A MSC Adams-Marc-EDEM Co-Simulation Framework

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  – Native
  – Embedded
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  – Chain simulations

• Co-Simulation Overview

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MSC Adams Approach to Multi-Physics

• Three approaches:
  – Native implementation of FEA
    • Adams assembles the equations, Adams solves all equations.
  – Embedded implementation of FEA
    • FEA code assembles equations of a subsystem, Adams solves all equations.
  – Co-simulation
    • FEA code solves its equations, Adams solves its equations.
  – Chain simulations
    • Adams exports a FEA dataset
MSC Adams Approach to Multi-Physics

- **Native** implementation of FEA
  - Distributed mass beam elements (ANCF based)
  - Geometrically nonlinear formulation
  - Curved isoparametric
  - Variable cross section
  - Contact support
  - Expression based distributed loads
  - Full support in dataset language

- In the development pipeline we have shells/plates and solid ANCF based elements, material nonlinearities.
MSC Adams Approach to Multi-Physics

- *Native* implementation of FEA
MSC Adams Approach to Multi-Physics

- *Native* implementation of FEA
MSC Adams Approach to Multi-Physics

- **Embedded** implementation of FEA
  - Support for SOL400 (nonlinear)
  - Distributed solution
  - Extension of existing FLEX_BODY object.
  - Labelled MaxFlex
  - Full support in dataset language
  
  - Contact support programmed for v. 2016
MSC Adams Approach to Multi-Physics

- *Embedded* implementation of FEA
MSC Adams Approach to Multi-Physics

- **Embedded** implementation of FEA
MSC Adams Approach to Multi-Physics

- Co-Simulation
  - Not FMI based
  - Algorithm base on work by Elliot et al. (2000)
  - Adams Co-Simulation Interface (ACSI) released 2014
  - Extensible architecture
  - Distributed parallel
  - Version 2014 support for MSC Marc
  - Version 2015 support for MSC Marc and stiffness matrix
  - Version 2016 support for EDEM (Alpha version available now)
MSC Adams Approach to Multi-Physics

• **Co-Simulation**
MSC Adams Approach to Multi-Physics

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- **Co-Simulation**
MSC Adams Approach to Multi-Physics

- **Co-Simulation**

  Time: 0 s
MSC Adams Approach to Multi-Physics

- **Chain simulations**
  - Export a fully editable MSC Nastran model
  - Not a dataset translation
  - High fidelity, eigenvalues computed in Adams match eigenvalues computed in Nastran
MSC Adams Approach to Multi-Physics

• *Chain simulations*
MSC Adams Approach to Multi-Physics

- **Chain simulations**

![Graph: Chassis - Frequency error vs. Mode number]

Mode number

% Error

% Error vs. Mode number
Co-Simulation Overview

• 2014 First release of Adams Co-Simulation Interface (ACSI)
  – Support for MSC Marc only

• 2015 Enhanced support for MSC Marc
  – Support for stiffness matrix exchange

• 2016 Enhanced support for EDEM (DEM Solutions, UK)
  – Alpha version available now
Co-Simulation Overview

• Co-simulation setup
  – Assume fixed joint between Adams and other codes
Co-Simulation Overview

• Co-simulation setup
  – Extrapolated force values acting on Adams
Co-Simulation Overview

• Co-simulation setup
  – Other code provides a tangent stiffness matrix to Adams
  – (EDEM passes a zero matrix)
Co-Simulation Overview

- Co-simulation setup
  - Prescribed motion on the controlled surfaces/nodes on other code

\[ \phi_i(u) - f_i(t) = 0 \]

\[ \phi_j(u) - f_j(t) = 0 \]
Co-Simulation Overview

- **Variable communication step**
  - MBD model always goes first
  - Each code takes a step using its best settings
Co-Simulation Overview

- Impact lower control arm
Co-Simulation Overview

- Crankshaft torque modulator
Co-Simulation Overview

- Crankshaft torque modulator
  - Comparison Marc-only vs Co-Simulation
Co-Simulation Overview

- Battery housing damage

Time = 0.0000
Co-Simulation Overview

- Battery housing damage
Co-Simulation Overview

- **Advantages**
  - No limitations in Adams model
  - Some limitations in other codes
  - Multi-physics support in MSC Marc models
  - Parallel computation of other codes
  - Support for different units and reference frames
  - TCP/IP
  - Dynamic, static and quasi-static simulations
Co-Simulation Overview

• Usage
  – User instruments the models
    • Easy to follow instructions
  – User writes a configuration script to define
    • Model topology (interactions between codes)
    • Units for each code
    • Relative location of reference frames
    • Model specific parameters
    • IP location of servers
    • Interpolation/extrapolation algorithms
  – User launches the master code (a.k.a. glue code)
    • Glue code prompts the user to launch the co-simulating codes.
Co-Simulation Overview

• Configuration script example

#-------------------------------------------
# Example of Adams, Marc and EDEM
#-------------------------------------------

cosim_ip       = 127.0.0.1
end_time      = 3.0
Co-Simulation Overview

• Configuration script example (cont.)

```plaintext
# Adams process
process {
    id           = 99
    name         = Rigid parts and springs
    code         = adams

    interaction {
        name       = gforce1
        connection = Box
        gforce_id   = 1
    }
}
```
Co-Simulation Overview

• Configuration script example (cont.)

```
# Marc process
process {
    id      = 3
    name    = Intermediate block
    code    = marc

    interaction {
        name       = Left_node
        connection = GFORCE_2
        node_id    = 1332
    }
}
```
Co-Simulation Overview

- Configuration script example (cont.)

```bash
# EDEM process
process {
    code = edem
    name = Box
    id = 50
    ip_address = 127.0.0.1

    interaction {
        name = Box
        connection = gforce1
        geometry_name = Box
    }
}
```
Co-Simulation Overview

• Limitations
  – No inertia effects from other model accounted for in Adams model
  – No simulation step rejection in the other codes
  – Interaction points are fixed joints
  – Only one Adams model is supported
  – Results are visualized independently or by CEI Insight
Co-Simulation Overview

- **Future development**
  - The ACSI (Adams Co-Simulation Interface) is an extensible framework
    - As of 2016 it does not have a plug-in architecture
  - In the development pipeline we plan extensions to:
    - Chrono::
    - SOL700 (MSC Dytran)
    - Custom codes