Adams/Machinery
A Powerful Simulation Suite for Mechanical Drive Systems
Agenda

• Why should you care?
• What is Adams/Machinery?
• Key Benefits for Engineers
• What Problems Does It Solve?
• Adams/Machinery Capabilities
  – Gear Module
  – Belt Module
  – Chain Module
  – Bearing Module
  – Cable Module
  – Motor Module
• Q&A
Product Design Concerns

• Will it perform,
  Is it functional?

• Is it strong enough,
  Is it safe?

• Is it comfortable?

• How long will it last?

• Is it too loud?
What is Adams/Machinery?
A Powerful Simulation Suite for Mechanical Drive Systems

- A set of productivity modules bundled into a single Adams/Machinery offering:
  - Offers automated creation of common mechanical components via a wizard interface
  - Set in the Adams/View environment
  - Prerequisite: Adams/Studio (i.e. Adams/View & Adams/Solver)
  - Available via MK+ tokens and seat license
Key Benefits for Engineers

Productivity Benefits:

- High-fidelity simulation of common mechanical parts, such as gears, belts, and chains
- Enhanced productivity with incredibly quick model-solve-evaluate process times
- An automated, wizard-driven model creation process for ease-of-use
- Straightforward evaluation of results in Adams/Postprocessor
What Problems Does it Solve?

- **Gear Module:** Study the impact of gear effects (gear ratios, friction, backlash, etc.) on system performance.

- **Belt Module:** Predict the impact of transmission ratios, tension variations, belt dynamics, etc. on system performance.

- **Chain Module:** Quantify chain effects on system behavior. Typical chain effects: drive ratios, tension variations, friction, chain dynamics, etc.

- **Bearing Module:** Calculate Bearing Forces, Bearing Service Life, etc.
The Problem:

- Building complex models has traditionally involved:
  
  **Adams/View scripting**

- Result:
  
  - Takes a lot of work
  - Requires an Adams expert who knows the command language
  - Methods very problem-specific. Difficult to re-use!
The Solution:

- The solution to setting up these hard models is *Adams/Machinery!*
- For example:

<table>
<thead>
<tr>
<th></th>
<th>Traditional Method</th>
<th>Using Adams/Machinery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Create frame and shafts</td>
<td>0.25 day</td>
<td>0.25 day</td>
</tr>
<tr>
<td>Build the gear box</td>
<td>1.0 day</td>
<td>0.25 day</td>
</tr>
<tr>
<td>Build the belt system</td>
<td>5.0 days</td>
<td>1.0 day</td>
</tr>
<tr>
<td>Build the chain system</td>
<td>5.0 days</td>
<td>1.0 day</td>
</tr>
<tr>
<td>Define desired output</td>
<td>0.5 days</td>
<td>0 days</td>
</tr>
<tr>
<td>Total time</td>
<td>11.75 days</td>
<td>2.5 days</td>
</tr>
</tbody>
</table>
Traditional Workflow for analyzing Planetary Gear in Adams

Create/Modify Geometry

CAD Process 2 hour

Load Geometry

Create Connections, Contacts

Simulation

Wait 3 hr

Adams Process 2 hour
New Workflow with Adams/Machinery

Create/Modify Planetary Gear In Adams/Machinery → Simulation

Adams Process 1.5 hours → Wait 0 hr
## Time Saved with Adams/Machinery

<table>
<thead>
<tr>
<th>Traditional Workflow (Total time)</th>
<th>Adams/Machinery Workflow (Total time)</th>
<th>Time Saved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Create Planetary Gear 4 hours</td>
<td>1.5 hours</td>
<td>2.5 hours (63%)</td>
</tr>
<tr>
<td>Modify the Gear 1 time 11 hours</td>
<td>3 hours</td>
<td>8 hours (73%)</td>
</tr>
<tr>
<td>Modify the Gear 2 times 18 hours</td>
<td>4.5 hours</td>
<td>13.5 hours (75%)</td>
</tr>
</tbody>
</table>

Plus: Much Less dependent on CAD software!
Adams/Machinery Capabilities

- **Modeling Fidelity Options**
  - Belt
  - Chain
  - Gear
  - Bearing
Adams/Machinery Capabilities

- Modeling Fidelity Options
  - Belt
  - Chain
  - Gear
  - Bearing
Belt Module: Rapidly evaluate Pulley-Belt system

- **Constraint**
  - Kinematic joint coupler

- **2D/3D Links**
  - Discretized belt formulation
    - Rigid parts connected by field elements
    - IMPACT-based contact subroutines for contact with pulleys
  - For 2D: 2D parts, not 3D parts constrained in 2D

<table>
<thead>
<tr>
<th>Belt Types</th>
<th>Modeling Fidelity Options</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Constraint</td>
</tr>
<tr>
<td>Poly-V Grooved</td>
<td>✔</td>
</tr>
<tr>
<td>Trapezoidal Toothed</td>
<td>✔</td>
</tr>
<tr>
<td>Smooth</td>
<td>✔</td>
</tr>
</tbody>
</table>
Belt Module: Rapidly evaluate Pulley-Belt system

- **Tensioner**
  - Arm and Smooth Pulley
  - Rotational or Translational Spring Damper

- **Actuation**
  - Torque or Motion Functions
    - Constant
    - Harmonic Series
    - Curve
    - User Defined

- **Output Considerations**
  - Belt Tracking
    - Fixed Position on Span
    - Follow Individual Segments
Belt Module: Rapidly evaluate Pulley-Belt system

- **What Problems does it Solve?**
  - Avoid power transmission failure due to improper operating tension by studying the effect of belt tension to the system performance
  - Predict the load history of the pulley to perform fatigue analysis
  - Analyze the impact of belt slippage on system load performance
  - Study the effect of Belt compliance on the system output speed

- **Value/Benefits:**
  - Reduce the modeling time of pulley-belt systems by 80%-90% compared to the traditional method
  - Automated model creation process makes it possible for the new Adams users to create pulley-belt system
  - Shorten the development cycle for belt-driven systems
Adams/Machinery Capabilities

- **Modeling Fidelity Options**
  - Belt
  - Chain
  - Gear
  - Bearing
Chain Module:
Quickly analyze Chain-Driven Systems

- **Constraint**
  - Kinematic joint coupler

- **2D/3D Links**
  - Discretized chain formulation
    - Separate rigid parts per link connected via various compliance options
    - IMPACT-based contact subroutines for contact with sprockets

### Chain Types

<table>
<thead>
<tr>
<th>Chain Types</th>
<th>Modeling Fidelity Options</th>
<th>Chain Compliance Options</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Constraint</td>
<td>2D Links</td>
</tr>
<tr>
<td>Roller Chain</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Silent Chain</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

Roller Chain
Silent Chain (aka Involute)
Chain Module: Quickly analyze Chain-Driven Systems

• **Compliance Options**
  - **Linear**
    - Linear bushings connect links
    - Only x-direction stiffness
  - **Nonlinear**
    - Uses field elements to connect links
    - X and Y-direction stiffness defined by a polynomial with 3 coefficients
  - **Advanced**
    - Link and Roller stiffness can be defined
    - Uses field elements to connect links
    - X and Y-direction stiffness defined by a polynomial with 5 coefficients

• **Tensioner**
  - Pivot, Translational and Fixed Guides
  - Spring Damper and User-entered function for tensioner
Chain Module: Quickly analyze Chain-Driven Systems

- **Actuation**
  - Torque or Motion Functions
    - Constant
    - Harmonic Series
    - Curve
    - User Defined

- **Output Considerations**
  - Chain Tracking
    - Fixed Position on Span
    - Follow Individual Links
Chain Module: Quickly analyze Chain-Driven Systems

- **What Problems does it Solve?**
  - Avoid tensile failure of the chain system by studying the chain tension under certain load condition
  - Predict the load history of the sprocket to perform fatigue analysis
  - Analyze the Chain vibration due to different preload
  - Study the effect of Chain compliance on the system output speed

- **Value/Benefits:**
  - Reduce the modeling time of sprocket-chain systems by 80%-90% compared to the traditional method
  - Automated model creation process makes it possible for the new Adams users to create sprocket-chain system
  - Shorten the development cycle for chain-driven systems

Roller  
Silent (aka Involute)
Adams/Machinery Capabilities

- Modeling Fidelity Options
  - Belt
  - Chain
  - Gear
  - Bearing
Gear Module: Simulate Gear Train system with high-fidelity

- **Coupler**
  - Kinematic joint coupler

- **Simplified**
  - Analytical contact calculation
  - Initial Backlash as input value (design variable) for rattle investigations, etc.

- **Detailed**
  - Analytical contact calculation
  - “True” backlash based on actual working centre distance and tooth thickness
  - Capture the effect of variation of loading between 1-3 teeth (noise generator)

- **3D Contact**
  - Geometry based contact
  - Gears can have all 6 Degrees Of Freedom
  - “True” backlash based on actual working centre distance and tooth thickness
  - Option to explicitly set backlash
  - Tooth tip relief and crowning can be represented for spur and helical gears

<table>
<thead>
<tr>
<th>Gear Types</th>
<th>Modeling Fidelity Options</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coupler</td>
</tr>
<tr>
<td>Spur Gear (Internal/External)</td>
<td>✔</td>
</tr>
<tr>
<td>Helical Gear (Internal/External)</td>
<td>✔</td>
</tr>
<tr>
<td>Bevel Gear Straight</td>
<td>✔</td>
</tr>
<tr>
<td>Bevel Gear Spiral</td>
<td>✔</td>
</tr>
</tbody>
</table>
Gear Module: Simulate Gear Train system with high-fidelity

- **Planetary Set**
  - Model construction automation
  - Simplified-level and 3D contact gears in a planetary configuration
Gear Module: Simulate Gear Train system with high-fidelity

**What Issues can they Solve?**
- **Study the effect of Gear backlash** on system output speed
- **Predict the Contact force between Gear pairs**
- **Study the effect of Gear friction** on the system performance

**Value/Benefits:**
- Reduce the need for Gear Geometry creation in CAD software by 80%-90%
- Automated planetary Gear creation process makes it easy to model and analyze the planetary Gear set in the transmission design
- Shorten the development cycle for Gear Train systems
Adams/Machinery Capabilities

- **Modeling Fidelity Options**
  - Belt
  - Chain
  - Gear
  - Bearing
Bearing Module: Accurately predict Bearing Contact force
Bearing Module:
Accurately predict Bearing Contact force

- **Simple Methods**
  - Joint (simply kinematic joints)
  - Compliant (linear bushing)

- **Detailed Method**
  - 14 types of *rolling element bearings*
  - Inputs
    - User-input bearing characteristic dimensions
    - Lookup in KISSsoft database (over 24,000 bearings from 8 manufacturers)
    - Inputs for many bearings are derived from catalogs nit direct from manufacturers
  - Calculation
    - GFORCE representation (no moving parts)
    - Embedded calculation from KISSsoft for nonlinear stiffness at every integration step based on shaft position and velocity
    - Damping applied as user-entered factor on $\sqrt{\text{stiffness}}$
  - Results
    - Bearing force components
    - Bearing service life
      - Based on ISO/TS 16281
      - Over 120 lubricants
      - Estimated service life under load/speed conditions of each output step
Bearing Module: Accurately predict Bearing Contact force

• **What Problems does it Solve?**
  – *Study the effect of changing Bearing parameters* on system performance  
  – *Predict the Bearing loads* based on accurate Bearing stiffness 
  – *Predict the bearing service life* under the specified simulation conditions

• **Value/Benefits:**
  – Reduce the need for testing and measuring the bearing parameters by 70%-80%, thus saving cost. 
  – Accurate prediction of Bearing stiffness and contact force improves the design quality of mechanical systems 
  – Shorten the development cycle by reducing the number of physical tests
Adams/Machinery: New Cable Module

- **Summary**
  - Cable modeling automation module
  - Simplified method is fast and accurate when cable mass can be neglected
  - Discrete method for cable mass effects (e.g., vibration)
  - Planar wrapping, full 3D simulation

- **Why is it better?**
  - Much faster model creation
  - No user need for Adams/View scripting skills

- **Applications**
  - Cable systems in cranes, heavy equipment, elevators, aerospace, exercise equipment, etc.
Adams/Machinery: New Cable Module
Summary
- Adams/Machinery will offer enhanced geometry modification (tip relief and crowning) for spur and helical gears, as well as 3D contact for planetary gear sets

Why is it better?
- Enhanced fidelity of system dynamic response
- Improved access to design details that matter to users
- Faster modeling of 3D Contact method for planetary gear applications
Adams/Machinery: 3D Belt & Chain

- **Summary**
  - Adams/Machinery Belts and Chains no longer constrained to a plane
  - Simplified (massless) 3d belt model
  - An extension to 3d of the existing discretized models of smooth/flat belt and roller chain

- **Why is it better?**
  - Broader set of problems can be addressed

- **Applications**
  - Power transmission applications
  - Belt “skew” and “walk” problems where lateral belt movement on the pulley is important
Adams/Machinery: 3D Belt & Chain
Adams/Machinery: More Gear Types

• **Summary**
  – Addition of Hypoid, Worm and Rack & Pinion gear types

• **Why is it better?**
  – New gear types were not previously supported

• **Applications**
  – Hypoid, worm, and rack & pinion gears
  – Gear loading, backlash and rattle studies where rigid body assumption is sufficient
Adams/Machinery: More Gear Types
Adams/Machinery: New Electric Motor Module

- **Summary**
  - Electric Motor modeling automation module
  - Multiple modeling styles:
    - Torque-speed curve definition
    - Analytical (DC, DC Brushless, Stepper, and AC Synchronous)
    - External 1D model import from Easy5 or Simulink

- **Why is it better?**
  - More accurate than kinematic motions
  - Much faster model creation

- **Applications**
  - Fine position control, motor sizing, vibration, and motor mass motion effects
Adams/Machinery: Parameterization

• **Summary**
  – Expand parameterization capabilities of components to support topology changes
  – Improve component copy, modify, and delete behavior

• **Why is it better?**
  – Enables more DOE and design studies
  – Improves ease of use

• **Applications**
  – Existing Adams/Machinery applications, especially those requiring design study and DOE
New Native Nonlinear Solver Technology

• **Summary**
  – Implementation of Absolute Nodal Coordinate Formulation (ANCF) 2D/3D beams with distributed mass

• **Why is it better?**
  – More realistic modeling
  – Support for nonlinear geometry
  – Faster modeling; no need to use flexible bodies and MFORCEs

• **Applications**
  – Adams/Machinery Belt Module
  – Adams/Machinery Cable Module
ANCF Example
Q&A