Why RBD?

ANSYS Rigid Body Dynamics & Simpler
Agenda

- Intro to Rigid Body Dynamics (RBD)
- System level analysis using Simpler-RBD co-simulation
- Advanced user control using command snippets
History & Motive

• 15 years ago, most of the simulations were done on single part models
• Automatic contact detection and easy contact modeling
  ➢ Assemblies are now a common phenomenon for analysts

Contact detection on an engine assembly

Contact is not always what you need

• Some abstraction could be more efficient
• “Kinematics” description better for some cases
Contact Based Kinematics

Example of contact misuse

Frictionless: Ear to Base, Pin to Base
Bonded: Ear to Pin

Solution time: 160 seconds
Joint Based Kinematics

Joints are a very elegant solution to this problem

- Developed for Rigid Body Solver, now also available in ANSYS Mechanical

**Revolute Joint:** Ear to Base, Pin to Base

**Fixed Joint:** Ear to Pin

**Solution time:** 40 seconds
Joint Types

- Revolute
- Cylindrical
- Spherical
- Planar
- Translational
- Slot
- Universal
Where can I use Joints?

Joints are available for most analyses

- Static, Modal, Transient, Harmonic, Random Vibration.
- Rigid Dynamics, Flexible Dynamics
- Perfect and Imperfect Joints
  - Stiffness, Damping, Stops and Locks can be defined
Rigid Dynamics vs. Continuum Mechanics

Linear Dynamics

Flexible Dynamics

Rigid Dynamics
For the Rigid Dynamics Solver, Joints are “native”:

- They hold the degrees of freedom
- Here, each revolute has one DOF
- No additional constraint needed
- Input can be Loads and Motion
- Output can be Motion or Joint Forces and Torques
- Runge Kutta Solver much faster than the Mechanical FEA Solver for most applications.
**Rigid Dynamics / Transient Structural**

**Question:** Transient Structural analysis allows rigid body, why do I need RBD?

**Transient Structural**
- Designed for (large) FE models
- Designed for stress computation

**Rigid Dynamics**
- DOFs are relative motion at joints (small number of DOFs)
- Designed for accurate forces computation
- Keep total energy balance (no numerical damping)
- Accurate event detection (shock, collision)
- Easy to set-up and use

RBD is fast and simple and computes accurate forces.
Rigid Body Dynamics Solver

Applications

• Longer duration simulation of rigid body assemblies.

• Complex load/time history problems – in Aerospace/Auto/Agriculture applications
Perform Component Level Stress Analysis

Export of motion loads as static loads

- Export joint and inertial loads at a given time
- Allows creation of “static” loads on the selected parts
**Rigid Dynamics to Transient Structural**

1. **RBD analysis**
   - Start with an RBD analysis considering all bodies as rigid

2. **Joint Forces time history**
   - The outcome is the joint forces for all time points

3. **Export Motion Loads**
   - Export loads at a given time

4. **Static Structural**
   - Static stress analysis of one body turn flexible
   - Compare elastic energy with RBD kinetic energy

5. **Ep<<Ek**
   - Otherwise, perform a Transient Structural analysis with the body turn flexible

If it’s small, try static analysis with another body
Or export loads at another time point

Stresses time history
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System Level Simulation in 14
System level analysis using Simplorer- RBD co-simulation

Motivation

• Include realistic control / command with a rigid dynamic system
  ➢ Using Simplorer’s large library of hydraulic, electric, electronic components

• Include realistic mechanical models as part of a system level simulation
  ➢ Rigid dynamics is highly non-linear. No reduced order models can be created

• Higher fidelity models

• Optimize the overall system
Simplorer Highlights

System Simulation

Multi-Domain Simulation

Mixed-Signal Simulation

Multi-Coupling Simulation
ANSYS System Simulator: Simpler

**Blocks:**

- C/C++ User Defined Model
- Matlab® Real Time Workshop
- Matlab Simulink®
- ANSYS RBD
- ANSYS Maxwell

**Circuits:**

- Electromagnetic (FEA)
- Mechanical (FEA)
- Thermal (FEA)
- Fluidic (CFD)

**States:**

- VHDL-AMS

**Model Extraction:** Equivalent Circuit, Impulse Response Extracted LTI, Stiffness Matrix

```
IF (domain = quiescent_domain)
  V0 == init_v;
ELSE
  Current == cap*voltage'dot;
END USE;
```
Piston Train with Firing Control

Forces applied every cycle
Two forces out of phase

Small starting torque

Measure rotation (used in force calculation)
Piston Train with Firing Control-Results

Force Applied on Pistons

Rotational Displacement

Rotational Velocity
Hydraulic command of a landing gear
Mechanical Side

Rigid Dynamics Model

Simplorer Model
Hydraulic command of a landing gear
Mechanical Side

- RBD Model and Simplorer Model are link via “PINS”
- These PINS are defined directly from the Mechanical Window
- They are attached to joint degrees of freedom
- Pins are “input” (Simplorer will feed the value to RBD) or “output” (RBD will feed the value to Simplorer
- Typically, the same joint will have one “input” pin and one “output” pin
- Here, the hydraulic cylinder translational joint hold an input displacement pin, and an output force pin.
Hydraulic command of a landing gear Simpler Side

• RBD model appears as a sub-circuit
• PINS are the connecting points between the RBD model and the rest of the circuit
• Here the model is made of
  • Hydraulic pump and by-pass
  • ON/OFF Command
  • Three way valve
  • Cylinder, with end stop sensor
• Acting on the ON/OFF and the Valve, a full simulation can be carried
Hydraulic command of a landing gear

Results are available both on the
Simplorer side and in the
Mechanical window

Displacement of the
cylinder
System level analysis using RBD Simpler co-simulation

Sequencing of a 5 axis robot from the Simpler Window

Rigid Dynamics Model  

Simplorer Model
Sequencing of a 5 axis robot from the Simplorer Window - Results

Pick and Drop cycled defined in Simplorer

Results are available both on the Simplorer side and in the Mechanical window

Rotation of Axis 3
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Generalized Contact

Generalized contact now available

- Robust collision detection
- Event driven scheme $\implies$ exact time, no penetration
- Impacts are governed by Newton’s law
- Restitution factor between 0 and 1

$$v_2^+ - v_1^+ = -e(v_2^- - v_1^-)$$

- Can handle
  - high velocity
  - small gap
  - large time step
Restitution factor effect

Restitution factor = 1.0

Restitution factor = 0.8

Total energy conservation

A fraction of total energy is lost at each shock
Sliding contact examples

Frictionless contact but Frictional, Rough, no separation on the way

Cam on plane

Geneva drive

Rollers and rail
14.0 Contact Applications

- Chain and Sprockets
- Gears (helical, spur, hypoid...)
- Cams
- Wheels and Rails

...
Enhanced Constraints in 14

RBD Command snippets based on the Python language allow to model complex relationships between joints, help create new load and provide results export.
A torque limiter is an automatic device that protects mechanical equipment, or its work, from damage by mechanical overload.

- It couples motion as long as motion is less than the threshold.
- It uncouples as soon as the threshold has been reached.
Simulation Model

Grounded on one side

Revolute joint for the Torque Limiter

Increasing torque applied by varying the weight location
Overcoming Limitations with Snippets

- Coupling can be included using a zero velocity joint condition on the revolute joint.
- BUT joint conditions can only be activated / deactivated by (time-triggered) load steps.
- Time of uncoupling is not known \textit{a priori} under complex loading conditions.

Command snippets can help you defining more general conditions!
Python commands could also be used here to extract / export these results to other applications (Excel post processing, fatigue analysis,...)
Extend Connections

Enhancement to allow use of Constraint Equations to represent gears and couplers

- 6 CE’s between 3 central gears and the external gear and central joint
Summary

- RBD Solver – a nice option to model large rigid assemblies.
- System Simulation allows for comprehensive simulation including controls, hydraulics etc.
- Contacts and Constraints greatly improved in 14.
Rigid Body Dynamics

QUESTIONS?