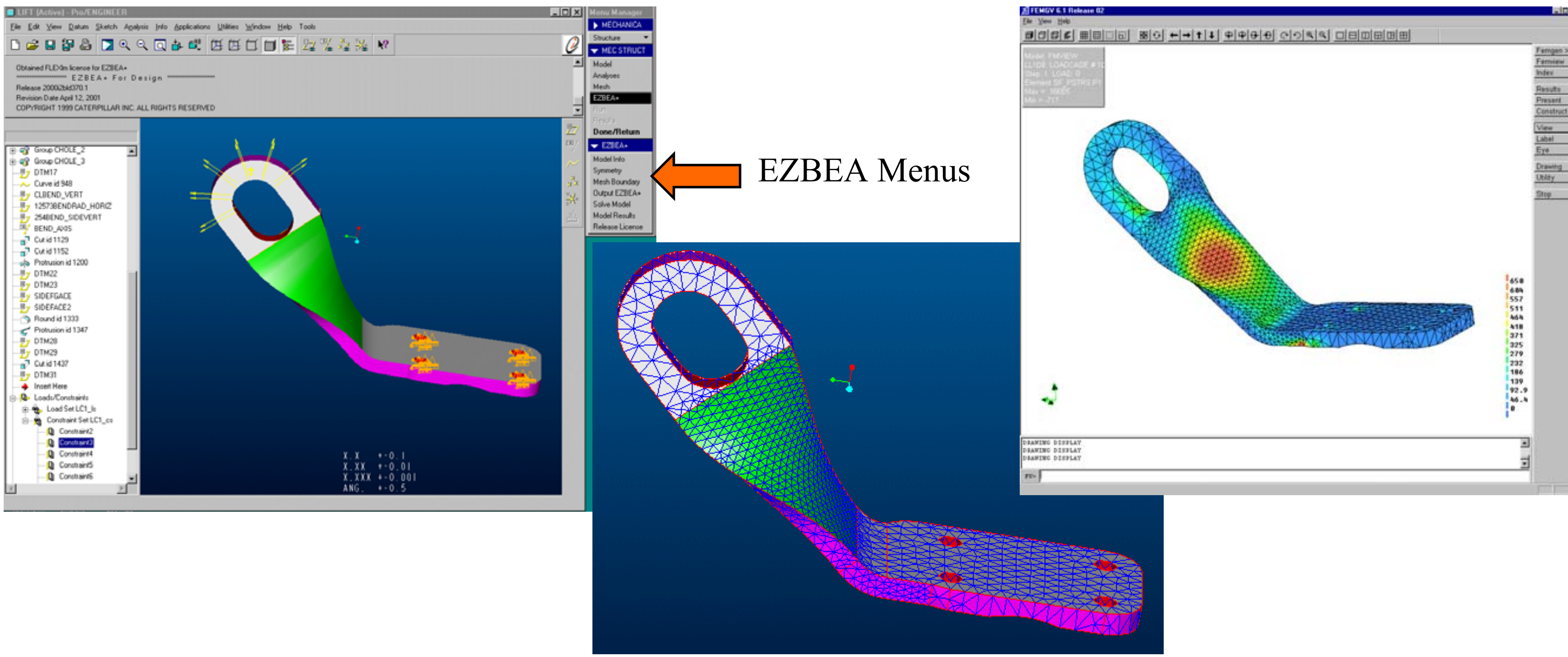
- Powertrain components
  - Gear
  - Shaft

Challenges

- Longer solve time compared to FEA analysis
- Nonlinear (contact) analysis
- Not suitable with thin body (fabricated) structures

EZBEA+

- EZBEA+ - provides integration with Pro/Mesh



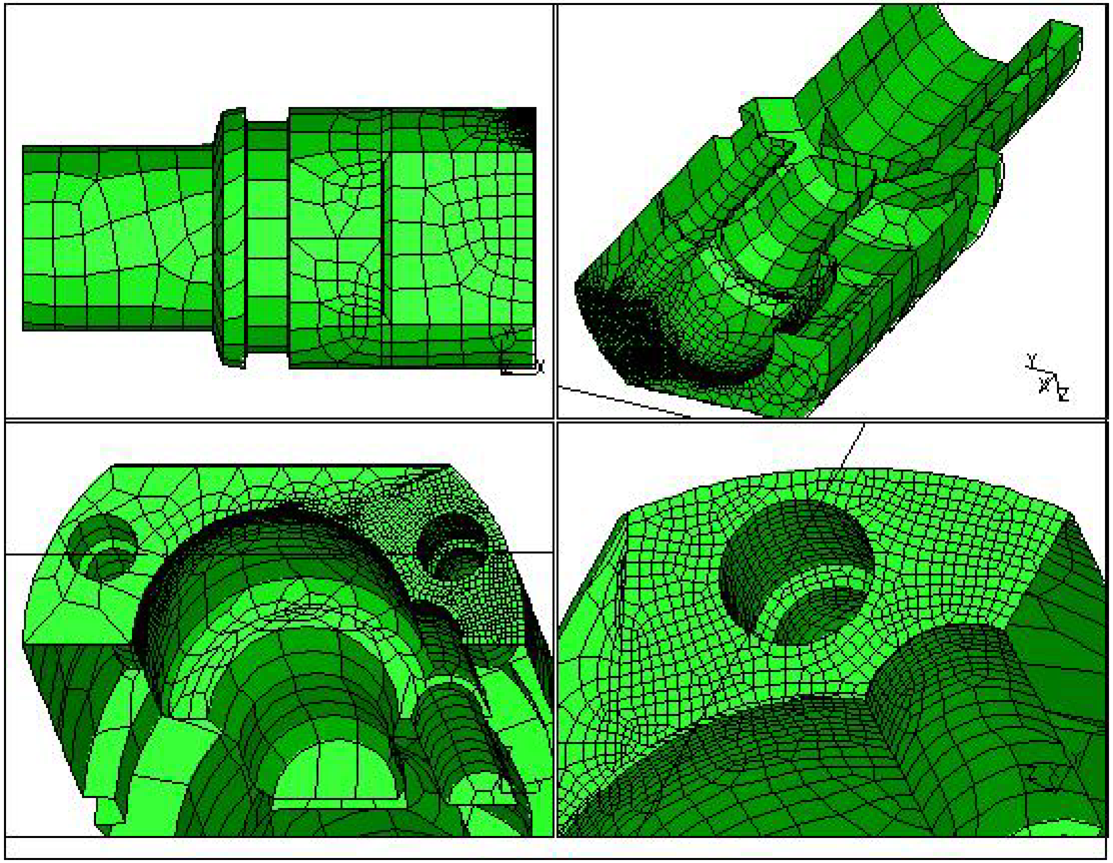
EZBEA Capabilities

- Analysis types
  - steady-state heat conduction
  - static thermoelasticity
  - beam section properties
- Domain types
  - planar
  - axisymmetric
  - general 3D
- Material
  - Isotropic, linear, 1 per subregion
- Symmetry:
  - planes of geometric symmetry
  - planes of loading symmetry/anti-symmetry

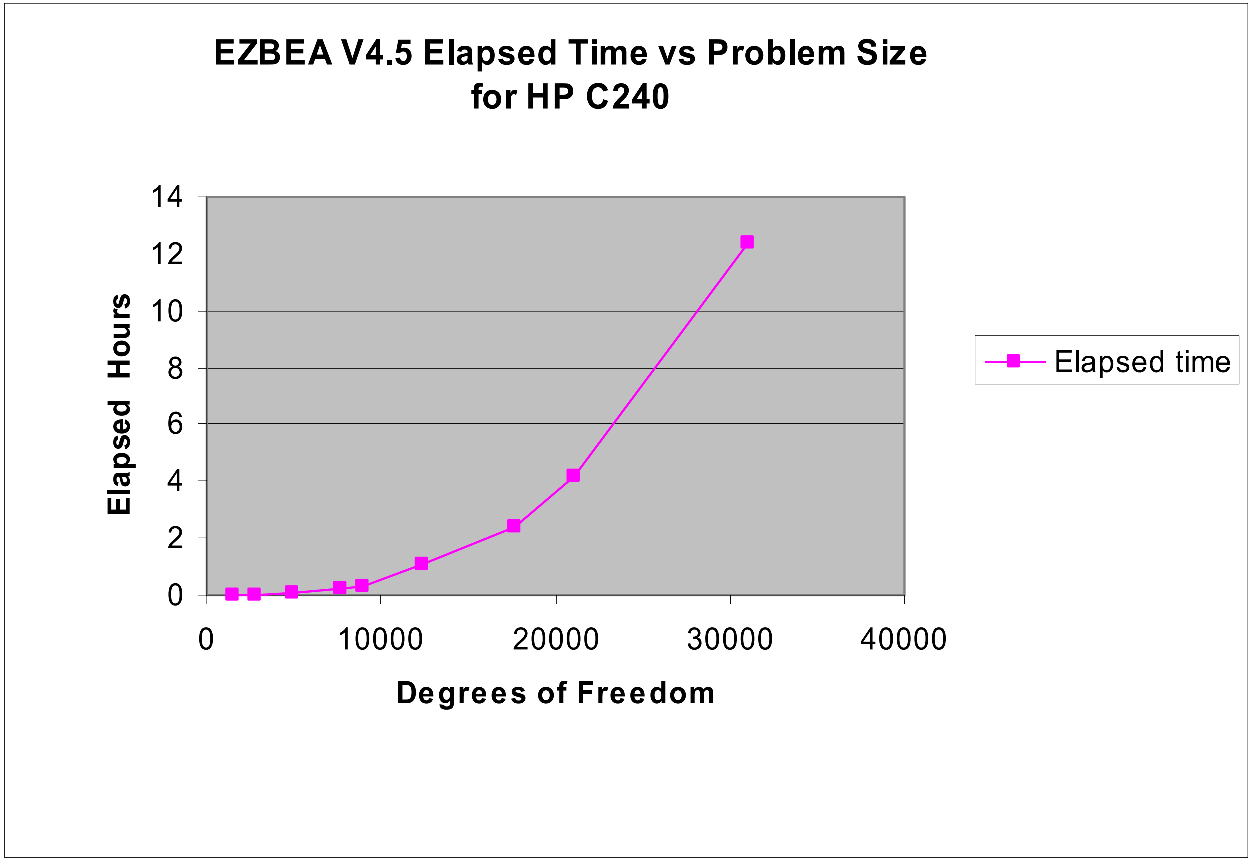
EZBEA Capabilities

- Loading and Boundary Conditions
  - Only linear, static loads and boundary conditions
    - point load constraints
    - edge pressure constraints
    - surface pressure constraints
    - surface displacement constraints
  - Loads and boundary conditions in nature have area associated with them.
    - A true point load is impossible
    - A knife edge constraint is impossible
    - These loads would result in infinite stress

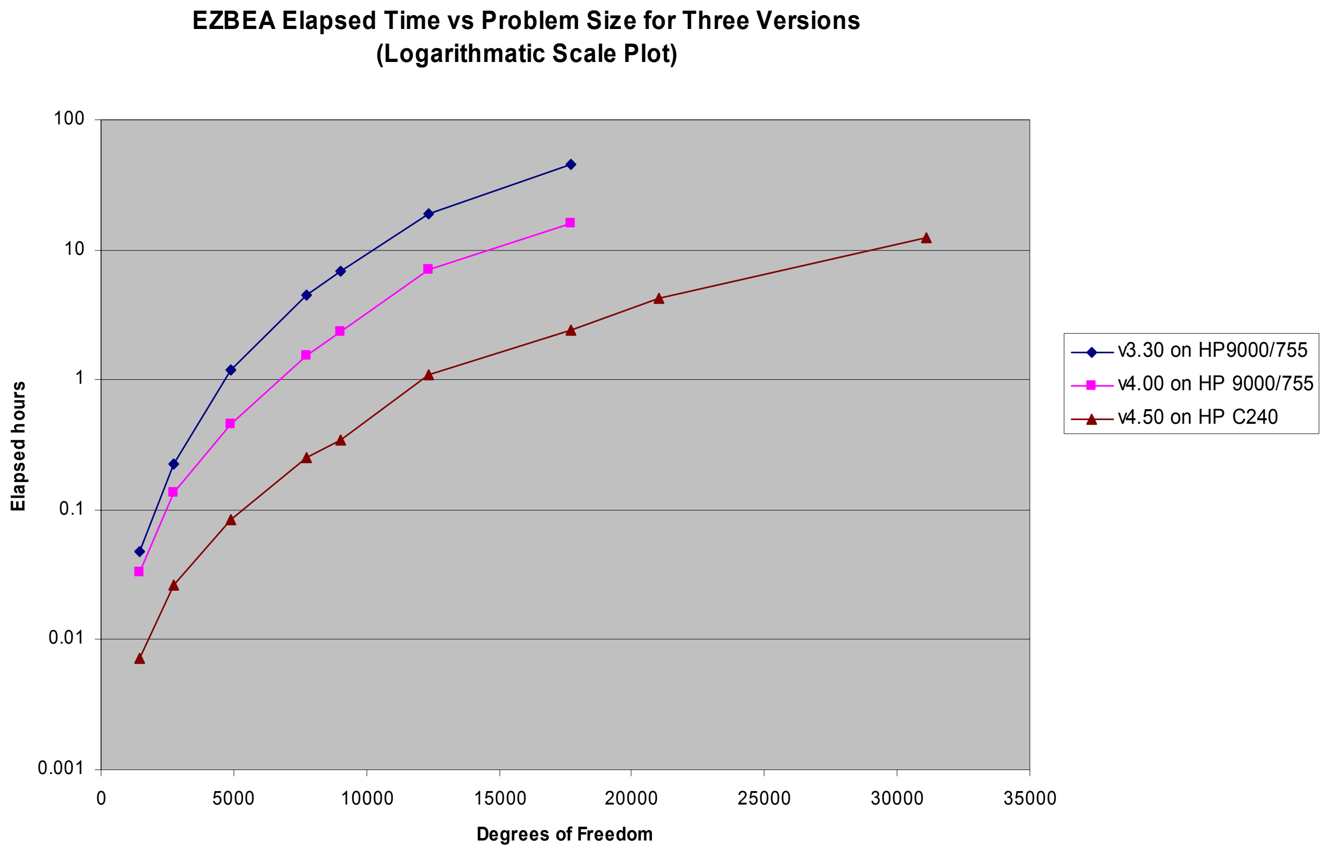
An Example: 9881 nodes, 20 hours on HP C240



Current Models size vs. Time Plot on HP C240



Speedup


EZBEA Elapsed Time vs Problem Size for Three Versions
(Logarithmatic Scale Plot)
Elapsed hours
100
10
1
0.1
0.01
0.001
0
5000
10000
15000
20000
25000
30000
35000
Degrees of Freedom
v3.30 on HP9000/755
v4.00 on HP 9000/755
v4.50 on HP C240

Future Work

- Eliminate the physical limit on number of elements and nodes
  - dynamic memory allocation
  - scratch files
  - accuracy issue when elements get smaller(double precision)

Future Work

- Solver improvement (performance issue)
  - improve current solver (direct solver, $O(N^3)$)
  - iterative solver ($O(N^2)$)
    - Caterpillar has looked into this before
    - Does not always converge for large problems

Future Work

- Multipole accelerated BEM (O(NlogN) operations)
  - significant performance gain
  - has to use iterative solver
  - convergence for large problem questionable
  - would involve significant work

Future Work

- Continue gap, contact work
  - capability to analyze assemblies
- implement line integral for thinner structures
  - improve accuracy