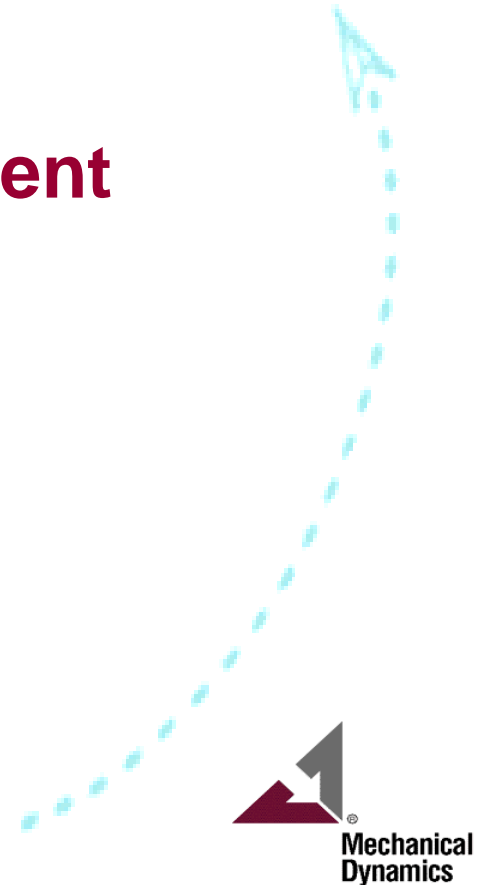
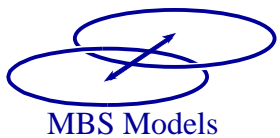




ADAMS

ADAMS/Hydraulics - an Embedded Hydraulics Environment



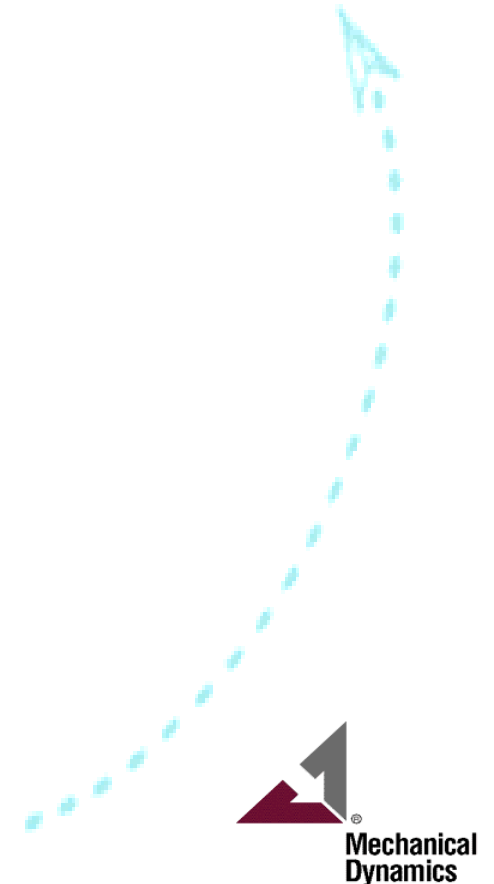


ADAMS

ADAMS/Hydraulics

Background

- Market Driven Activity
- Consortium Developed
 - ◆ Volvo Construction Equipment Group, Sweden
 - ◆ Valmet Oy, Järvenpää Works, Finland
 - ◆ Valmet Oy, Rautpohja Works, Finland
 - ◆ MBS Models Oy, Finland
 - ◆ Mechanical Dynamics, Inc., USA
 - ◆ Institute of Hydraulics and Automation of Tampere UT, Finland
- 2 Years of Intensive Development
- Targeted for System Level Virtual Prototyping

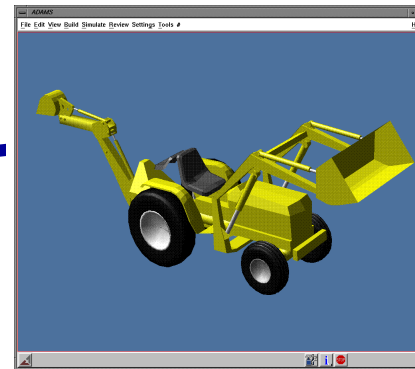




ADAMS

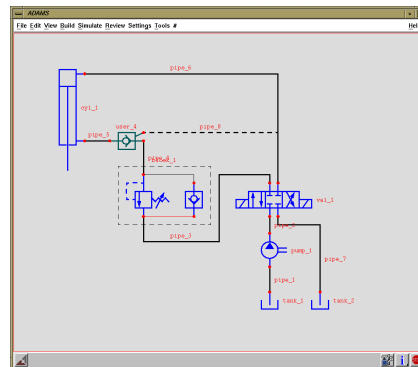
ADAMS/Hydraulics

Embedded into System Level Product Development Process



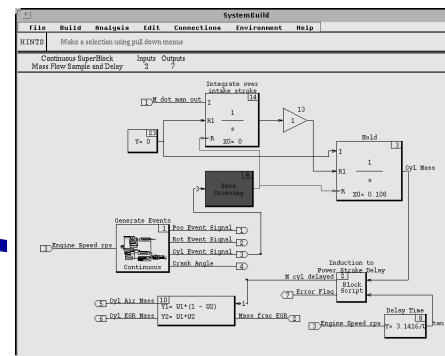
Mechanics

ADAMS



Hydraulics

ADAMS/Hydraulics



Controls

(shown is MATRIXx from ISI
executing through ADAMS/Controls)



MBS Models

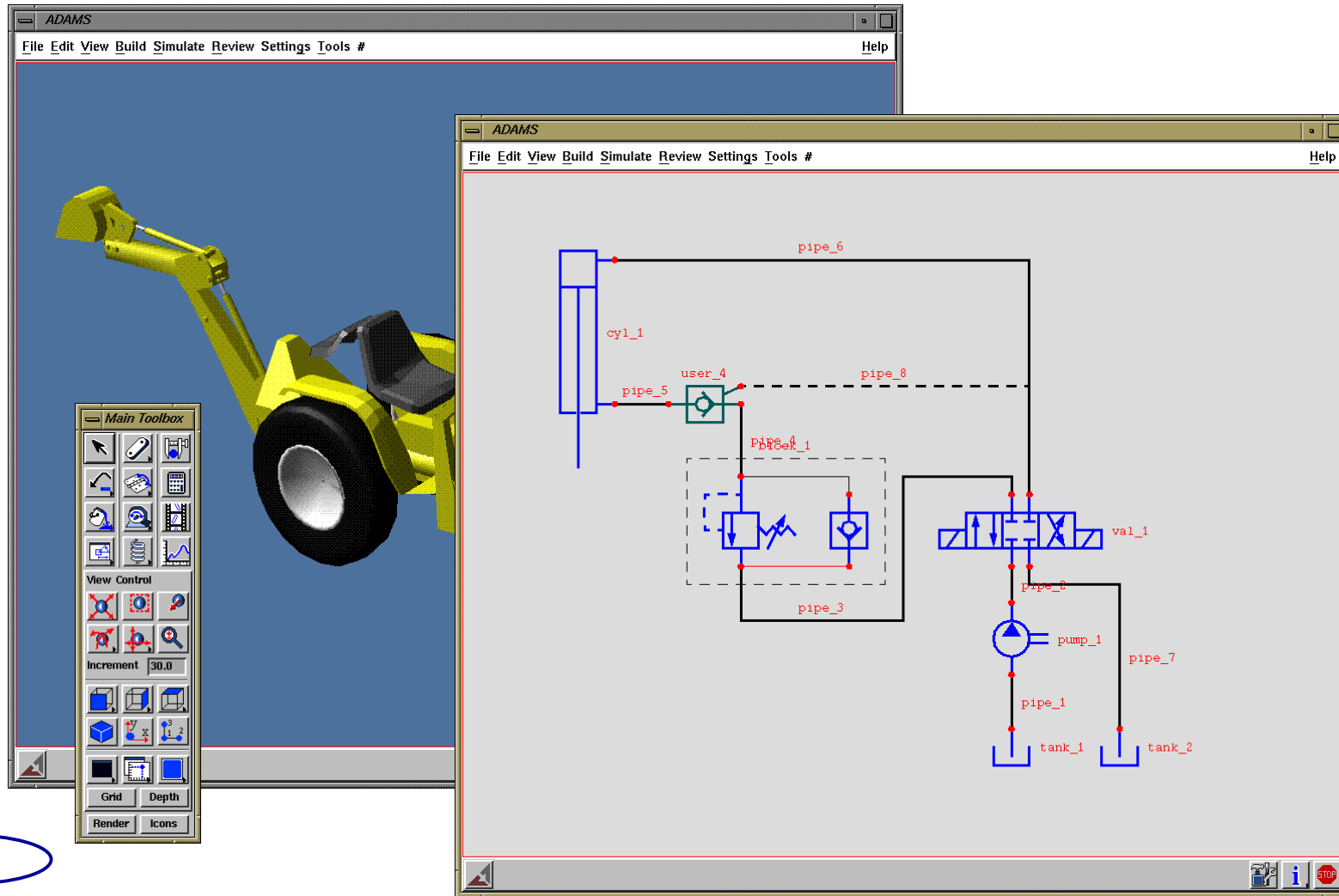


Mechanical
Dynamics



ADAMS

ADAMS/Hydraulics Graphical User Interface





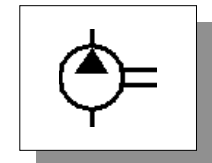
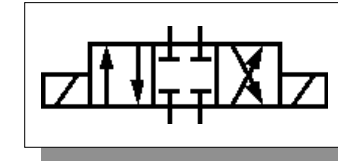
ADAMS

ADAMS/Hydraulics

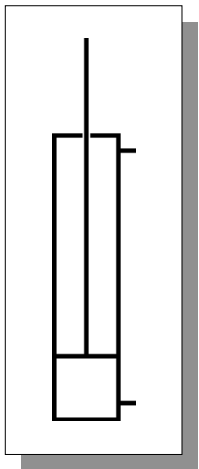
Library of Component Models

- Highly **parametric component models**
 - Defined through **characteristic curves**
 - Also **primitive components**
(1 dof mass, force source, ...)

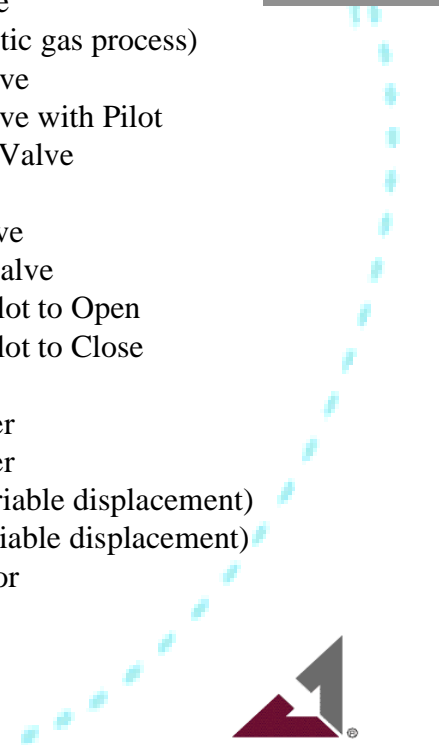
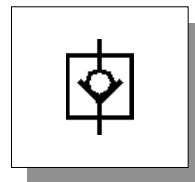
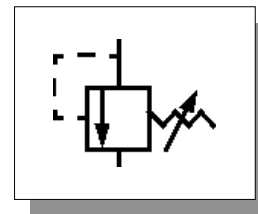
with Strong Physical Background



- 2/2-Directional Control Valve
- 3/2-Directional Control Valve
- 4/3-Directional Control Valve
- Check Valve
- Pressure Relief Valve
- Accumulator (adiabatic gas process)
- 1-way Restrictor Valve
- Counter Balance Valve with Pilot
- 2-way Flow Control Valve
- 4/3-Servo Valve
- 2-way Cartridge Valve
- Pressure Reducing Valve
- Check Valve with Pilot to Open
- Check Valve with Pilot to Close
- Shuttle Valve
- 1-directional Cylinder
- 2-directional Cylinder
- Hydraulic motor (variable displacement)
- Hydraulic pump (variable displacement)
- Generic Pump / Motor
- Level 1 Pipe Model



- Fluid
- Adjustable and/or constant Orifice
- Laminar Orifice
- Spline-based Orifice
- Reservoir (flexible and/or rigid walls)
- Tank
- Pressure Source
- Flow Source
- 2-way Junction
- 3-way Junction
- Sum of Flows
- Force Source
- 1-DOF Mass





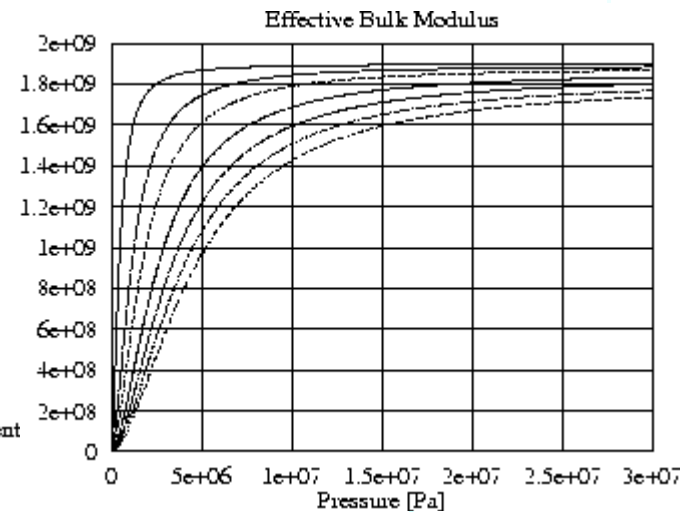
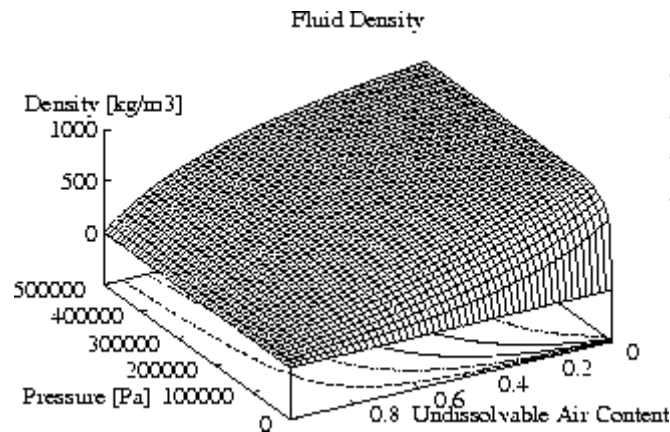
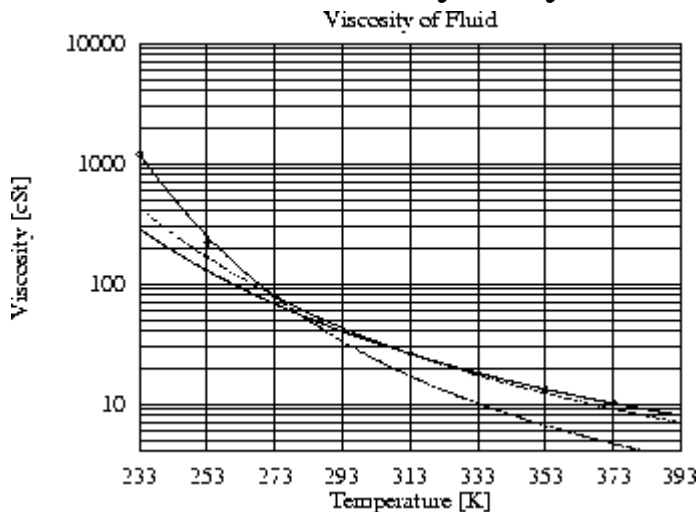
ADAMS

ADAMS/Hydraulics

Technical Highlights

Fluid is treated as an object of its own

- Equation of State, $G(p, V, T) = 0$
 - with dissolvable and undissolvable air content
 - => automatically handles **cavitation at low pressures**
 - => **pressure dependency of bulk modulus** automatically covered
- **Viscosity-temperature** dependency built-in
 - => very easy to **vary system temperature**, change one number!



MBS Models



Mechanical
Dynamics



ADAMS

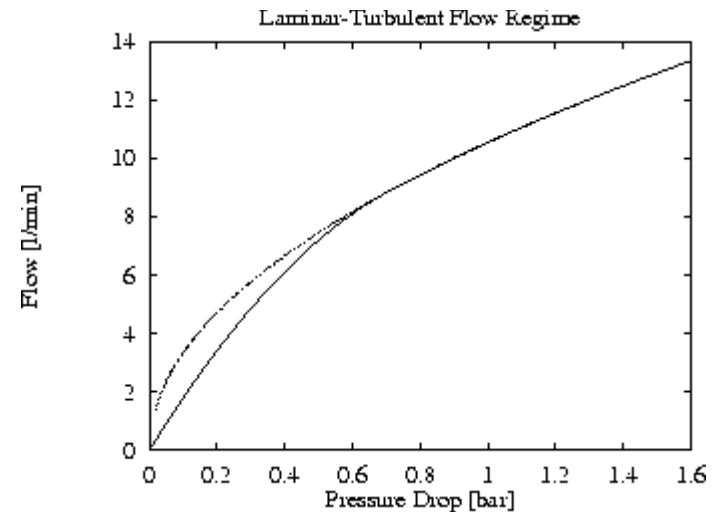
ADAMS/Hydraulics

Technical Highlights

All component and flow models automatically handle switch between **laminar and turbulent** flow conditions in a **continuous and smooth** way.

You never have to predefine laminar or turbulent flow conditions for your analysis.

That's how nature does it as well!



MBS Models



Mechanical
Dynamics



ADAMS

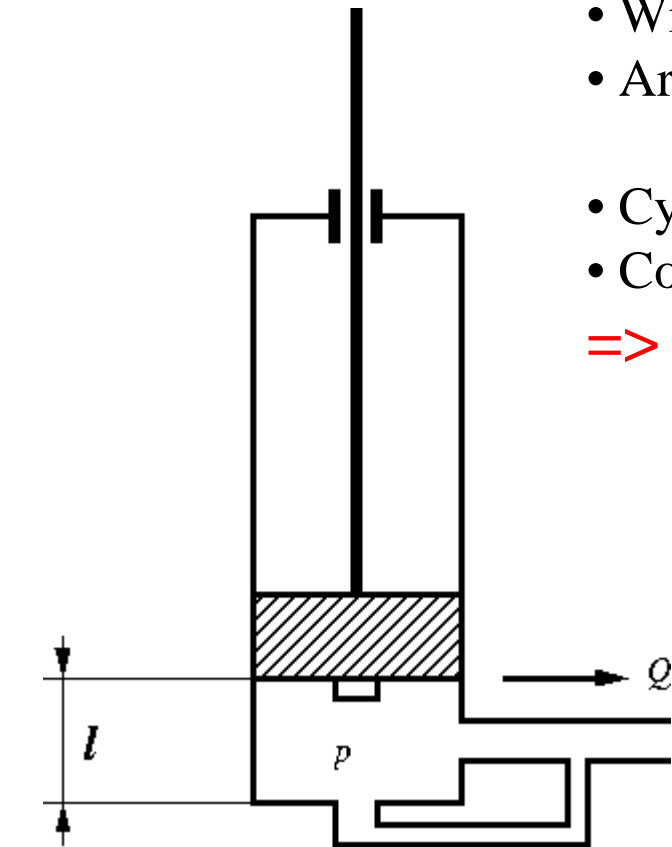
ADAMS/Hydraulics

Technical Highlights

Function Expressions

- Wide coverage over different component constructions
- Arbitrary functions allowed
 - => user specific components without programming
- Cylinder end-stops (damping constructions)
- Coupling to ADAMS/Controls

=> **Unique Modeling Flexibility**



MBS Models

$$Q = Q_{\text{nom}} \sqrt{\frac{\Delta p}{p_{\text{nom}}}}$$

$$Q_{\text{nom}} = f(l, \dots)$$

All hydraulic and mechanical states allowed



ADAMS

ADAMS/Hydraulics

Applications

- Heavy Machinery - Excavators, Forwarders, ...
 - General Machinery - Paper Machines, Test Hardware, ...
 - Brake Systems
 - Shock Absorbers
 - Landing Gears, ...
- Look at functionality of **hydraulics with true mechanics**
 - **Couple with Controls** for a complete Virtual Prototype
 - Find appropriate valve sizes, pipeline dimensions, ...



MBS Models



Mechanical
Dynamics



ADAMS

ADAMS/Hydraulics

Problems Solved

- ADAMS/Hydraulics allows you to design and analyze hydraulic circuits which drive your mechanical systems
 - ◆ hydraulic effort and sizing requirements: pumps, orifices, cylinders, valves, etc.
 - ◆ vibration issues: interaction between hydraulic elements and mechanical design
 - ◆ loads determination: more accurate loads due to including hydraulics and controls effects
 - ◆ system transient analysis: how smooth and how fast will the system respond





ADAMS

ADAMS/Hydraulics

Architecture - Full Coupling

1 Hydraulic Component = 1 GSE in Solver

- **full coupling** between sets of equations
 - enables **static** analysis
 - enables **linear** analysis (eigenmodes and -frequencies)
- **100% compatible** with ADAMS mechanics
 - **symbolic derivatives** built-in for numerical robustness
 - **SI units** used internally, all conversions automatic

1 Hydraulic Component = 1 Entity in View

- **2D block diagram** (ISO drawing symbols)
 - **transparent** to ADAMS users, only **one environment** to learn
 - **easy** to use
- fully employs **power of ADAMS**
 - **function expressions**
 - design variables, **design studies**, **DOE**, **optimization**



MBS Models

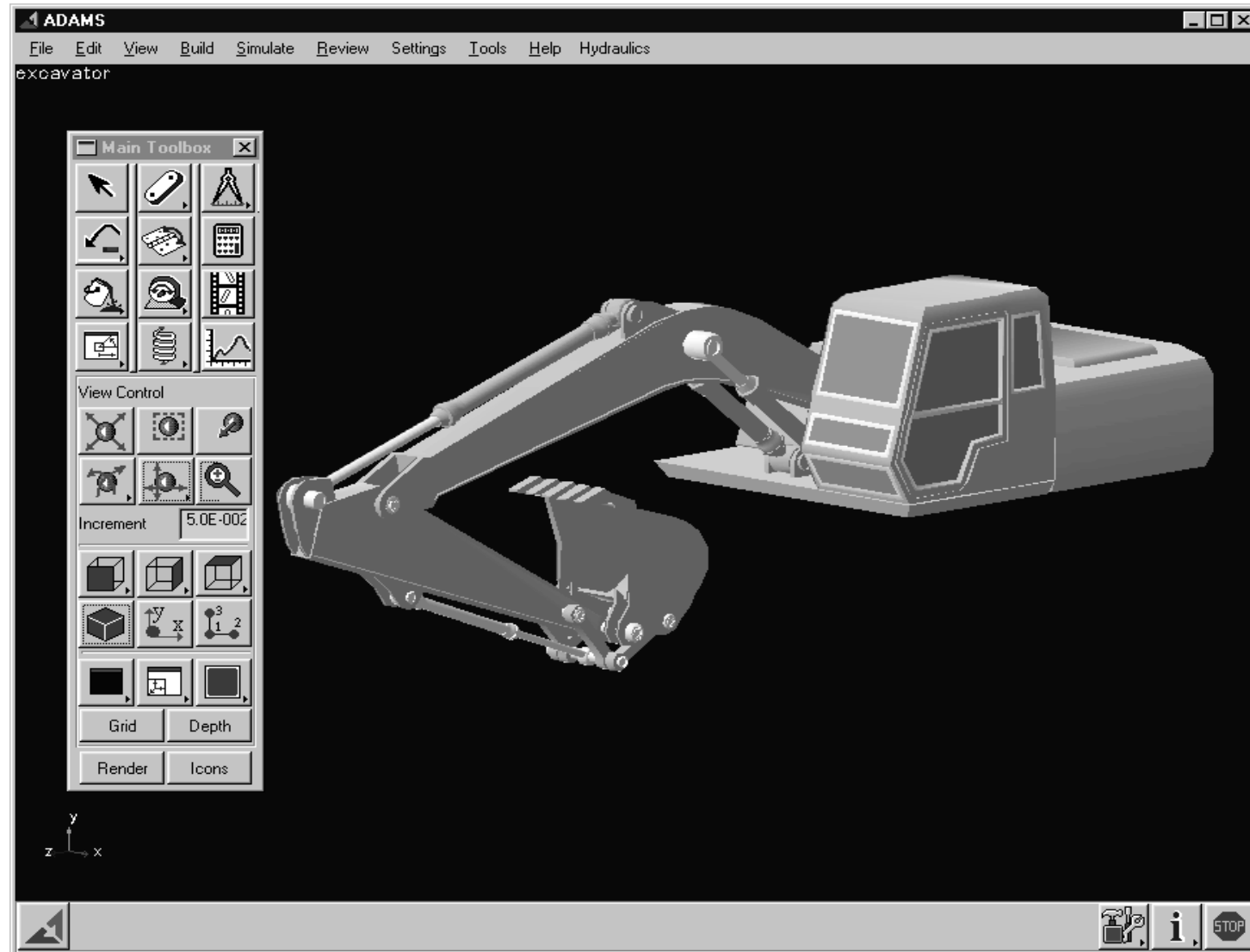


Mechanical
Dynamics



ADAMS

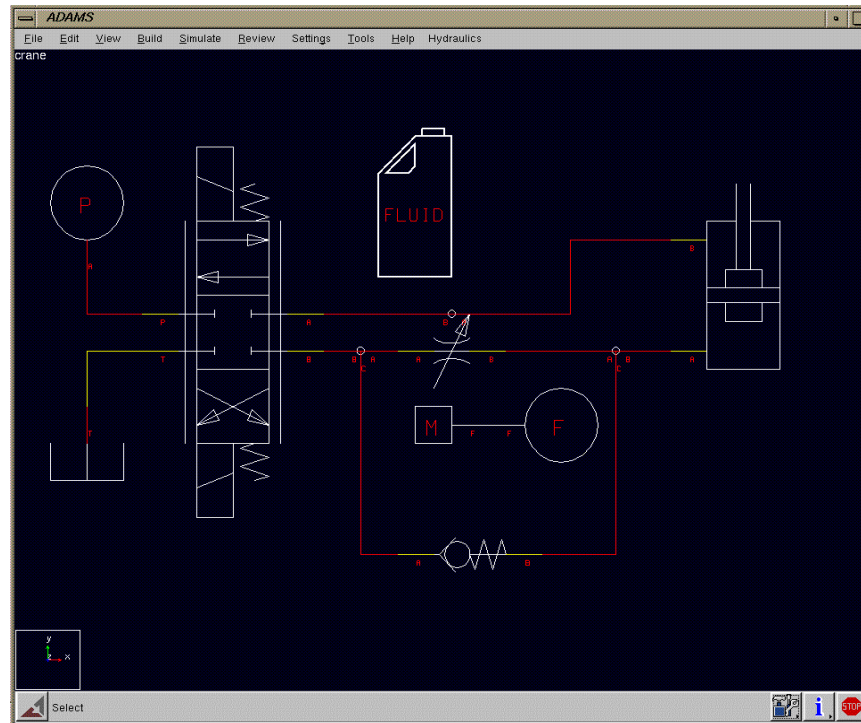
Example: Excavator Control



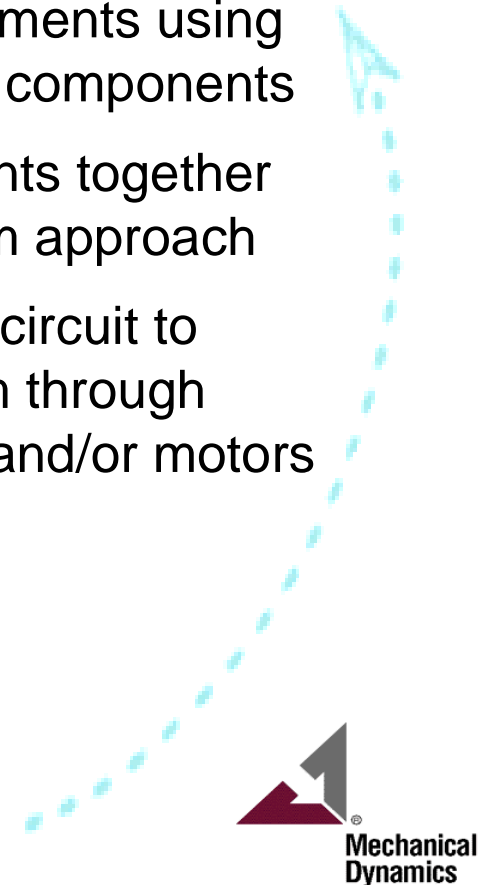


ADAMS

Hydraulic Circuit Model



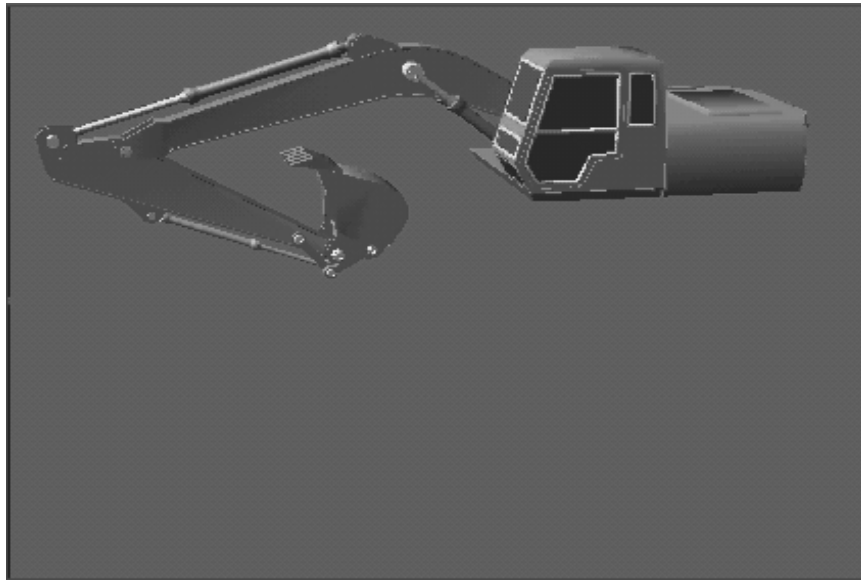
- Create specific elements using library of hydraulic components
- Connect components together in 2d block diagram approach
- Connect hydraulic circuit to mechanical system through cylinders, pumps, and/or motors





ADAMS

Hydraulic + Mechanical Simulation

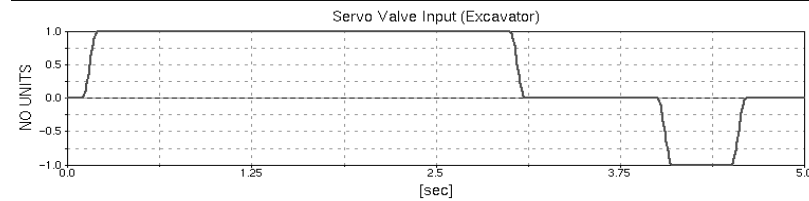
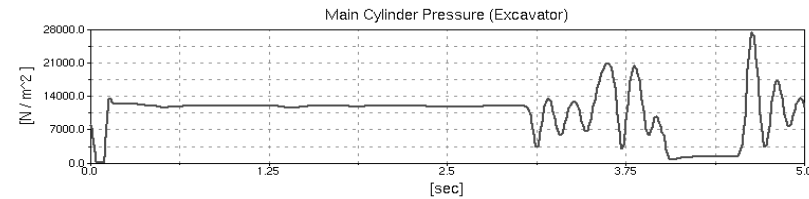
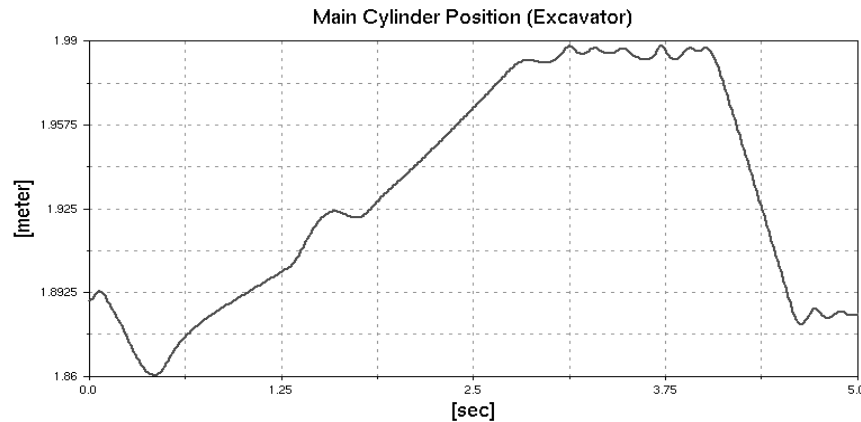


- Run complete system simulations including the effects of hydraulic circuits
- Run static, transient, dynamic, and linear analyses
- Tune the hydraulic elements using DOE, Design Sensitivity, and Optimization

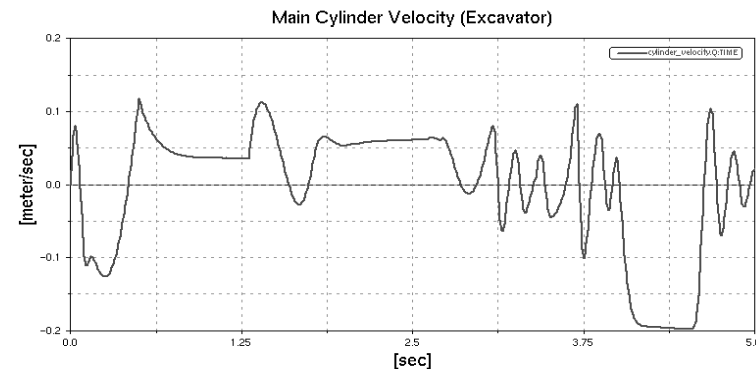


ADAMS

Postprocess all of the Hydraulic Results



- Postprocessing includes pressures, flow rates, valve positions, cylinder positions, friction forces ...





ADAMS

Conclusions

- ADAMS/Hydraulics enables system level design
- ADAMS/Hydraulics expands the scope of virtual prototyping beyond pure mechanics
- ADAMS/Hydraulics simplifies and speeds up modeling of hydraulic circuits substantially

