# Using RecurDyn

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1.0 Multibody Dynamics Overview

Multibody Dynamics (MBD) is the simulation of the behavior of mechanical systems that respond to input motions, actuator forces, inertial loads and gravity. Engineers perform multibody dynamics simulations because they want to find out if a new or modified product design will operate properly throughout its work cycle. Engineers hope to use up-front simulation to reduce product development costs, evaluate more design alternatives, and reduce the time it takes to bring a new product to market.

Outputs of interest include:

- Motion of the bodies (timing requirements)
- Interferences between bodies (a “virtual prototype”)
- Contact loads and constraint loads (used to find stresses and predict life)
- Vibrations at certain operating points (NVH requirements)

A mechanical model is a set of rigid or flexible bodies that may be attached by constraints. Contacts between geometry can be defined. System motion may be driven by force actuators, external forces or gravity loads.

Multibody dynamics software can be used with other simulation tools in order to consider more complex or complete mechanical systems.

- CAD/CAM (Computer-Aided Design / Computer Aided Manufacturing software creates solid geometry with mass properties used to define MBD bodies.
- Finite Element Analysis (FEA) software creates modal and mesh information used to describe flexible bodies. MBD body loads can be exported to FEA to specify load cases.
- Co-simulations can be done with control system software, hydraulic system software and pneumatic system software.
- Optimization software inputs system behavior predicted by MSS and adjusts system parameters to improve performance.
2.0 Multibody Dynamics Applications

There are many applications for multibody dynamics:

**Machinery:**
- Industrial appliances
- Robotic systems
- Machinery with belt or chain drives
- Intricate mechanisms in cameras, video recorders, and computer disk drives
- High-speed electrical switches / relays

**Media Transport**
- Paper-handling equipment such as photocopiers or printers
- Cameras and medical imaging devices

**Automotive:**
- Suspension systems
- Passenger vehicles (ride and handling characteristics)
- Anti-lock braking systems
- Body hardware (latches, connections)

**Aerospace:**
- Automatic control systems for maintaining satellite attitude
- Control surface linkages
- Landing gear and latching devices for aircraft doors
3.0 What is RecurDyn and How Is It Different?

RecurDyn is a new generation of multibody dynamic software which uses a recursive formulation to develop the equations of motion. Dynamics researchers consider recursive formulation to be the most efficient computational approach. Before RecurDyn, the recursive approach was only used in private tools for limited applications because manual code development was required for each application. RecurDyn is the first application of the complete recursive algorithm and it allows users to develop models with a comfortable building-block approach.

Relative coordinates are also used in the development of the equations, resulting in improved performance of RecurDyn compared to other software, especially as models become larger.

Figure 1 summarizes the results of the technical approach used by RecurDyn. RecurDyn identifies the independent variables of the mechanical system. In this 2D example the pendulum has a single rotational degree of freedom and only one equation is needed for the RecurDyn displacement calculation. Other multibody dynamics software packages treat all degrees of freedom of the body and add additional equations for calculating the reaction forces at the joint. Five equations must be solved at each integration time step rather than one equation. The equations developed by RecurDyn are Ordinary Differential Equations (ODEs) and are easier to solve than the Differential Algebraic Equations (DAEs) developed by other software.

![Figure 1. Comparison of Equation Formulation](image)

RecurDyn
Relative Coordinates (ODEs)
High-speed Problems: Good
Stiff Problems: Good

\[ I \ddot{\theta} + mgI \sin \theta = 0 \]

Other Programs
Global Coordinates (DAEs)
High-speed Problems: Poor
Stiff Problems: Poor

\[
\begin{bmatrix}
  m & 0 & 0 \\
  0 & m & 0 \\
  0 & 0 & I \\
\end{bmatrix}
\begin{bmatrix}
  \Phi_q^T \\
  \Phi_q \\
\end{bmatrix}
\begin{bmatrix}
  \dot{q} \\
  \lambda \\
\end{bmatrix}
= \begin{bmatrix}
  0 \\
\end{bmatrix}
\]

Where
\[
\Phi_q = \begin{bmatrix}
  1 & 0 & l \cos \theta \\
  0 & 1 & -l \sin \theta \\
\end{bmatrix}
\]

\[
q^T = [x \ y \ \theta]
\]

\[
g = \begin{bmatrix}
l \cos \theta \dot{\theta}^2 \\
l \sin \theta \dot{\theta}^2
\end{bmatrix}
\]
### 4.0 Types of RecurDyn Analysis

RecurDyn performs a consistency check of the model before starting any type of analysis. The user is notified of any serious problem so that the model can be fixed.

**Assembly**

This can be thought of as an initial conditions analysis that is done prior to the static, quasi-static, and dynamic analyses. The positions of the bodies are adjusted as needed to satisfy the constraints in the model.

**Kinematic Analysis**

A kinematic analysis simulates the motion of the system, including displacements, velocities, and accelerations of any point of interest on a mechanical device. The motion inputs must fully define the motion of all bodies in the model. Typical applications include linkage analyses and interference checking.

**Static Equilibrium Analysis**

The static equilibrium analysis determines a state for the system such that all internal and external forces are balanced. All system velocities and accelerations are set to zero. The static equilibrium analysis may be used to find a good starting configuration for a dynamic analysis.

**Quasi-Static Analysis**

A quasi-static analysis is a sequence of static analyses performed at fixed time intervals throughout a prescribed motion for the system.

**Dynamic Analysis**

A dynamic analysis calculates the time-history solution of the displacements, velocities, accelerations, and internal reaction forces in a mechanical system driven by an arbitrary combination of motion inputs, external forces, inertial forces and gravity.

**Linear Analysis**

Linear analysis converts the nonlinear equations for a mechanical system to a set of linear equations at a single operating point. The linear model can be used to perform an eigen-analysis of the model. The linear model can also be exported in the form of state-space matrices for use as a linear plant model in control system development.
5.0 MBD Simulation Process

The process of analyzing a mechanical system consists of:

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The sections below provide information for each step.

5.1 Deciding how to model the physical system

The modeling process begins with the idealization of a real mechanism as a system of basic components. Idealization is necessary because it is not efficient to model all aspects of a model in great detail. For example, you might replace the motion from a complex system of gears with a revolute joint and an applied motion. The steps for idealization of a physical model are:

- Define the purpose of the model. You should decide on the physical behaviors of interest, the simulations you want to perform with the model, the output you need, and the required degree of accuracy. Some key questions that you can ask yourself are:
  - Am I interested in the overall motion of the system, in the static configuration, in the dynamic loads, or in other behavior?
  - Will I use the same model for more than one analysis or with different initial conditions or forcing functions?
  - What output will I need to analyze the results?
  - How will the accuracy of the solution affect the usefulness of my results?

- Simplify the model to remove unnecessary complexity. Model simplification is a creative process that uses ingenuity and experience. You should carefully examine the model to determine the significant versus the negligible characteristics, the unnecessary degrees of freedom, and the symmetric and redundant subsystems. The simplification of the model requires some assumptions or approximations. You may have to rely on sound engineering judgment when portions of the required input data are missing or incomplete.
5.2 Defining and detailing the basic MBD components

You select the MBD building blocks that you will define in your GUI (graphical user interface). The basic system components include bodies, constraints, contacts, and applied loads.

**Bodies**

A simple body is rigid and is used to define components that act as rigid structures. The definition of flexible body is based upon an FEA modal representation or a series of rigid bodies with bushing connectors.

**Constraints**

A constraint restricts the relative movement of one body with respect to another body or ground. Some constraints act between a point on one body and a point on another body. Higher-pair constraints consider sliding motion along curves and surfaces, such as cam constraints.

**Applied Forces**

Applied forces may be environmental forces (gravitational forces, aerodynamic forces, electromagnetic forces, etc.) or compliance forces (springs, bushings, tires, flexible booms, and so on). Forces may be applied in translational and rotational degrees of freedom, and have a magnitude that is dependent upon state variables, including displacements, velocities, accelerations, forces, and time.

Note that body inertial forces and constraint reaction forces are calculated automatically and are not defined by the user.

5.3 Constructing and Solving the System Equations

RecurDyn automatically constructs and solves the model equations. The solution process includes a variable step size integrator, where the step size is adjusted as needed to control the accuracy of the results.

5.4 Reviewing the Model Outputs

In Section 5.1 you idealized the model while considering the desired results for the simulation. Most common outputs are produced automatically. RecurDyn allows users to also request additional, customized outputs. Outputs are generated at the requested output time interval.

Graphical output in the form of animations can help pinpoint specific problems, such as:

- Improper connectivity
- Misapplied motions or forces
- Unwanted oscillatory behavior
- Clearance problems

Plots are used to studying the specific behavior of a model. For example, you could plot the translational reaction forces at a joint over the course of the entire simulation and quickly determine the maximum load.