ENGINSOFT

Fluid Dynamics

Tolerance Analysis

Optimization

Mechanics

Crash and Impact Dynamics

Fatigue and Durability

Environmental and Vibroacoustics

Process Simulation

Multibody

Meshless Methods

EXPERTS IN CAE

A Key Partner in Design Process Innovation

Simulation Based Engineering Science

EnginSoft is the leading technology transfer company in the field of Simulation Based Engineering Science (SBES). We leverage CAE tools to help customers solve complex product development problems by combining technology transfer with consulting, training and research. Combining statistical approaches, knowledge and experience, we assist customers to safely and effectively navigate, exploit:

Computational Fluid Analysis

Finite Element Analysis

Meshless Methods

Impact and Crash

Multibody Dynamics

Acoustics

Additive Manufacturing

Tolerance Analysis

We work across a broad range of industries that includes automotive, energy, oil and gas, aerospace and defense, civil and structural engineering, metals, machining and manufacturing, consumer goods and appliances, healthcare and biomechanics, helping customers to leverage existing legacy and emerging simulation technologies.

1,500
Delighted Clients

3,000
Successful Customer Projects

200
Specialized Training Courses

80
R&D Projects

EnginSoft at a Glance

- Founded in 1984
- Over $40 million Annual Revenue
- Global Presence - USA, Europe, Asia

Core Business

Collaborative partnerships with customers for computer aided engineering (CAE) that focuses on the design and production processes, as well as on the entire product to create robust, accurate, reliable simulation models that guarantee strategic innovation, and maximize ROI and competitive business advantage for these customers.

Key Drivers

Leading-edge design-process innovation – including emerging technologies, such as generative design, additive manufacturing, robotics, digital twin, virtual and augmented reality, optimization, cyber security, and high performance computing. Through collaboration with academia and the R&D centers of major industrial groups we participate in governmental R&D projects and in technology transfer from research to industry.

Highly Qualified Staff

More than 250 graduates in engineering, mathematics, and physics with proven experience in mechanical and structural engineering, metallurgy, computational fluid dynamics, high & low-frequency electromagnetism, multi-physics, multibody dynamics, acoustics, tolerance management, and additive manufacturing.

ENGINSOFT

Business Outcomes

We help companies identify where, when and how simulation can make a difference to their business - with a view to its integration into their designs, production processes, and integration with other technologies. We show companies how to use of their existing and new investments to obtain the best possible system that solves product and process challenges, guarantees strategic innovation, maximizes return on investment and provides a competitive advantage.

Design Quality

A simulation model is only as good as the initial process description. That is why we invest skill, experience and effort in helping our customers focus on each component of the process to create robust, accurate, reliable simulation models that improves their designs, processes and the interaction of these processes.
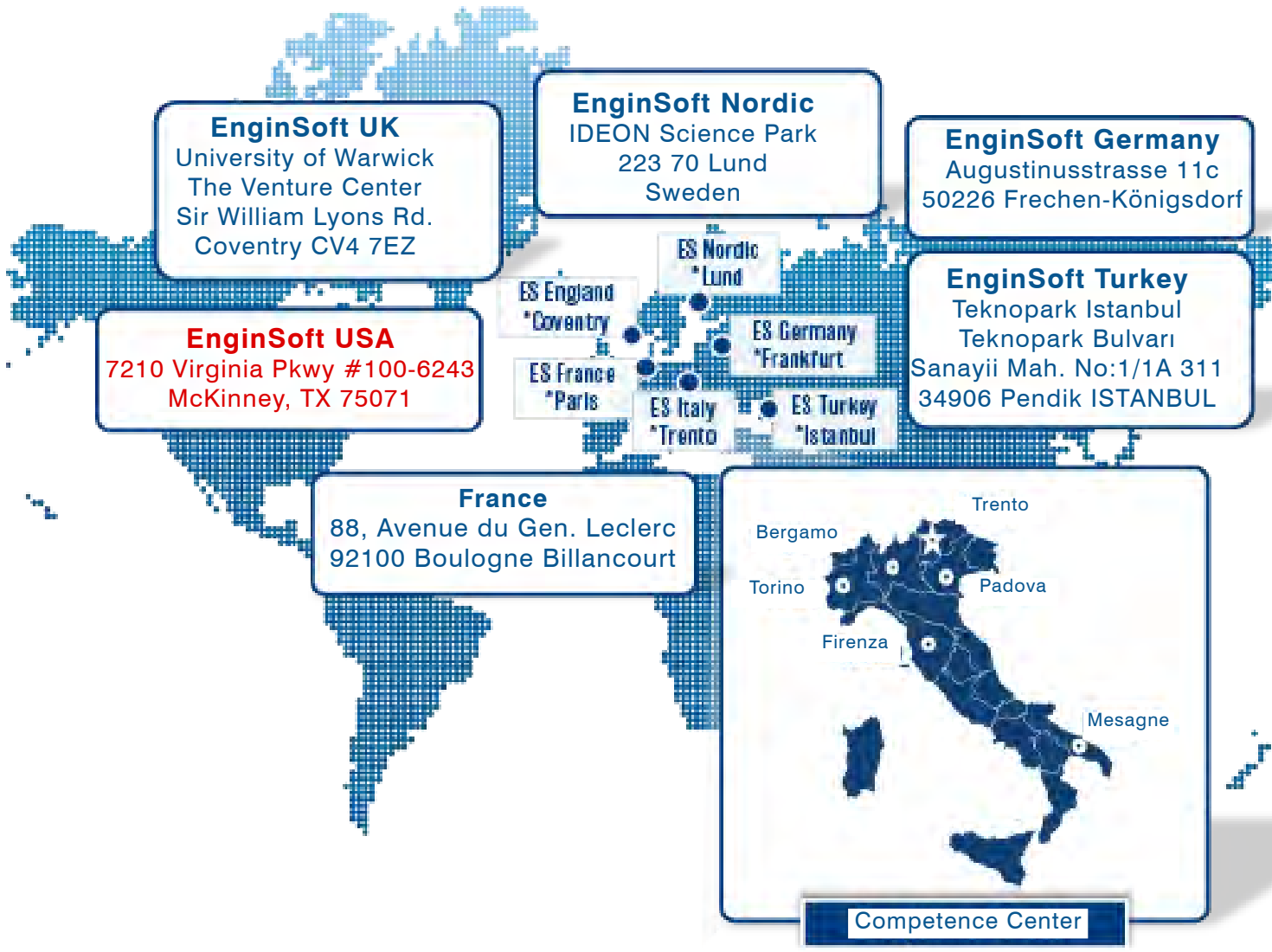
Technology for Specific Industrial Context

We assist clients to find the optimal solution to meet their particular needs – either by identifying and recommending the best available combination of commercial software packages, or by building custom modules based on our knowledge and experience, and then ensuring smooth integration between all of these products and the customer's existing software investments. This requires ongoing collaboration with customers and commercial software vendors.

Multidisciplinary Simulation

We advocate the use of multi-disciplinary technologies to provide engineers, at every stage of the product cycle, a clear picture of the impact on the whole project. No matter how small, each part and process in the chain must be considered when creating robust, accurate, reliable simulation models.

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ES Nordic
°Lund

ES France
°Paris

ES Germany
°Frankfurt

ES Italy
°Trento

ES Turkey
°Istanbul

Trento
Bergamo
Torino
Padova
Firenza
Mesagne

Competence Center

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RECURDYN

Professional Multi Flexible Body Dynamics Simulation Software

- Professional
- MFBD
- Particle Interface
- Control
- CoLink
- Automation / Customization
- DOE & Optimization
- Toolkits

The Concept of Multi-Body Dynamics

Multi-Body Dynamics predicts the dynamic behavior of an assembly in motion, where forces may be applied to one or more rigid bodies that are connected to each other through kinematic constraints or contacts. It uses rigid bodies to perform a transient analysis, which allows you to obtain results quickly.

MFBD (Multi Flexible Body Dynamics) is a technology that analyzes the dynamic behavior of systems in motion which include both rigid and flexible bodies. The use of flexible bodies provides more accurate results for many applications because the vibration and structural damping of the flexible bodies is included in the simulation.
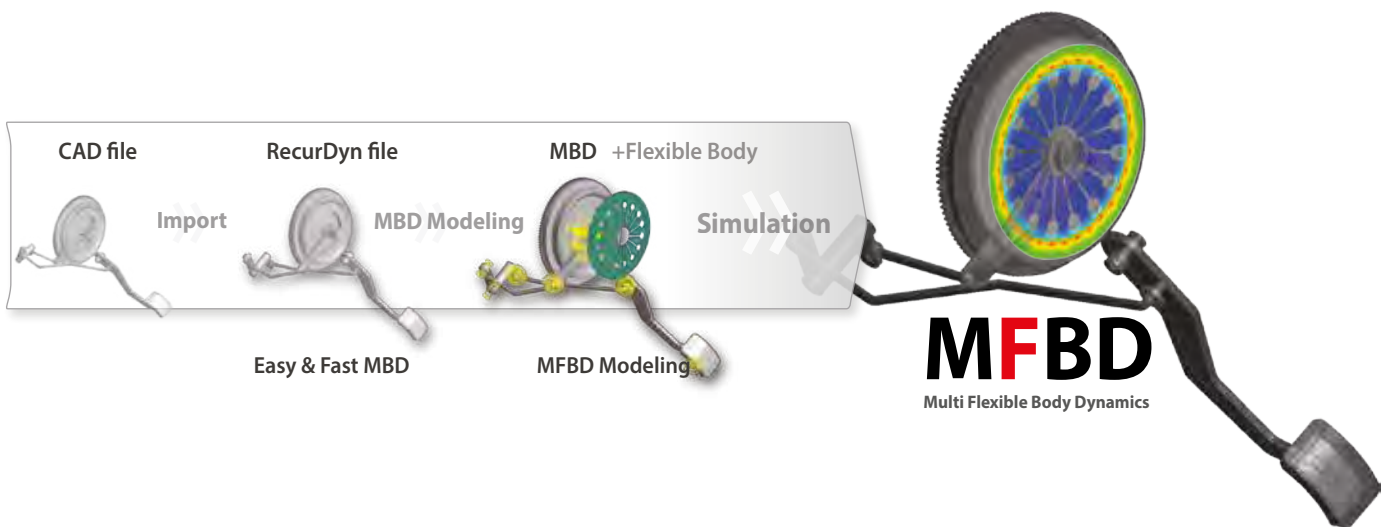
The MBD analysis results include the position, velocity and acceleration of each body and the reaction forces or frictional forces at each constraint (joints, etc.) as well as forces at each contact. With these outputs, you can view and understand the dynamic behavior of the system. Flexible bodies output stress and strain.

These outputs can also be used as input values for structural analysis or durability analysis. When analyzing an MFBD model, it is possible to verify the results of a flexible body's deformation, stress and strain. These outputs can be also used to better understand the behavior of the assembly.

You can create and simulate virtual models instead of building real mechanical systems, reducing the costs and time required to design and develop a product.

MBD is widely used in many industries, including automotive, aerospace, industrial machinery, construction, electrical/electronics, and defense. MBD is used to predict the dynamic behavior of a system, load calculation and vibration, and to simulate mechatronics systems such as robots, which require precise control. It is also used to simulate the coupled interaction between solid bodies and fluids in motion (lubricant in an engine or water behavior in a washing machine, etc.)

5 Advantages of RecurDyn

1 **Pre/Post environment specialized for MBD analysis**

MBD analysis requires a complete modeling environment to enable the definition of a variety of mechanical systems, including the definition of inputs and post processing (animation and plotting).
RecurDyn provides a fast and efficient modeling environment. The MBD optimized UI is based on the feedback from experts and engineers in the field of MBD.

2 **Fast, accurate and diverse Contact library**

Sophisticated technology is required to calculate contacts in a mechanical system. RecurDyn enables you to quickly and accurately analyze contacts in a complicated model using world-class contact algorithms. In addition, the Contact library is optimized for specific geometries such as ellipsoid, cylinder, or box.

3 **Analysis of the motion of an assembly containing rigid and flexible bodies**

MFBD technology can accurately simulate a system containing rigid and flexible bodies. It is possible to simulate nonlinear elastic cases including contact and large deformation as well as linear elastic cases. The processes of mesh creation and durability analysis are also supported within RecurDyn.

4 **Various application toolkits**

Various toolkits support complex sub-systems including drivetrains, media transport products such as printers and copiers, tracked vehicles such as construction machinery, machinery components such as chains and belts. The toolkits allow users to perform modeling quickly and easily, enabling an accurate analysis with specialized solvers.
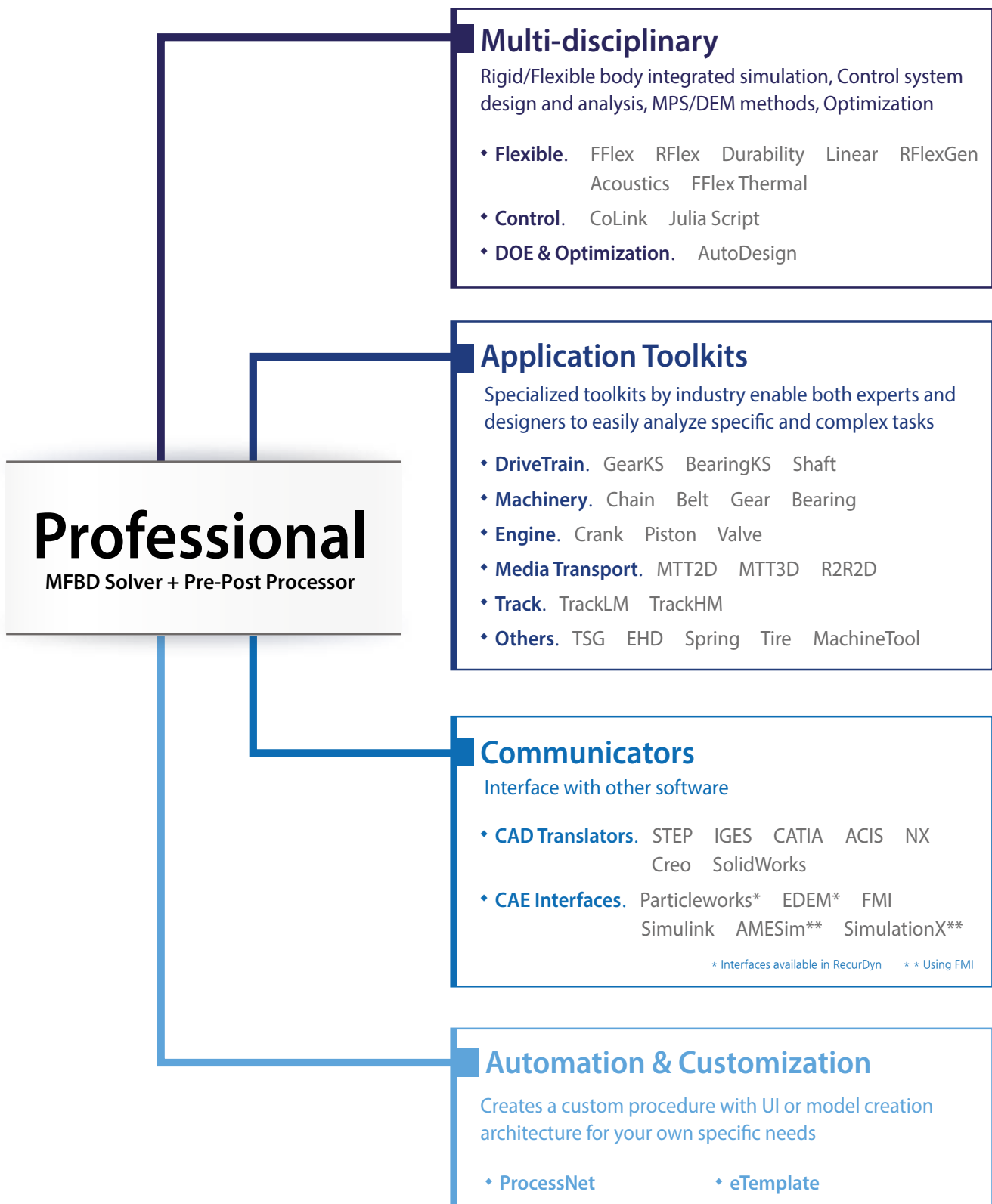
5 **Scalability for multidisciplinary integrated analysis**

RecurDyn provides the scalability for multidisciplinary integrated analysis such as simulation between the mechanical system and fluids through co-simulation with CFD software, control system simulation through co-simulation with Simulink, AMESim, SimulationX..., and optimal design of mechanical systems using robust optimization algorithms.

works
CFD

MBD

MFBD

DEM

Control

MBS-FE Coupling

EDEM

CoLink

Simulink

FMI

SimulationX

Product Components

RecurDyn combines dynamic analysis of rigid bodies and nonlinear flexible bodies experiencing large deformations and contact with control system analysis, optimization, and particle-based fluid and granular material analysis using the MPS and DEM methods.

Professional
**MFBD Solver + Pre-Post Processor**

Multi-disciplinary

Rigid/Flexible body integrated simulation, Control system design and analysis, MPS/DEM methods, Optimization

- **Flexible**.   FFlex   RFlex   Durability   Linear   RFlexGen   Acoustics   FFlex Thermal
- **Control**.   CoLink   Julia Script
- **DOE & Optimization**.   AutoDesign

Application Toolkits

Specialized toolkits by industry enable both experts and designers to easily analyze specific and complex tasks

- **DriveTrain**.   GearKS   BearingKS   Shaft
- **Machinery**.   Chain   Belt   Gear   Bearing
- **Engine**.   Crank   Piston   Valve
- **Media Transport**.   MTT2D   MTT3D   R2R2D
- **Track**.   TrackLM   TrackHM
- **Others**.   TSG   EHD   Spring   Tire   MachineTool

Communicators

Interface with other software

- **CAD Translators**.   STEP   IGES   CATIA   ACIS   NX   Creo   SolidWorks
- **CAE Interfaces**.   Particleworks*   EDEM*   FMI   Simulink   AMESim**   SimulationX**

* Interfaces available in RecurDyn   * * Using FMI

Automation & Customization

Creates a custom procedure with UI or model creation architecture for your own specific needs

- **ProcessNet**   - **eTemplate**

▊▊Various application examples
▊Automotive

You can analyze the dynamic behavior or calculate the load applied to each component by performing dynamic analyses on the full vehicle, suspension, engine, and clutch, considering various driving and operating conditions.
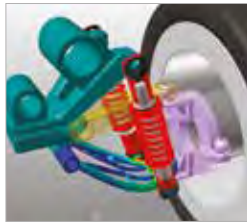
▊Camera

You can analyze the behavior of a camera lens barrel during zoom operations based on the operation of the camera gear train.
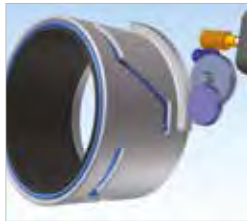
▊Robot

You can use dynamic analysis to calculate the dynamic load applied to each connection when the robot moves in various ways.

▊Landing Gear

You can analyze the retractable mechanism of the landing gear as well as the vibrations, sliding and the load applied to the landing gear when the airplane takes off or lands.
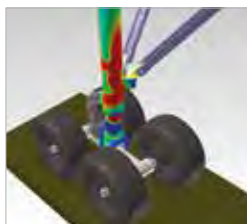
▊Printer, Flexible Media

Design transfer systems using a model that considers detailed sheet behavior, sensors, air resistance, suction power and static electricity.
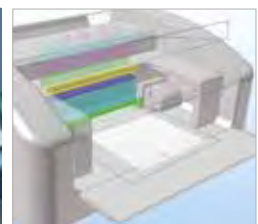
▊Construction Machinery

You can use analysis to calculate the load applied to each component during the digging and transport operations.

▊Machine Tools

You can calculate the load applied to each connection when a machine tool is in use.

* In addition, RecurDyn is widely used in many other fields including the defense industry, agricultural machinery, and biotechnology.

Professional

RecurDyn's intuitive and sophisticated GUI runs on the Windows operating system.
RecurDyn includes various libraries of bodies, joints, and forces for rigid body modeling as well as various contact libraries that enable you to easily model mechanical systems. The rigid body solver, which is based on a recursive formulation, can perform dynamic and static analyses (and others) quickly, accurately, and robustly. RecurDyn also includes various functionalities to aid in the analysis of the results such as 3D animations and plots.

Intuitive UI

The UI allows designers to perform modeling quickly and conveniently.

High-Performance Graphic Engine

The MBD-optimized graphics engine easily manipulates complex models.

Easy Modeling of Rigid Body Geometry

High compatibility with CAD software because of the embedded Parasolid Kernel
(Imports CAD data in STEP, CATIA, NX, Creo, SolidWorks, IGES, and STI formats – CAD hierarchy considered)
Support for geometry creation and editing (even for imported geometry)

Fast and Convenient Post-Processor

The animation and plot outputs allow you to easily and intuitively examine the results of a dynamic analysis, such as the magnitude and direction of the displacements, velocities, accelerations, and forces.

Fast and Accurate Solver

The recursive formulation and the implicit G-Alpha integrator perform simulations quickly, accurately, and robustly.
The contact algorithms of RecurDyn are exceptionally robust, enabling the analysis of problems with complex contacts.
Solver supports both rigid and flexible bodies

Parametric Study and DOE

Support for parametric study and DOE by easily defining parameters as parametric values

▌▌Various Contacts

▌General Contact

- Available for any geometry
- Contacts are readily defined for imported CAD geometry.

- Contact elements based on Hertzian theory
  (Nonlinear stiffness)
- Consideration for friction effects
  (Kinetic friction/Static friction, Linear/Nonlinear)
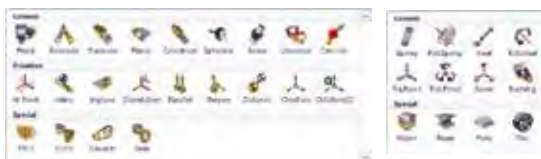- Easily definable contact among multiple bodies

▌Primitive Contact

- Faster and more accurate analysis is possible for specific geometries. (Sphere, Cylinder, Box, Torus, etc.)

- Noise reduction of contact forces through a smoothing algorithm
- Magnitude and direction of contact force displayed on the screen
- Multiple, distributed contact forces are displayed
  (Geo Contact family)
- Fast calculation using SMP

▌▌Various Joints and Forces

- Support for various joint and force elements necessary for mechanical system modeling
- Gear, Coupler, Point on Curve, Curve on Curve
- Special force elements such as Beam Force, Plate Force

▌▌Subsystem

- Complexity reduction and enhanced recyclability by modeling each sub-assembly in the system independently

▌▌General Purpose Sensor

- Capable of modeling two types of general-purpose sensors (box and laser)

Box

Point

Sensor Direction
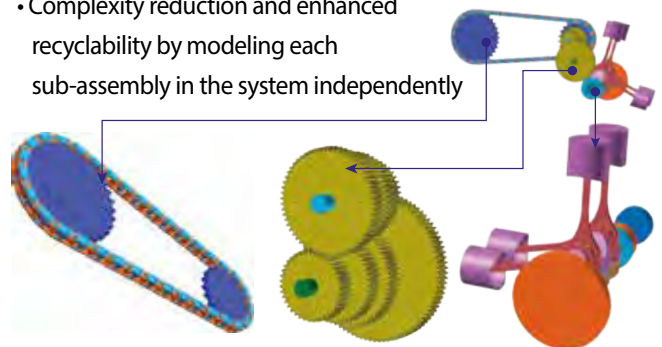
▌▌Function Modeling with Text Expressions

- Formula definition using various math functions and functions that extract current values in the model during simulation
- Ability to define time-varying position of bodies, forces, and user defined constraint equations
- Ability to process analysis results (results after analysis) into desired quantities
- Objective function definition for DOE and optimization

▌▌Relation Map

- Easy to read diagram that shows the topological relationship of the various elements in the multibody dynamics model
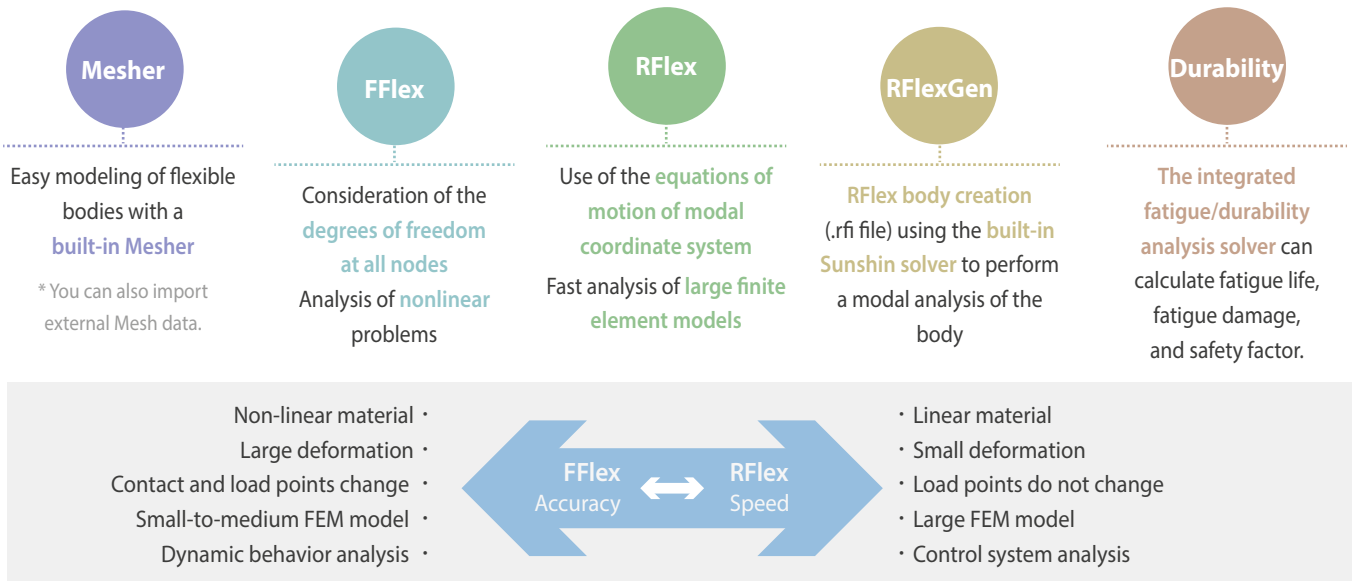
▌▌Post Processor

- Result verification using an integrated Post Processor
- System's movement verified through animation
- Plots display position, velocity, acceleration and reaction force
- Contour plot for time-varying stress and strain that can be confirmed by animation and output to AVI file.
- Easy to export data to a file that can be opened with Excel
- Various processing functions such as interpolation, calculus, FFT and filter
- Gap measurement/Interference Check
  · You can determine the minimum distance between multiple bodies or detect interferences.
  · You can determine the changes in values through animation after analysis.

MFBD

MFBD (Multi Flexible Body Dynamics) in RecurDyn is a technology to analyze the dynamic behavior of systems which include both rigid bodies and flexible bodies. It is the combination of MBD (Multi-Body Dynamics) analyzing the rigid body motion and the Finite Element Method (FEM) to analyze the motions, stresses, and deformations within flexible bodies. RecurDyn's solver combines with these two components into a single solver. RecurDyn is much faster and more robust than a co-simulation approach.

Two flexible body formulations are supported in MFBD in RecurDyn. One is modal superposition, in which the deformation of a body is represented by a set of linear mode shapes obtained from an eigen analysis of the flexible body. The other is the nodal (or mesh-based) method, in which all nodal degrees of freedom are considered. The nodal method supports both nonlinear geometric deformation and nonlinear material formulations, such as plastic strain and large-strain rubber-like hyperelastic materials. RecurDyn's powerful analysis environment combines both the modal and the nodal methods into the same solver, giving RecurDyn an incredibly robust, fast, and reliable solver.

Flexible body meshes can be either imported from externally created FE meshes, or the meshes can be conveniently created directly inside of RecurDyn using its built-in mesh engine. RecurDyn is the first Multi-Body Dynamics analysis software to incorporate a mesher, allowing the user flexibility and convenience in MFBD modeling and analysis.

Mesher	**FFlex**	**RFlex**	**RFlexGen**	**Durability**
Easy modeling of flexible bodies with a **built-in Mesher** *You can also import external Mesh data.	Consideration of the **degrees of freedom at all nodes** Analysis of **nonlinear** problems	Use of the **equations of motion of modal coordinate system** Fast analysis of **large finite element models**	**RFlex body creation** (.rfi file) using the **built-in Sunshin solver** to perform a modal analysis of the body	**The integrated fatigue/durability analysis solver** can calculate fatigue life, fatigue damage, and safety factor.

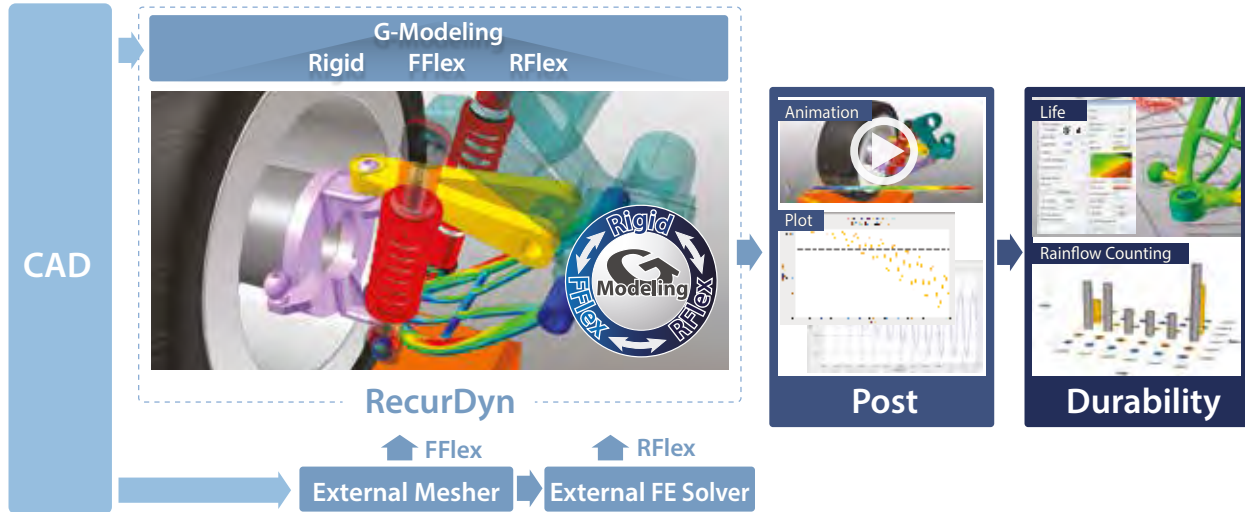| Non-linear material · Large deformation · Contact and load points change · Small-to-medium FEM model · Dynamic behavior analysis ·	**FFlex** Accuracy ⬌ **RFlex** Speed	· Linear material · Small deformation · Load points do not change · Large FEM model · Control system analysis

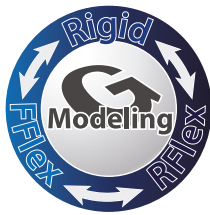## ■ Modeling and Analysis Highlights

- FFlex and RFlex can be used at the same time.
- Mesh-Pre-Solve-Post (one-stop process) within RecurDyn
- Convenient conversion of Body type (Rigid↔Flexible)
- Existing Joint, Force and Contact connections are preserved when the body type is converted.
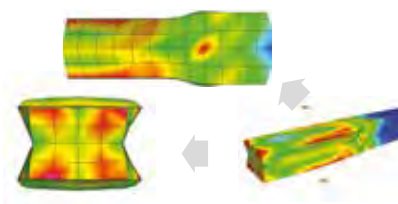
CAD file   RecurDyn file   MBD   +Flexible Body

Import   MBD Modeling   Simulation

Easy & Fast MBD   MFBD Modeling

MFBD
Multi Flexible Body Dynamics
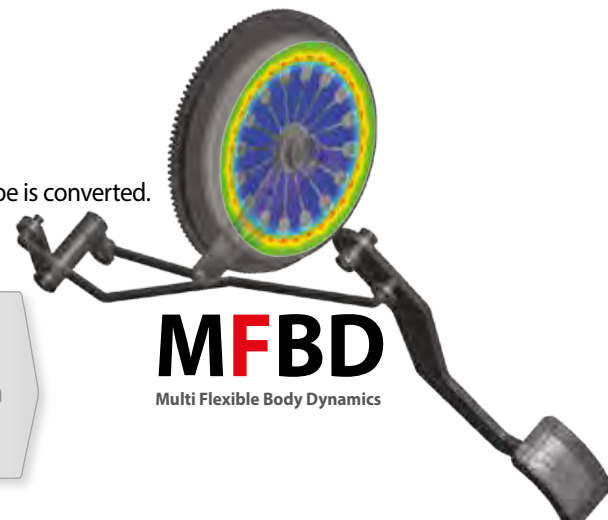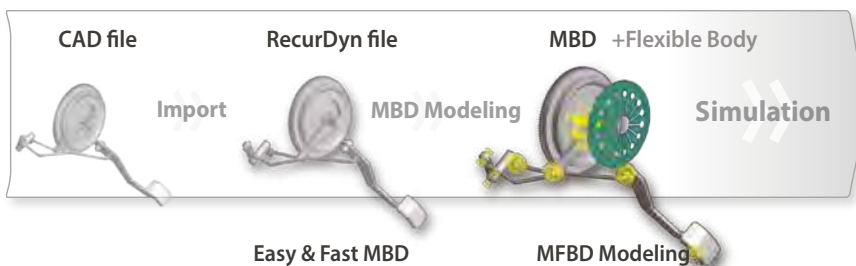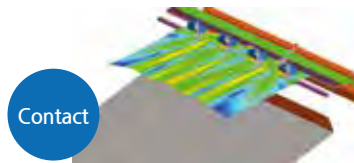
Modeling and Analysis Process in MFBD
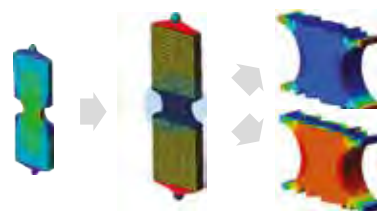

Differentiators of MFBD

Convenient conversion of Body type
(Rigid↔Flexible)
(existing Joints/Forces/Contacts are preserved.)
Same Joint/Force/Contact can be used.
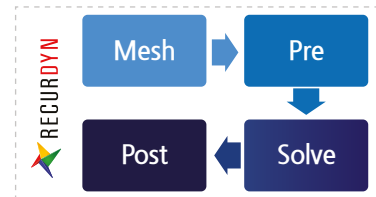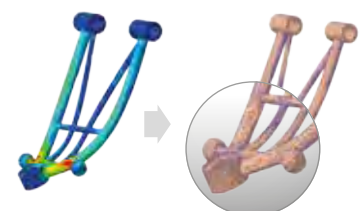regardless of the body type.

Contact between different types of bodies
(Flexible-Flexible / Rigid-Flexible / Rigid-Rigid)
Self Contact between surfaces
on the same flexible body

One-stop process within RecurDyn

Nonlinear material properties

Durability Analysis using
MFBD analysis results

Extract mesh data from
the analysis result
(Preserving Residual stress)

Other features of MFBD

- 2D and 3D contacts
- Boundary conditions can be defined for individual nodes.
- Support for various rigid body elements (Rigid, Interpolation)
- Support for various elements (Beam, Shell, Solid, Rigid)
- Fast analysis using SMP support
- The results can be output in the FEMFAT format.
- Support for noise source analysis using ERP in Acoustics toolkit

- Nodal flexible bodies can be created by importing mesh data generated externally.
  (ANSYS, Nastran, Design Space formats are supported.)
- Modal flexible body can be created by importing modal analysis results generated by external FEA software.
  (ANSYS, Nastran, IDEAS, RADIOSS/OptiStruct are supported.)
- Fast and accurate static analysis of MFBD models

MFBD

◼ FFlex

- MFBD analysis toolkit for simulating rigid and flexible bodies together
- Not only flexible body contact but also geometric nonlinearity (large deformation/rotation) and material nonlinearity (plastic/hyperelastic material) can be considered.

- Import meshes generated from third party meshing software (ANSYS (*.cdb, *.inp), Nastran (*.bdf, *.dat))
- Support for various boundary conditions (constraint, initial velocity, concentrated load)
- Joints, forces, and contacts can be applied to flexible bodies in the same way as rigid bodies
- Flexible-Flexible Contact, Rigid-Flexible Contact, and Self Contact
- Support for Thermal Load

MBD   MFBD
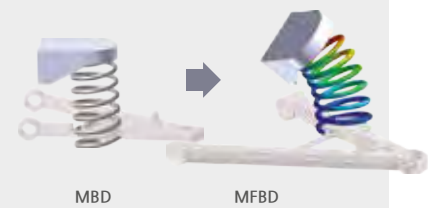
◼ Mesher

- Built-in mesher in RecurDyn to generate high quality meshes for MFBD analysis quickly
- Existing joint, force and contact connections defined in the rigid body are preserved after meshing.
- Automated process using G-Modeling enables MFBD model creation faster and more efficiently than using an external mesher.

- Automatic mesh functions specialized for MFBD models (Beam, Shell3, Shell4, Solid4, Solid6, Solid8, Solid10)
- Local Mesh, Remesh, and Manual Mesh for mesh quality improvement
- Geometry Refinement to remove unnecessary small shapes in the mesh
- Node Split, Node Merge and Mesh Spin/Sweep to create high quality elements
- Intuitive and detailed Quality Check for high quality mesh creation

◼ RFlex

- RFlex can solve the MFBD model with large flexible bodies faster by using modal analysis results.
- Easy to convert rigid bodies and FFlex bodies into RFlex bodies using G-Modeling and RFlexGen

- Flexible body can be created by importing modal analysis results generated by external FEA software (ANSYS, Nastran, IDEAS)
- Simulation time can be adjusted by checking and selecting the mode to be used for analysis
- Support for Frequency Response Analysis (FRA)
- Joints, forces, and contacts can be applied to flexible bodies in the same way as rigid bodies
- Flexible-Flexible Contact, Rigid-Flexible Contact

FE Model   Mode Shape

MBD   MFBD
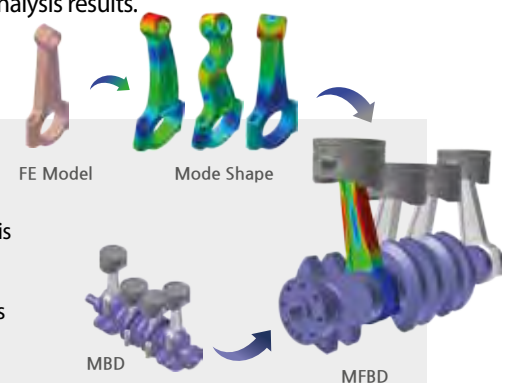
◼ RFlexGen

- RFlexGen is a toolkit to create RFlex bodies (rfi files) in RecurDyn without any additional FEA software.

- RFI creation to generate RFlex bodies through modal analysis result
- Easy 'Interface Node' definition using Node Set
- DOF of each node and the number of modes to be generated can be specified
- Various options for optimizing RFI file size and processing speed

G-Modeling

- Easy and intuitive conversion between rigid and flexible bodies makes anyone conveniently take advantage of MFBD technology so that MFBD modeling is now easier for beginners and more efficient for experienced users.
- Joints, forces, and contacts can be applied to both rigid and flexible bodies and existing joints, forces, and contacts are preserved when the body type is converted.
- Maximizes the simulation efficiency by freely changing the body type according to the purposes, such as analysis speed, accuracy, and etc.
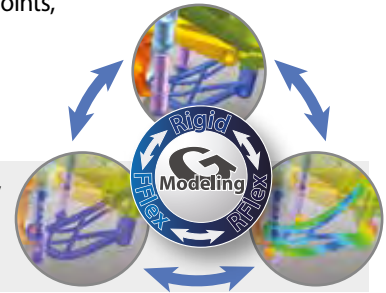
  - Easy conversion among Rigid, FFlex, and RFlex bodies to improve the simulation speed or accuracy
  - Automatic creation of FDR (RBE) and Patch Set to preserve the existing joints, forces, and contacts when converting the body type

Durability

- Toolkit to calculate fatigue analysis results such as fatigue life, fatigue damage, and safety factor from MFBD analysis results
- Determines the location where fatigue failure can occur and predicts its direction as well as the fatigue analysis results
- Easy durability analysis using MFBD analysis results in RecurDyn without other third party software

  - Support for various fatigue life prediction methods
    (Manson-Coffin, ASME, Brown-Miller, Morrow, Smith-Watson-Topper, Goodman)
  - Durability analysis using dynamic simulation results over time
  - Provides about 180 material libraries
  - Stress calculated in FEA software can be applied as pre-stress
  - Displays Rainflow-counting and Stress/Strain Time History for the region of interest
 - Contour plot of fatigue analysis results

Rainflow-counting
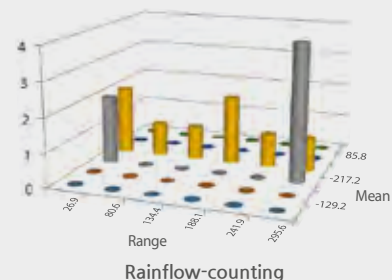
Acoustics

- Acoustics can calculate Equivalent Radiated Power (ERP) that represents the noise characteristics from the MFBD analysis results.
- Prediction and analysis of the noise source of a system by checking ERP distribution (which parts of a flexible body may emit more noise and which frequency band is dominant)

  - Calculates the noise characteristics of the system with minimal parameter inputs.
  - ERP calculation can be performed only for the specified time domain, enabling efficient post-processing
  - Calculates the ERP for the defined Patch Set using the MFBD analysis results
  - ERP results can be displayed on the surface of a flexible body as contour plot during animation.
  - ERP results can be displayed as various types of graphs through the Scope dialog box.
  - The contribution of each mode of RFlex body to the noise can be analyzed so that the dominant vibration mode that affects the noise can be confirmed.
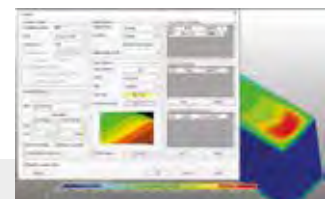
Contour plot of ERP
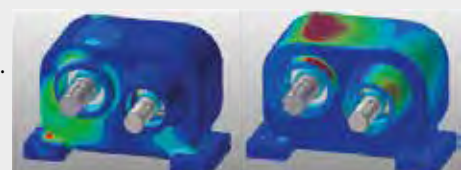
Noise source determination using ERP

Particle Interface (EDEM & Particleworks)

RecurDyn contains an interface specially for co-simulation between RecurDyn and either fluid or granular dynamics software. This allows RecurDyn to simulate rigid body dynamics properly interacting with fluids or granular materials. RecurDyn is the world's first commercial Multi-Body Dynamics software to offer such an interface. This interface allows you to easily simulate complicated fluid-solid interactions that were very difficult to simulate in the past.
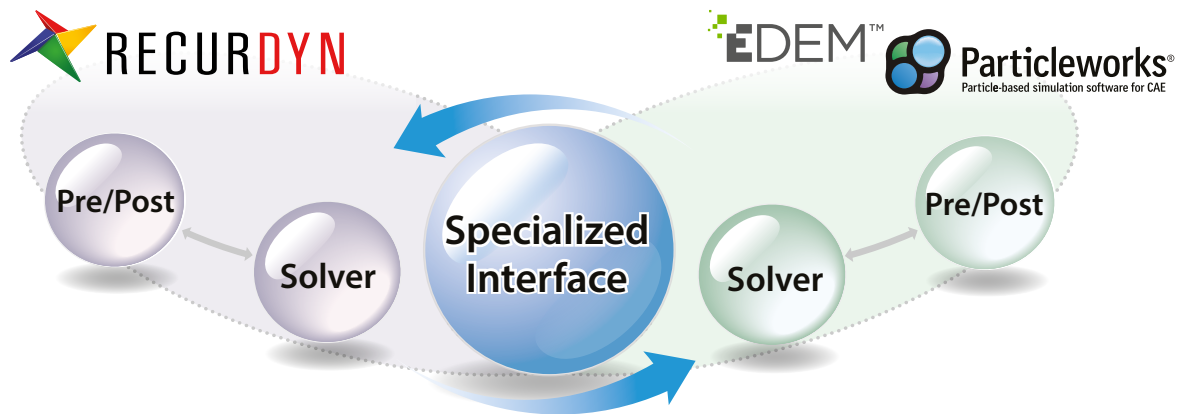

■ RecurDyn X EDEM

- Setting up and running a co-simulation between EDEM and RecurDyn is very simple and intuitive.
- Particle results calculated by EDEM can be animated in the RecurDyn environment with the RecurDyn model results.
- Co-simulation of EDEM with RecurDyn achieves more accurate results, enabling deeper potential for analysis of the interaction between granular particles, such as gravel, stone, sand and mud, and the mechanical system or applied load.

■ RecurDyn x EDEM Co-simulation Examples

Co-simulations between EDEM and RecurDyn enable powerful analyses of material handling and off-road machine handling characteristics. For example:

- **Automotive/Construction machinery:** Analysis considering the driving characteristics of special vehicles and equipment in off-road environment and the effect of bulk particles
- **Mining industry equipment:** Design and evaluation of equipment used for mining and transport of minerals
- **Agricultural machinery:** Development and verification of agricultural machinery such as cultivators or harvesters
- **Chemical and pharmaceutical equipment:** Development and evaluation of equipment for mixing, coating, and transporting of various raw materials

Dump Truck

Drill Machine

Construction Machinery

Transport Equipment

Mixer

Offroad Vehicle
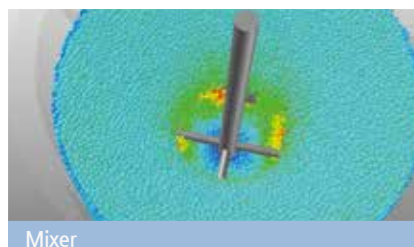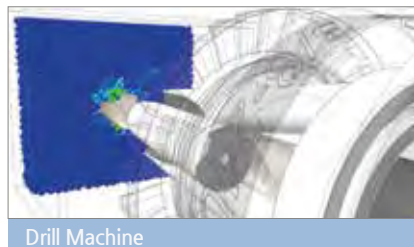
▋▋ Features of Particleworks

Particleworks allows you to analyze fluid behavior precisely and stably without a mesh so that the flow of liquid such as water or oil can be represented using the particles.

It is possible to analyze free surface problems having contacts between two fluids such as water and air or moving-boundary problems.

Particleworks also lets you analyze tens of thousands of particles and large scale analysis using GPU and compute-cluster hardware, making it ideal for co-simulation with dynamic analysis and can further widen its scope through co-simulation with RecurDyn.

Splash phenomena can be simulated
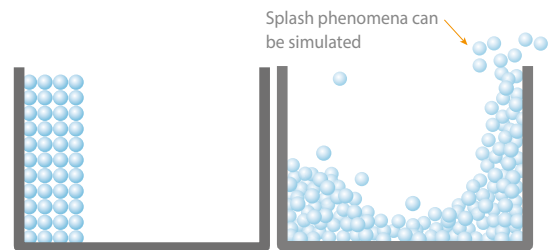
▲ Particle-based CFD methods easily handle free surfaces and moving boundary geometry, and no mesh is used.

▋▋ RecurDyn/Particleworks Interface

- Intuitive UI for easy modeling of co-simulation with Particleworks
- Simulates the interaction between motion of the mechanical system and fluid behavior
- Support for interactions not only between rigid bodies and fluids but also between flexible bodies and fluids
- Animation, contour plot and trajectories of fluid particle results analyzed in Particleworks, can be shown in the RecurDyn environment with the RecurDyn model results.
- Measuring the number of fluid particles in a specified area for each time interval
- Visualizing the outer line of fluid particles in 2D Profiles
- The effect of the behavior of the mechanical system can be seen in the surfaces and turbulence of the fluid.
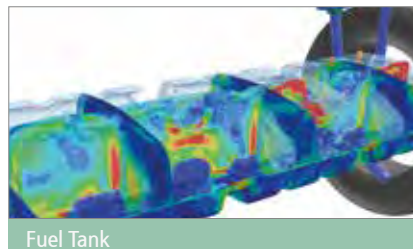- 2-way coupled thermal analysis between FFlex bodies and fluids

Position, velocity and acceleration of mechanical system

Fluid force acting on the parts of the mechanical system
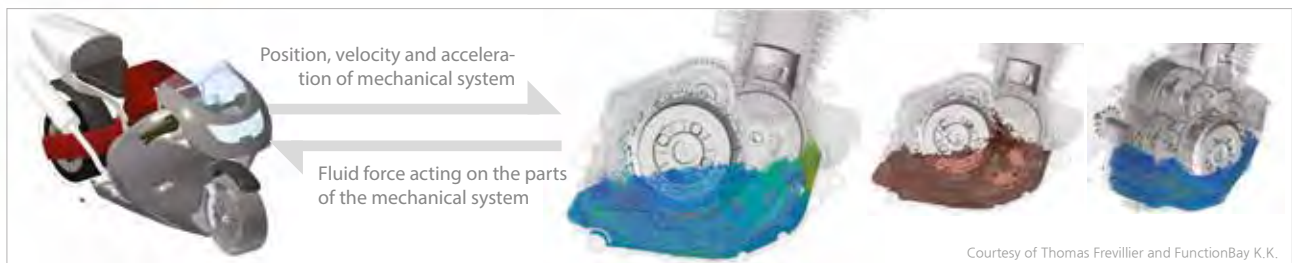
Courtesy of Thomas Frevillier and FunctionBay K.K.

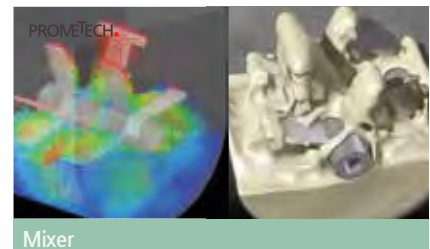## ▋▋ Example - RecurDyn x Particleworks Co-simulation

- A vehicle on a flooded road
- Fuel behavior in fuel tank
- Agitation of high-viscosity fluid
- Oil sloshing of a powertrain
- Vibration evaluation and reduction of washing machine
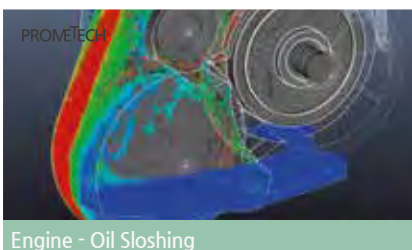- Viscosity according to the temperature of lubricating oil

RECURDYN X Particleworks

The National Crash Analysis Center (NCAC) of The George Washington University under a contract with the FHWA and NHTSA of the US DOT

Automotive

Fuel Tank

PROMETECH

Mixer

PROMETECH

Engine - Oil Sloshing

Washing Machine

Engine - Hot Oil vs Cold Oil

Control

Accurate and robust models of a mechanism are required for the design and parameter optimization of control system algorithms, as well as their reliability verification. RecurDyn provides a diverse set of tools to analyze mechanism models coupled with the control system algorithm.

RecurDyn provides an interface for co-simulation with the MATLAB/Simulink software that is widely used in mechatronics. In addition, RecurDyn supports FMI to incorporate the use of AMESim and Modelica-based applications. RecurDyn/CoLink allows for fast and accurate control system analysis through the deep integration of the control simulation code with RecurDyn's dynamics solver.
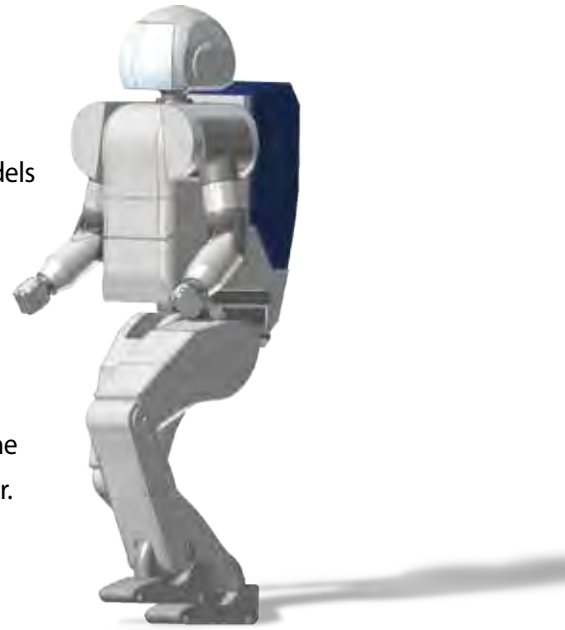
◼ MATLAB/Simulink Interface

RecurDyn/Control includes an interface for co-simulation with MATLAB/Simulink. This allows mechanical systems that contain control and drive systems, such as controllers and motors, to be analyzed.

- RecurDyn/Control includes an interface which allows it to utilize a realistic dynamic model of RecurDyn in a MATLAB/Simulink model.
- It is possible to use a RecurDyn model including contacts or flexible bodies as well as various joints or forces in the model created by Simulink.
- A RecurDyn model can be integrated with a Simulink model using a UI which easily creates an S-Function for the RecurDyn Plant model.
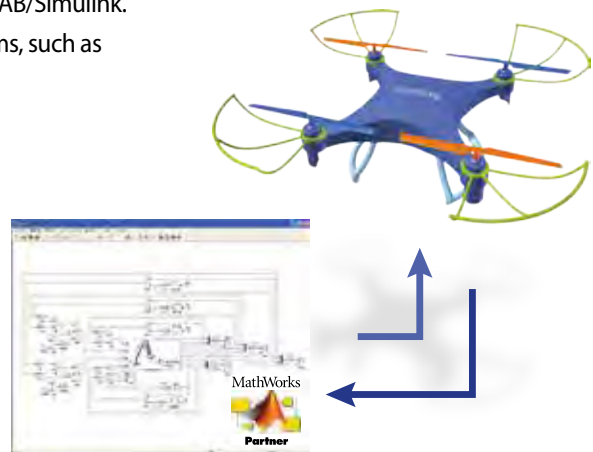
◼ FMI (Functional Mockup Interface)

- RecurDyn supports FMI, a standard interface based on Modelica, and co-simulation with applications that support FMI.
- Support for co-simulation with AMESim, SimulationX, Simplorer, ...
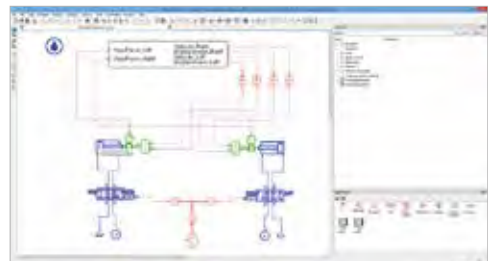
CoLink

RecurDyn/CoLink, a control system simulator integrated into RecurDyn, allows the user to model complicated control systems, electrical systems and hydraulic systems. It also provides a platform for integrated analysis of firmware design, electronics design and mechanical system design by connecting with RecurDyn model.
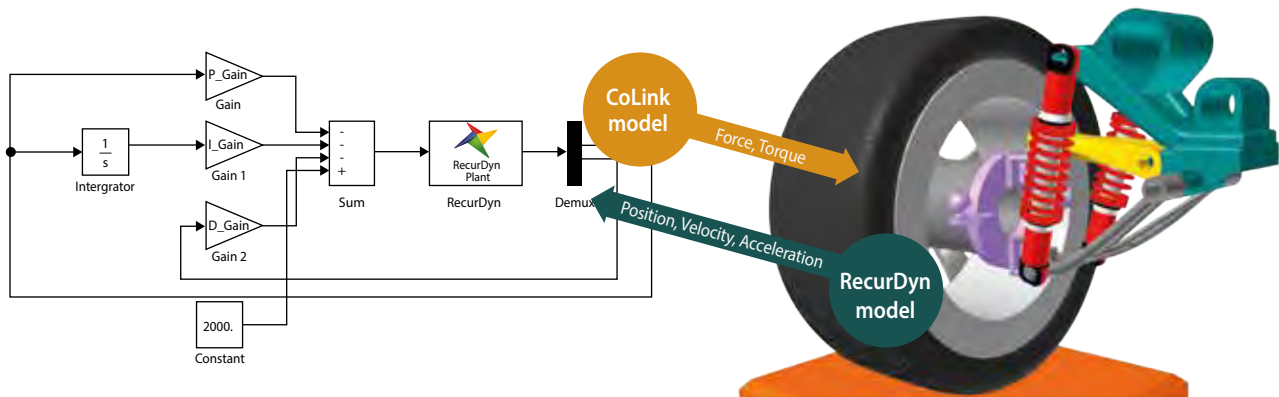
Simple Modeling using Block Diagram

Modeling of a complicated mechatronic system can be easily performed because it is possible to represent a control system with a logical block diagram. The data transfer between the controller and the mechanical system is clearly defined.

Various Block Libraries

Frequently used block libraries in the electrical/electronic/control system are provided to allow the user to easily create a complicated controller.

Fast Simulation using the Integrated Solver with RecurDyn

• An integrated solver can simultaneously analyze the dynamic model and the controller as a continuous system and provide a fast and accurate analysis.
• A discrete system can also be analyzed by co-simulation.
  (A CoLink model with no connection with a RecurDyn model can be also analyzed.)

Example - Copier Control Simulation

• When a sensor detects a sheet, a roller starts operating and transports the sheet.
• It is possible to verify the change of sheet properties (bending/crumpling) or proper operation timing in advance (CoLink and MTT2D are required.).

Example - Hydraulic Control Simulation of Lifting Equipment Attached to an Agricultural Machine

Courtesy of NewtonWorks Corporation and FunctionBay K.K.

• It is possible to verify the complex lifting behavior in an agricultural attachment with a hydraulic cylinder in advance.
• This was done using co-simulation between RecurDyn and SimulationX (1D-CAE software) using FMI.

Automation / Customization

The design and simulation of a mechanical system can be made more efficient by the automation of repetitive tasks and the use of customized user interfaces. RecurDyn provides a specialized environment for the automation of repeated tasks and custom UI creation.

■ RecurDyn/ProcessNet

RecurDyn/ProcessNet is a powerful, script-based customization environment that is built into RecurDyn/Professional. RecurDyn/ProcessNet allows users to create their own GUI features for RecurDyn that can manipulate model data, create customized dialog boxes and UI features, automate tasks, and encapsulate domain knowledge and best practices. RecurDyn/ProcessNet can access and manipulate both pre-processing data and post-processing data. RecurDyn/ProcessNet supports Python, C#, and VB.NET. Through RecurDyn/ProcessNet users can dramatically extend the functionality of RecurDyn/Professional to meet their unique simulation requirements.

- Various RecurDyn APIs allow you to develop a variety of customized features using Python, C#, or VB.NET.
- Automation of repetitive tasks and personalized UI development are available using simple programming.

Level 1	Level 2	Level 3	Level 4
Batch Run (simple automation)	User-created interface	Integrated utility within RecurDyn	New concept of Toolkit Application

■ RecurDyn/eTemplate

- RecurDyn/eTemplate is a tool that enables RecurDyn model data to be stored in Microsoft Excel spreadsheets. RecurDyn/eTemplate can read the spreadsheet data and create the RecurDyn model.
- RecurDyn/eTemplate is extremely powerful, yet simple, intuitive, and easy to use. It can be used as a powerful customization tool to make managing model data much more efficient.
  · Through eTemplate, users with little experience with RecurDyn can create and modify models and perform powerful analysis.
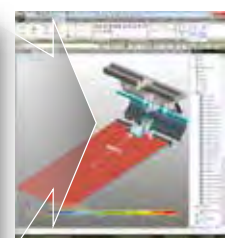
■ RecurDyn/Expression Helper

The RecurDyn Expression Helper helps you to more efficiently build expressions which are frequently used during system modeling. You can create various expressions by inputting intuitive parameters using Excel.

The Expression Helper can be downloaded for free from FunctionBay Technical Support website.
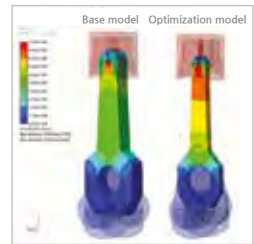
DOE & Optimization

Designing a mechanical system often involves optimizing the design variables with respect to specific performance metrics. RecurDyn provides a high performance optimization tool, AutoDesign, that requires very little knowledge of optimization to use because of its straightforward user interface.

▌▌ Unique Characteristics of AutoDesign

- Easy and intuitive interface which allows anyone to use with a little practice
- The world's first progressive meta-model algorithm, motivated from Bayesian Global Optimization
- Easy definition and customization of the design variables and objective functions
- Robust design optimization techniques to consider uncertainties such as tolerances and noises
- Multi-scale optimization techniques to solve the problems which have the different scales of design variables
- Easy and powerful multi-objective optimization algorithm which can be used regardless of the number of objectives
- Optimization with very small number of trials
  For example, it used only 116 analyses to optimize a design that had 105 design variables and 14 performance indices.

▌▌ Various Features of AutoDesign

▌ **Design Study :** Design Study provides 6 methods for DOE (Design Of Experiments).
- Provides ways to perform DOE with the optimal number of samplings.
- 2-level and 3-level orthogonal array experiments are automatically generated according to the number of design variables.
- Descriptive DOE which allows the users to define the level and the number of experiments
- Effect analysis, screening variables and correlation analysis are supported.

▌ **Design Optimization :** Design Optimization provides the functions for optimization of the system using the meta-model.
- Progressive meta-model based on optimization technique is employed to reduce the number of trials (analyses).
- Even beginner users can use optimization using automated methods.
- Various options are supported for the experienced users.
- The existing optimization results can be reused.
- All difficult selections of optimization algorithms are automated.

▌ **DFSS/Robust Design Optimization :** Optimization for DFSS (Design for Six Sigma) is supported.
- Progressive meta-model based on optimization technique is employed to reduce the number of trials (analyses).
- Approximate variance of performance during optimization process can be estimated.
- Users can define the tolerance and deviation of random design variables and random noise.
- Adaptive 6-sigma inequality constraints are considered unlike the other optimization tools which focus on only statistical dispersion.
- User can define the robustness of objective functions.

▌ **Reliability Analysis :** Revolutionary algorithm of Reliability Analysis can produce reasonable reliability results with a smaller number of samplings than the traditional methods.
- SAO Hybrid Method: Powerful Reliability algorithm which is integrated with Progressive meta-model based on optimization techniques and MPP-based DRM (Dimension Reduction Method)
- Adaptive Monte-Carlo Method: New method which uses sequentially adaptive Monte-Carlo algorithm to minimize the number of sampling points

DriveTrain

RecurDyn/DriveTrain is a solution that enables to model and simulate the components of a drivetrain consisting of gears, bearings, shaft, and other components. It consists of 3 toolkits: GearKS, BearingKS, and Shaft. Users can easily simulate and analyze drivetrain systems with specialized modelers that can easily create gears, bearings, and shafts, a specialized solver, and dedicated post-processing.

In particular, GearKS and BearingKS have been developed through the technical partnership with Gleason's KISSsoft. This allows users to accurately capture not only transmission error for noise and vibration evaluation but also other results by using the RecurDyn's dynamic solver and KISSsoft's Gear Analytic Contact.

GearKS	BearingKS	Shaft
Intuitive Gear Modeler	Intuitive Bearing Modeler	Intuitive Shaft Modeler
Supports Spur/Helical/Planetary Gear	15 different types of bearings	Flexible shaft to calculate the deformation and torsion
Analysis considering detailed gear geometry	Bearing database of 8 global brands	Automatic FDR creation for bearing and gear engagement
Theory-based contact specialized for gears	Bearing creation with user-defined parameters	Support for Planetary Shaft for planetary gear
Built-in KISSsoft UI for gears		Post-processing specialized for Shaft

◼ 6 Advantages of RecurDyn/DriveTrain

Accurate Gear Analytic Contact
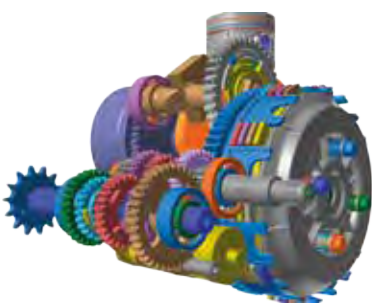Consideration of detailed gear parameters
Accurate prediction of Transmission Error

Easy Modeling with Specialized UI
Modelers for gears, bearings, and shafts
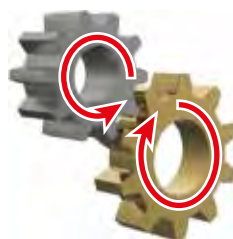Built-in KISSsoft UI for gears

Various Bearing Libraries
17 different types of bearings
Provides bearing database of 7 global brands
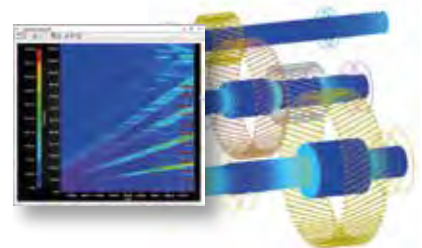(SKF, KOYO, TIMKEN, FAG, IBC, INA, KRW)

System Modeling
Assembly analysis
using MFBD technology

Transient Analysis using Dynamic Solver
Dynamic Transmission Error evaluation
Gear Misalignment by various causes can
be considered

Check the Transmission Errors
Transmission Error determination
Campbell Diagram (Order Tracking Analysis)
Various results of gears, bearings, and
shafts can be reviewed

Gear Analytic Contact of RecurDyn/DriveTrain

- Since Transmission Error is very small (μm) so that the accurate contact calculations are crucial.
- FunctionBay provides accurate Gear Analytic Contact through technical cooperation with Gleason/KISSsoft.
  - Theory-based contact calculation considers detailed gear design parameters.
  - Considers deformation and tolerance of gear tooth.
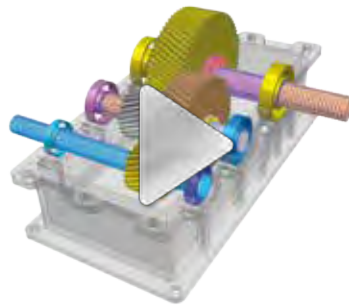- High speed contact calculation through pre-calculation (Gear Meta-Model)

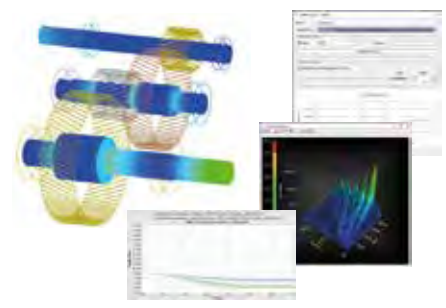## Simulation Process using RecurDyn/DriveTrain
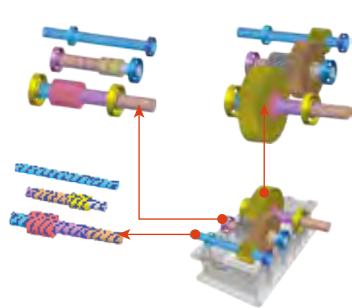
Modeling
Build components (shafts, bearings, gears) and Drivetrain system

Simulation

Post-processing

Benefits of RecurDyn/DriveTrain

Save time and cost by performing analysis under varying conditions in virtual environment	• Precise and detailed gear design
	Various types of bearings
	Various bearing positionings
	Varying operating conditions (rotation speed, torque)

Evaluation of products that are difficult to be tested	• Replacement of the physical test that may cause safety problems or breakage
	Performance evaluation in extreme conditions, such as space and deep sea
	Micro gears used for small parts that are difficult to be measured

Various performance evaluations of Drivetrain system	• Performance evaluation of the system consisting of gears, bearings, and shafts
	Effect analysis caused by gear vibration and shaft deformation
	Whine noise analysis through Transmission Error
	Rattle noise analysis caused by backlash
	Dominant noise source determination and noise reduction (RecurDyn/Acoustics is required)

Machinery

The machinery toolkits contain customized UIs to facilitate the modeling of the elements of mechanical systems common to machinery, such as chains, gears, belts, and bearings. These toolkits have specialized solvers optimized for these elements. This allows the user to perform modeling quickly and easily, enabling an accurate analysis of complicated mechanical systems.

RecurDyn/Chain

The RecurDyn/Chain toolkit dramatically simplifies the modeling of complex chain systems and automatically defines contacts within the chain system, including contacts between the chain links. It also includes a highly specialized solver for chain systems.

- Automatic chain assembly with automatic contact
- Graphical or spreadsheet design of sprocket teeth profile
- Various types of chains
- Various chain system libraries
  - Roller Chain · Multiplex · Silent Chain · Sprocket · Roller · Guide · Chain Links · Lateral Links · Group Guide

RecurDyn/Belt

The RecurDyn/Belt toolkit is used for the modeling of belts and pulleys systems. MFBD technology can be used, which makes it possible to produce more realistic analyses by modeling belts as flexible bodies.
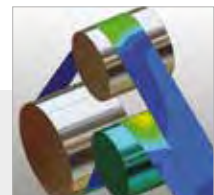
- Automatic belt assembly with automatic contact
- Various types of belts as rigid bodies
- Various types of belts as flexible bodies
  - Flat Belt · V Belt · Ribbed V Belt · Timing Belt
  - Beam · Shell
- Various types of rollers and pulleys
  - Roller · V-pulley · Flange · Ribbed V-pulley
- Crown Roller (You can model a roller as a desired shape using Crown Roller)
- 2D belt and guide for analysis speed improvement

RecurDyn/Gear

The RecurDyn/Gear toolkit is used to define and analyze systems of gears. It defines the gear geometry, the contact surfaces, and it provides a specialized solver code for the gear system.

- Various gear libraries
  - Spur Gear · Helical Gear · Scissors Gear · Spur-Internal Gear · Helical Internal Gear
  - QFB (Quasi-Flexible Body) Gear · Worm & Worm Gear (Single-Enveloped) · Bevel Gear (Straight Type, Spiral Type, Zerol Type)
- You can confirm the vertical force and friction force occurring at a contact point.
- Vibrational characteristics of gear and DTE (Dynamic Transmission Error) can be analyzed considering backlash and tolerance.

RecurDyn/Bearing

- The RecurDyn/Bearing toolkit is used for the modeling of bearing systems. It simplifies the creation of bearings and the contact surfaces.
- The toolkit also supports EHD (fluid) bearings and simulates lubrication properties during analysis (RecurDyn/EHD is required).

- Bearing shape creation and automatic definition of contact between parts
- Consideration for the deformation of outer ring by modeling the flexible body
  - Ball Bearing · Roller Bearing
- EHD Bearing (combined with RecurDyn/EHD)

Engine

RecurDyn's engine toolkits dramatically simplify the modeling and analysis of the major components of internal combustion engine systems, such as valves, pistons and crankshafts. This allows you to create and analyze highly realistic engine models quickly and easily.

RecurDyn/Valve

- The RecurDyn/Valve toolkit is for the design and analysis of valve train systems. It automates the creation of valve train assemblies.
- This toolkit supports various valve types and camshafts. It also allows for the use of flexible bodies in the analysis.

- Creation of valve train part shape and automatic definition of contact among parts
- Various types of valves
  - Direct-acting
  - Center-Pivoted arm
  - End-Pivoted Arm
  - Push-rod & Center-pivoted arm
- Convertible to a flexible model

RecurDyn/Piston

- The RecurDyn/Piston toolkit automates the creation of engine piston systems.
- The toolkit is designed for contact analyses of pistons and cylinders. It can perform a bearing analysis that models the lubrication properties of EHD bearings between a piston pin and a connecting rod or between a piston pin and a piston (RecurDyn/EHD is required).

- Easy modeling with part shape creation of piston and automatic definition of contact
  - Piston
  - Piston Pin
  - Connecting Rod
  - Engine Block
  - Liner Connector
  - Engine Mount
  - Gas Force
- Piston pin (combined with RecurDyn/EHD)

RecurDyn/Crank

The RecurDyn/Crank toolkit automates the creation of drive shaft-related parts, such as crankshafts, balancing shafts, and flywheels.

- Easy modeling with part shape creation of crank and automatic definition of contact
- Types of crank train
  - Straight
  - Horizontal
  - V Type
- Types of crank shaft
  - Rigid
  - Beam, Torsional, Torsional + Bending
  - FFlex
  - RFlex
- All parts can be convertible to flexible models.
- Gas Force settings

Track

The Track toolkits allow efficient modeling and analysis of the tracked vehicle systems frequently used in construction equipments and military vehicles such as tanks. These toolkits significantly reduce the time needed for modeling and allow for fast and accurate analysis through a specialized solver.

■ RecurDyn/TrackLM

- The RecurDyn/TrackLM toolkit includes various libraries (for example, Track Link, Wheel, and Sprocket) for the simplification of the modeling of the low-speed tracked vehicle systems used in construction and heavy equipment.
- The toolkit includes a UI and analysis solver optimized for low-mobility tracked vehicle systems.
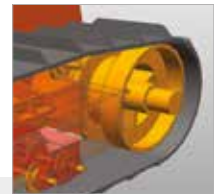
- Automatic track assembly with automatic contact
- Various libraries for tracked vehicles
  · Track Link   · Sprocket   · Roller Guard   · Flange   · Roller   · Roller Guard
- Graphical design of sprocket teeth profile (lines and arcs) and link grouser profile (line segments)
- Standard proving ground library
- Soil modeling with Bekker's theory
- Link designed by CAD can be used as Link for TrackLM.
- Track Link can be converted into flexible body for analysis.
- Study for dynamic performance of vehicle (ride and comfort), calculation of dynamic load history

■ RecurDyn/TrackHM

- The RecurDyn/TrackHM toolkit includes various libraries (for example, Track Link, Wheel, and Sprocket) for the simplification of the modeling of the high-speed tracked vehicle systems used in tanks and other military vehicles.
- The toolkit provides a UI and analysis solver optimized for high-mobility tracked vehicle systems.


- Automatic track assembly with automatic contact
- Various libraries for tracked vehicles
  · Track Link (Single, Double, InnerPin)   · Sprocket   · Single Wheel   · Double Wheel
- Graphical design of sprocket teeth profile (lines and arcs) and link grouser profile (line segments)
- Standard proving ground library
- Soil modeling with Bekker's theory
- Study for dynamic performance of vehicle (ride and comfort), calculation of dynamic load history

Media Transport

RecurDyn's media transport toolkits are for analyzing transport systems for flexible media, such as paper, films, and cards. This toolkit automates the modeling and analysis of sheets as flexible bodies and dramatically simplifies the creation of rollers and guides, making it the ultimate tool for the layout and design of media transport systems.
In addition, the toolkits also include various sensors and tools to model air resistance, suction, and static electricity.

▊▊ RecurDyn/MTT2D

- RecurDyn/MTT2D provides various components for the efficient 2D design of transport systems for thin media such as paper or film.
- 2D modeling and optimized solvers allow for faster analysis.
- Rollers can be modeled as flexible bodies made of materials such as rubber or sponge to capture the effect of roller flexibility on the behavior of the media.
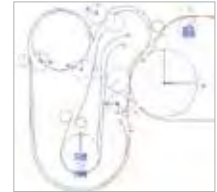
- Fast analysis using 2D modeling
- Various libraries for transport systems
  · Sheet   · Fixed Roller
  · Movable Roller   · Guide (Arc, Linear)
- Various sensors
  · Speed   · Event   · Distance   · Tension

- Creating the curled and folded sheet in the initial state
- Automatic definition of contact among Sheet, Roller and Guide
- Support for flexible roller as well as rigid roller
- Air resistance coefficient setting
- Layout design for transport system

▊▊ RecurDyn/MTT3D

- RecurDyn/MTT2D provides various components for the 3D design of transport systems for thin media such as paper or film including the simulation of steering and the onset of wrinkles.
- The RecurDyn/MTT3D toolkit is designed to analyze 3-dimensional media transport systems.
- This toolkit includes an optimized solver that performs analyses quickly, robustly, and accurately.
- The media is modeled as flexible bodies using MFBD technology.
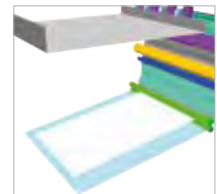
- Analysis of more realistic models using 3D modeling
- Various libraries for transport systems
  · Sheet   · Fixed Roller   · Movable Roller
  · Guide (Arc, Linear, Circular)
- Various sensors
  · Speed   · Event   · Distance   · Tension
- Support for flexible sheet using Shell element

- Definition of air resistance, absorption forces, and electrostatic forces by nodal forces (Node load of Sheets by User Subroutine)
- Air resistance coefficient setting
- Creating the curled and folded sheet in the initial state
- Automatic definition of contact among Sheet, Roller and Guide
- Providing the contour information to the displacement, stress, and strain within a sheet
- Layout design for transport system, analysis for various 3D characteristics

▊▊ RecurDyn/R2R2D

- RecurDyn/R2R2D provides a variety of libraries for the 2D design of Roll to Roll systems.
- Fast and accurate analysis using optimized solver for Roll to Roll system
- RecurDyn/R2R2D is especially optimized for winding behavior analysis and supports automatic definition of media that includes multiple winds around a spool or roller.
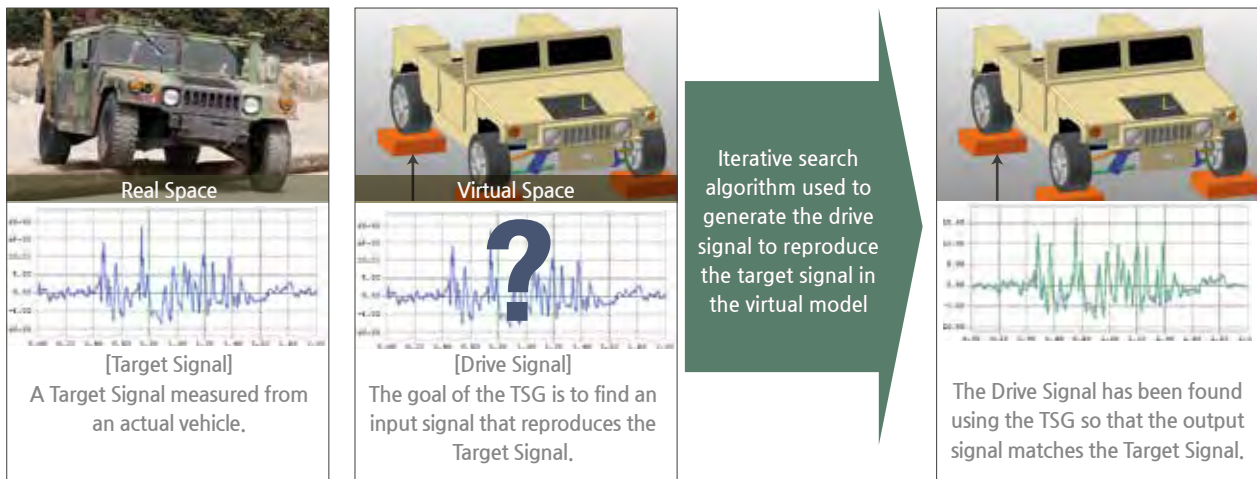

- Fast analysis using 2D modeling
- Automatic web generation function using beam elements
- Automatic definition of contact among Web, Roller and Guide
- Providing the contour information to the displacement, stress, and strain within web

- Various libraries for Roll to Roll system
  · Circle Roller   · General Roller   · Guide (Arc, Linear, Circle)
- Various sensors
  · Speed   · Event   · Distance   · Tension

Other Toolkits

■ RecurDyn/TSG (Time Signal Generator)

The RecurDyn/TSG finds an actuator signal in a RecurDyn model that causes an output signal (like a position, velocity, or acceleration) in the RecurDyn model to match an existing target signal provided by the user. This enables RecurDyn to reproduce a behavior that was measured in an actual mechanical system.

• A simplified virtual vibration-test-rig model in RecurDyn can eliminate various nonlinearities in the real vibration of an actual test environment, which enables faster and simpler analysis of vibration effects.

Real Space

Virtual Space

?

Iterative search algorithm used to generate the drive signal to reproduce the target signal in the virtual model

[Target Signal]
A Target Signal measured from an actual vehicle.

[Drive Signal]
The goal of the TSG is to find an input signal that reproduces the Target Signal.

The Drive Signal has been found using the TSG so that the output signal matches the Target Signal.

• Creates virtual sensors in the RecurDyn model in the same location as the sensors used to measure the target signal in the real mechanical system.
• Creates actuators to drive the model in RecurDyn.
• RecurDyn/TSG iteratively executes simulations in RecurDyn to find the proper Drive Signal to reproduce the Target Signal.
• If the responses of the virtual sensors in the RecurDyn model are acceptably close to the measured Target Signals, then the RecurDyn model is accurately capturing the desired behavior of the real system.

■ RecurDyn/EHD

• Simulates contacts that occur through a film of oil.
  Example applications are bearings on a crankshaft or a camshaft, or a piston sliding in a cylinder.
• RecurDyn/EHD calculates the thickness of the oil film and the corresponding pressure and force from the behavior information of the mechanical system. The effect of this pressure on the body is also taken into account in the simulation.

• EHD Bearing (Rotational Lubrication)
  · Models fluid lubrication between journal bearing surfaces rotating at high speeds.
  · Various effects, such as the Oil Hole and Groove Effects, can be included.

• EHD Piston (Piston Lubrication)
  · Analysis of fluid lubrication between a cylinder and a piston during high piston translation speed
  · The effect of the piston tilt during high speed motion on the pressure and thickness of the lubricant film can be analyzed.
  · If the cylinder or piston is modeled as a flexible body, the effect of body deformation on the pressure and lubricant thickness can also be analyzed

EHD Bearing   EHD Piston
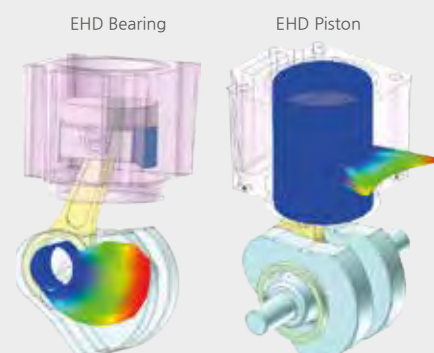
RecurDyn/Spring (Multi Mass Spring)

- Easy and fast modeling of springs that have dynamic responses that are a function of the mass with the coils of the spring
- It can be used to show different behaviors depending on the position of the spring or to consider contacts between spring coils.

- Type A : linear spring model that considers the collision between coils
- Type B : model using BMW's algorithm (nonlinear spring modeling using spline)
- Type C : model using YAMAHA's SAKAI algorithm (nonlinear spring modeling, dual-rate spring modeling)
- Type D : 3D MMS consisting of beam force and contact element
    It has nonlinear characteristics and is capable of expressing the contact between spring self contact and type D spring.

RecurDyn/Tire

RecurDyn/Tire provides various libraries to simulate the tires used in vehicles. Various types of tire modules (UA, Fiala, F-Tire, MF-Tyer, MF Swift) are supported depending on the applications.

- Easy modeling of tires using Tire Group
- Easy conversion between tire models
- Support for MF-Tyre and MF-Swift (previously TNO) allows the user to represent three dimensional surface contact, vibration and slip phenomenon.
- Support for F-tire of COSIN allows the user to model various types of tires including flexible ring tire model.

RecurDyn/MachineTool

RecurDyn/MachineTool allows manufacturers of machine tools to utilize MBD more easily and efficiently. It was developed based on the demands of manufacturers in the field using the joint efforts of FunctionBay, IWB (Technical University of Munich), and FRAMAG (machine tool manufacturer).

- Various levels of modeling capabilities are provided that consider various aspects of machine tool simulation.
- Analysis of ball screw motion drives, linear guides and bearings
- Analysis of models experiencing large motion including flexible bodies
- Data from suppliers' catalogs can be used for analysis.
- Functions for standard operation such as ISO circularity test
- Analysis of a motor with controller using CoLink

RecurDyn Support Site
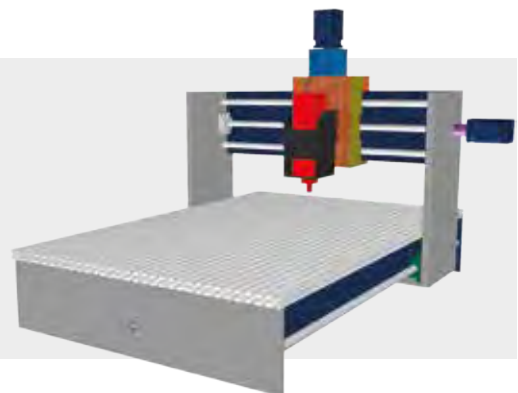
The Technical Support website is designed for all levels of users of RecurDyn software.
It not only describes the basics of how to use the software but also provides useful tips and learning materials about computer-aided engineering (CAE), and tutorials to help users efficiently utilize CAE software.

FAQ. Instructions and Practical Tips

FAQ-style tips to help users understand RecurDyn software easily. FAQs are created by analyzing questions frequently asked by users and contents that are not included in the tutorial.

Knowledge Base. Tutorials, Tips and Webinars

Easy-to-learn tutorials, technical tips and webinars on how to take full advantage of RecurDyn are provided to improve your training and competency.

Blog. Product Information, Success Stories, and Special Articles

Provides news on our product, RecurDyn and activities, customer success stories, and special articles

Forum. Community Forum

A community forum where users can receive technical supports for RecurDyn and freely communicate with other users

e-Learning. Self-Training Program for CAE Beginners

5 step learning process from RecurDyn Starterkit for CAE beginners to e-Learnings and tutorials for MBD modeling/simulation/result verification

Company

FunctionBay, Inc. is a CAE (Computer Aided Engineering) company that specializes in developing and selling solutions for engineering simulation and technology consultation service.

Founded in South Korea since 1997, FunctionBay is globally recognized as a leader in multidisciplinary CAE solutions. We have a global network of sales and support including branch offices in Japan, China, Germany, and the United States of America. We have dealer networks in Taiwan, India, Italy, Switzerland, France, as well as many other locations worldwide.

As a CAE company, FunctionBay is continuously investing in R&D activities including the funding of related research by the world's leading experts. In order to cope with the rapidly changing CAE market and its users' needs, FunctionBay seeks to listen to customers and solve problems together. All employees of FunctionBay and its sales channel will fulfill their duties with sincerity and will do their best to help customers improve their productivity.

South Korean Certificates/Awards

- Presidential Citation on Engineering day *by the Ministry of Security and Public Administration*
- 2014 K-Brain Power *by the Ministry of Trade, Industry and Energy*
- ATC (Advanced Technology Center) *by the Ministry of Trade, Industry and Energy*
- Korean World-class Product Award (Present) *by the Ministry of Knowledge Economy*
- Korean World-class Product Award (Next-Generation) *by the Ministry of Trade, Industry and Energy*
- INNO-BIZ Certification *by the Small and Medium Business Administration*
- ISO 9001: 2000 Certification *by International Certification Registrar*
- New Excellent Product Certification *by the Ministry of Commerce, Industry and Energy*
- IR52 Jang Young-Shil Award *by Korea Industrial Technology Promotion Association*

FunctionBay works to make the world a happy and beautiful place for all, including our users and employees as individuals, our families, the people in the world in general, and the world environment. FunctionBay strives for not only the pursuit of customer satisfaction, growth, and profit but also the philosophy: "Benefit the Sellers, Buyers, and People of the World"

FunctionBay's success in the field of mechanical analysis as a CAE professional company in Asia has led to our dream to become a leading CAE company in the world and continuously drives us to reach that goal.

FunctionBay embraces a youthful and creative entrepreneurial spirit that supports pure enthusiasm, freedom and fun. FunctionBay strives to create a more exciting and autonomous working environment so as not to lose the driving force to pioneer new fields and constantly improve.

FunctionBay

System Requirements

- Supported Operation Systems
  - Windows 10
  - Windows server 2012R2, 2012, 2016, 2019
  - Red Hat Enterprise Linux Server (4.8, 5.8, 6.3, 7.3, 7.4, 7.5)
  - Red Hat Enterprise Linux Client (7.3, 7.4, 7.5)
  - SUSE Linux Enterprise Server (10 SP1, 11 SP2, 12 SP3)

- CPU 2.4GHz (Recommended : 3.4GHz, Quad Core or better)

- RAM 8GB (Recommended : 32GB or more)

- HDD 10GB (Recommended : 1TB)

* RecurDyn is a trademark of FunctionBay, Inc. All other trademarks or registered trademarks belong to their respective holders.

* The included contents are available for RecurDyn 2023 or later version. In addition, contents may be added or deleted in future versions.

* RecurDyn supports only 64-bit OS.

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Particleworks™
Particle-based simulation software for CAE

Particleworks™
Particle-based simulation software for CAE

PROMETECH.

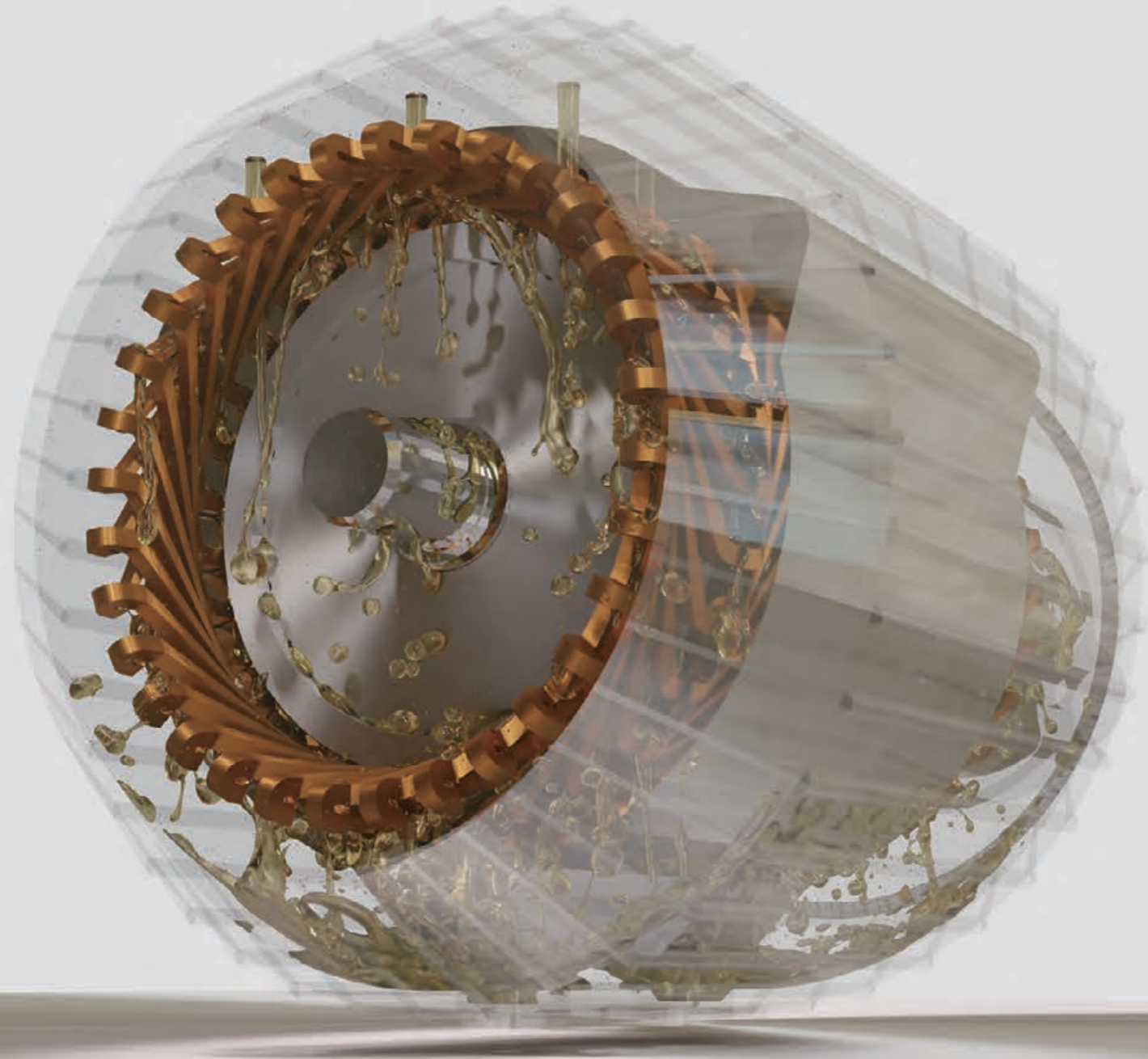[Developer, Main Domestic / Global Dealer]

Prometech Software, Inc.

H Q — **Hongo Dai-ichi Building, 8F, 34-3, Hongo 3-chome, Bunkyo-ku, Tokyo 113-0033, Japan**
Tel: +81-(0)3-5842-4812 Fax: +81-(0)3-5842-4123

https://www.prometech.co.jp/home_en.html   E-mail: kaidai@prometech.co.jp

2023.05

PROMETECH.

Computational Reality

Particleworks™
Particle-based simulation software for CAE

The particle method opens up advanced CFD

Simulates fluid behaviors at hi-speed

Particleworks is simulation software for fluids with large deformation that can solve various fluid-related problems — gear oil lubrication, motor cooling, waterway driving, mixing and stirring of chemicals and foods, landslides, and floods.

Shows its true power in GPU computing environments

Particleworks has been developed as being used in GPU computing environments. It drastically reduces resourcing costs and time of product development and encourages engineers to work more creatively.

Co-operation between Industry and Academia

Particleworks has been progressing to realize high value-added manufacturing, supported by knowledge from various universities and user companies.

Wide-range solutions applied for various industries

Because of its application potential, Particleworks has been adopted in various industries; Automotive, transportation, steel and metals, medical and pharmaceuticals, food and lifestyle-related products, civil engineering and construction, electricity, materials and chemicals, social infrastructure, and energy.

▪ Users / Industries and applications
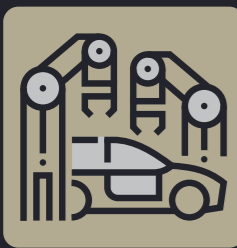
Automotive & Transportation
- Waterway driving
- Splash
- Gear oil stirring
- Chain oil
- Motor oil cooling

Civil engineering & Constructions
- Landslide and Tsunami simulation
- Concrete flow simulation
- Tunneling simulation

Infrastructure & Energy
- Coolant sloshing
- Flows in pressure vessel

Steel & Metals
- Cooling spray behavior simulation
- Extrusion

Chemicals & Materials
- Soldering, brazing, and welding simulation
- Agitation simulation
- Impregnation behavior simulation of composite materials

Foods & Consumer goods
- Food mixer simulation
- Cosmetic emulsification simulation
- Flow simulation inside a shower head

Electricity & Machinery
- Washing machine balancer simulation
- Washing simulation of cutting chips
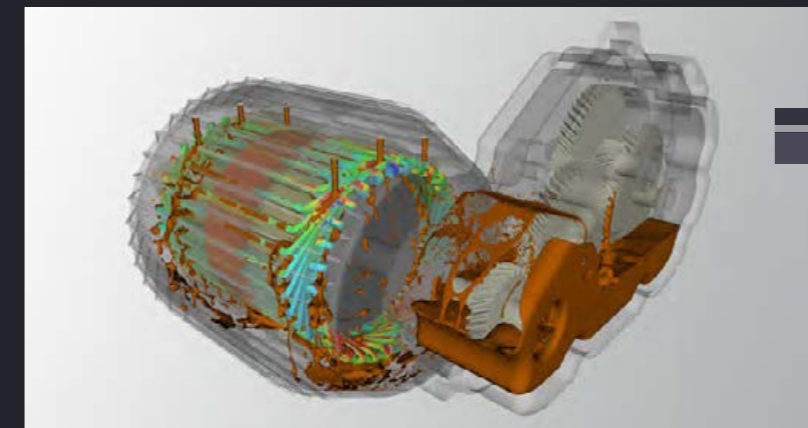- Water splash simulation on electric machine
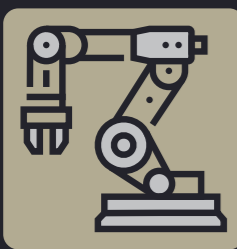
Medical & Pharmaceuticals
- Blood flow simulation
- Mouthwash simulation
- Tablet shape optimization
- Mixing medicine process simulation

Practical solutions

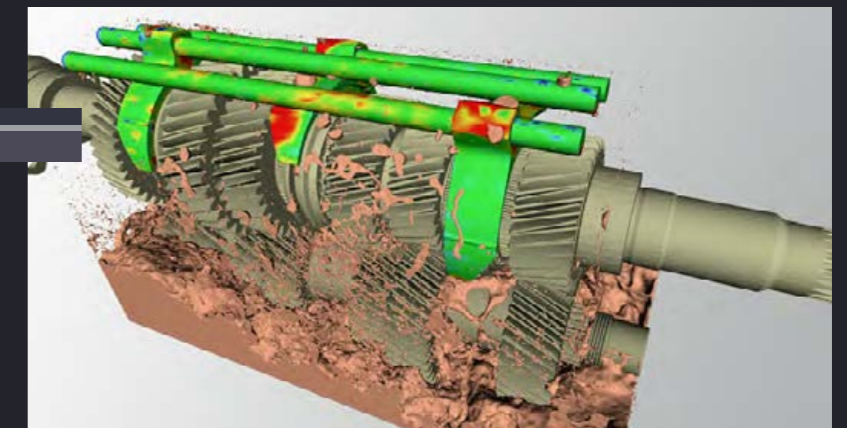We develop our software to solve on-site issues by incorporating customers' feedback.

Multiphysics simulation

Co-operating with other software realizes the broader range of simulation.

HPC Customization for your demand

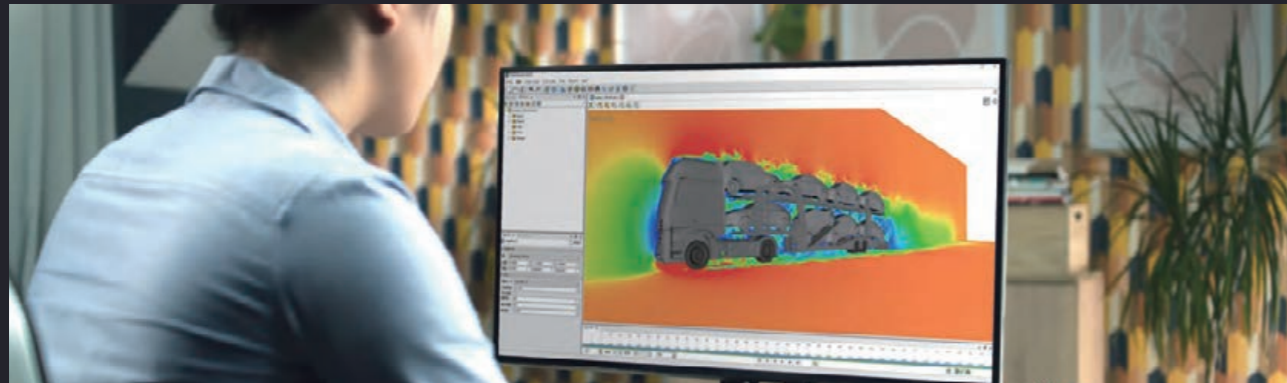We provide the best hardware environment for each customer.

Visualization

Let us know if you want photoreal images and videos based on CAE results.

Intuitive GUI

⊞ GUI

Equipped with a viewer compatible with Windows and Linux, the GUI allows intuitive operation of pre-processing, calculation, and post-processing. The efficient and simple design and architecture reduce the time spent on initial user training and facilitate complex project management, calculation setup, post-processing, and evaluation of calculation results.

⊞ Pre-processing

With an intuitive setting wizard, various calculation conditions such as material properties (e.g., density, kinematic viscosity coefficient), physical models (e.g., viscosity, surface tension), initial time step, initial particle distance, and calculation end time can be set. Physical properties and calculation conditions can be programmed as user-defined functions.

⊞ Post-processing

▍ Physical quantity measurement of fluid particles

In addition to functions necessary for evaluating calculations, such as particle information acquisition, physical quantity statistics, and filtering, our software also features detailed customization options including a color bar, ruler, and time code functions.

▍ Fluid surface extraction

A fluid surface mesh can be generated from the particle information based on the calculation results. This enables visualization close to reality and makes it possible to check the liquid surface behavior and calculate surface areas. The mesh can be exported in STL or OBJ format for external use.

▍ Video export / Screenshot

Input models with moving-rotating settings and calculation results can be animated in the view window and exported as a movie file or sequentially numbered image files. PNG, JPEG, MP4, and WMV are supported as output formats. The screenshot function exports PNG image files.

▍ Physical quantity mapping against polygon walls

The polygon wall does not have physical quantities, but it is possible to map them from particle information near the wall surface to vertices of the polygon wall shape. The results can be displayed or exported as text data.

▍ Exporting simulation results

Loading exported CSV files with spreadsheet software, physical quantities, such as particle coordinates, velocity, pressure, density, and shear rate, can be evaluated graphically.

▍ Free Viewer

For visualization, we provide a dedicated free viewer that can display the results of calculations without consuming a license, with features such as animation playback, color map modification, and snapshot application. These functions help with simple evaluation and analysis.

⊞ 4 Steps to complete the simulation process

There is no need to make troublesome model modifications. The whole simulation process, from settings to visualization of results, can be done with seamless operation along the wizard. The GUI makes it easy to set up even more complex conditions.

STEP 01   Modeling

The modeling phase would be done by simply importing CAD data (STL, OBJ, and Nastran are supported) directly into Particleworks.

STEP 02   Setting conditions

Apply motion and rotation conditions to the imported shape models, and specify fluid properties such as viscosity and surface tension for each fluid to be simulated.

STEP 03   Calculation

No meshing is required. Particles are automatically generated before the calculation runs. Results can be checked even during the calculation. GPU computing is supported, allowing for faster computation.

STEP 04   Post-processing

Visualization of simulation results is possible through a wide range of post-processing functions, including fluid surface extraction, data export in CSV format, and exporting movie data.

Make your process simpler with incredibly intuitive operation
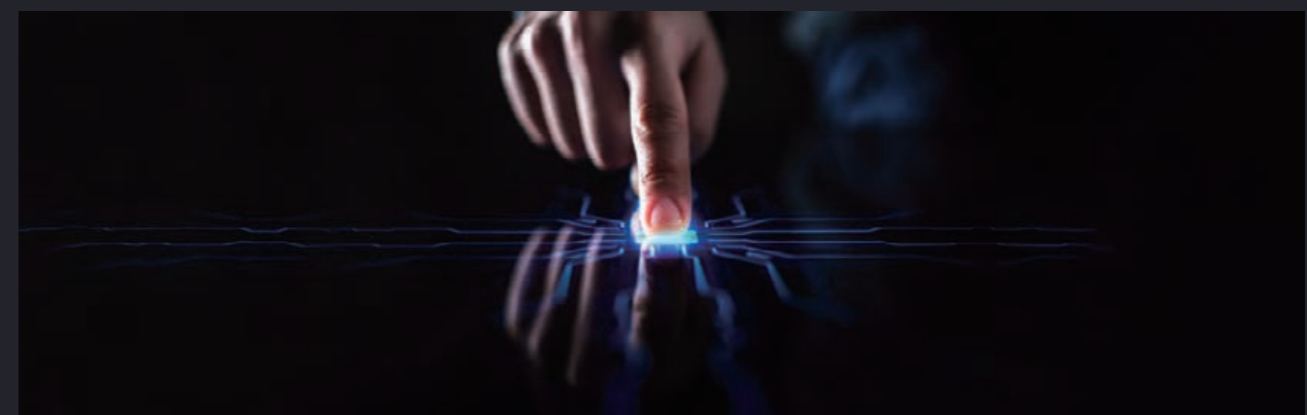
Basic functions & physics solver

In addition to robust and stable computations using the high-performance MPS solver as the core, a conjugate heat transfer solver and an airflow solver are included to enable multiphysics simulations that more closely approximate real-world phenomena.

GPU computing

High-speed computation can be performed with GPU computing. Highly scalable multi-GPU computing is also supported, allowing calculations with more than a hundred million particles.

Pressure calculation

Implicit method / Explicit method

You can choose between implicit and explicit pressure calculation methods. Calculations can be speeded up with the explicit method, provided that the speed of sound is appropriately given.

Pressure oscillation suppression function

The pressure oscillation suppression function reduces the spatial pressure fluctuations inherent in the particle method.

Viscosity calculation

Not only Newtonian fluids but also Bingham and non-Newtonian fluids using Power-law models are available. Moreover, you can achieve even greater flexibility in setting viscosity with table data and user function definitions.

Turbulence model

A hybrid model of the LES (Large Eddy Simulation) model and a wall model, which compensates for the lack of resolution near walls, is adopted as the turbulence model. This enables the simulation of flows containing turbulent effects.

Rigid model

Non-deforming objects can be set as rigid particles. Complex flow and rigid body behavior can be analyzed through coupled calculations with fluid particles.
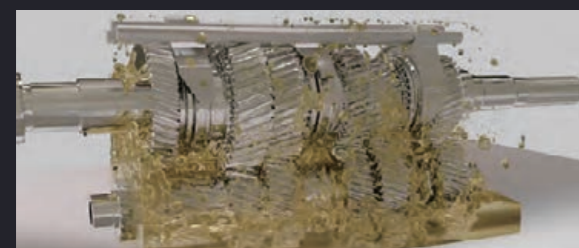
Boundary conditions

Wall boundary, moving boundary

Both particle walls and polygon walls are available for wall boundaries. Using polygon walls can reduce memory usage and speed up calculations. Moreover, the movement setting function allows for reproducing complex movements of walls (objects).

Inflow/outflow boundary, pressure boundary

The inlet function allows you to simulate the inflow of fluids and granular materials into the computational domain. You can set the motion of the inflow boundary and the time-varying velocity or flow rate.

Moving computational domain, periodic boundary

The computational domain itself can be arbitrarily moved to save computing resources for analyses covering a wide domain, such as waterway driving.

Surface tension model

CSF and potential models are implemented to calculate surface tension from the geometric shape of the interface and interfacial energy between objects, respectively. It is possible to consider contact angles between wall-fluid and fluid-fluid interfaces, enabling simulations of various immiscible fluids like water and oil.

Heat transfer coefficients

The heat transfer coefficients of fluid particles can be evaluated. The heat transfer coefficient distribution mapped on the structure can be exported for use in other software.

Advanced simulation functions and physical models

Multi-resolution

This method divides the simulation domain into the Coarse domain and the Fine domain, which are computed using coarse and fine particles, respectively. By only placing fine particles in areas that require high resolution or are narrow, it is possible to reduce computational load and memory consumption.

Conjugate heat transfer

Fluid-structure and structure-structure heat transfer calculations are available for both steady-state and transient simulations. Steady-state simulations support boundary settings via CSV files and fast computations with a high-speed matrix solver.
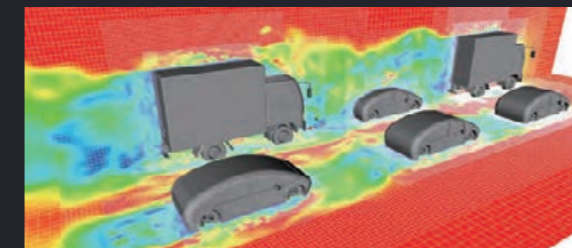
Snow model

We provide the modeling of snow as a Bingham fluid (a fluid that does not flow until it is subjected to a certain shear stress). This allows for calculations such as snow compaction behavior, where snow is deposited and compressed.

FVM airflow solver

The FVM solver enables one-way/two-way airflow -coupled simulation with MPS fluid particles. It supports both steady-state and transient simulations.

LBM airflow solver

The Lattice Boltzmann Method (LBM) solver enables airflow-coupled simulation with MPS fluid particles. It is possible to apply wall boundary conditions that model boundary layer flow near walls in high Reynolds number flows.

MPFI

MPFI is a method that simultaneously calculates the pressure and viscosity terms of the Navier-Stokes equations implicitly without separating them. This method is effective for problems with low Reynolds numbers and high pressure, such as the flow of high-viscosity fluids like resins.

Dynamic contact angle model

In surface tension calculations, both uniform and dynamic contact angle settings can be used, allowing representation of the forward and backward contact angles of sliding droplets.
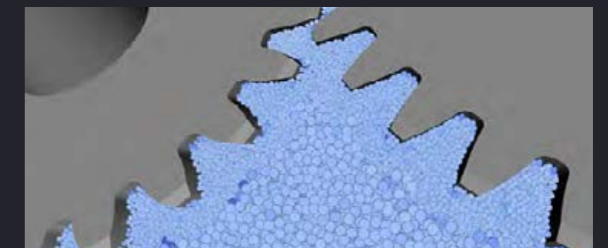
Particle shifting

The Particle Shifting function is implemented to move particles and make their distribution uniform by eliminating bias. This function effectively stabilizes calculations of highly viscous fluids where the particle distribution may not be uniform.

Negative pressure function

With the newly implemented pressure gradient model, stable calculations can be conducted without disregarding negative pressure. In the original MPS method, the minimum particle pressure was set to 0 Pa to stabilize the calculation, making it difficult to handle negative pressure.

Passive scalars

"Passive Scalars" like concentrations, which are transported passively without affecting the flow, are available and applicable to MPS particles and FVM grids.

Multiphysics simulation

For a more realistic evaluation of designs, various coupled calculations can be performed with Granuleworks, Prometech's granular solver, and third-party CAE software that handles other calculations such as; structure, impact, mechanism, fluid, and electricity.

▌ Fluid - airflow simulation

MPS-airflow coupling simulation is possible by coupling with the FVM（Finite Volume Method）and LBM (Lattice Boltzmann Method) solver in Particleworks. The coupling simulation with MPS fluid particles can be 1-way/2-way coupling.
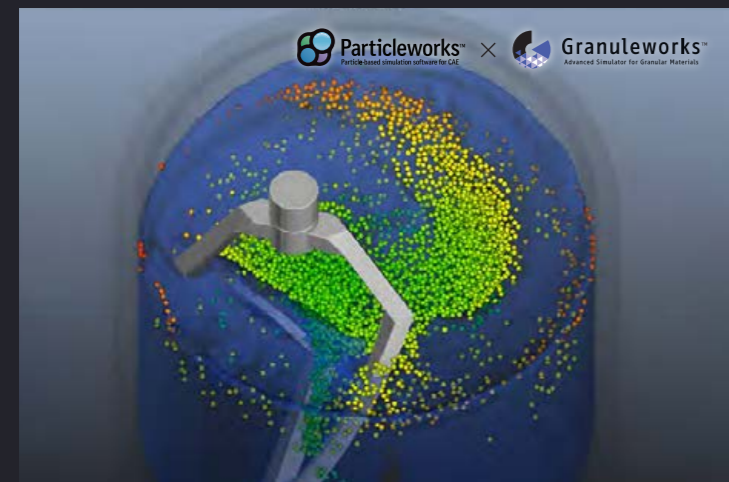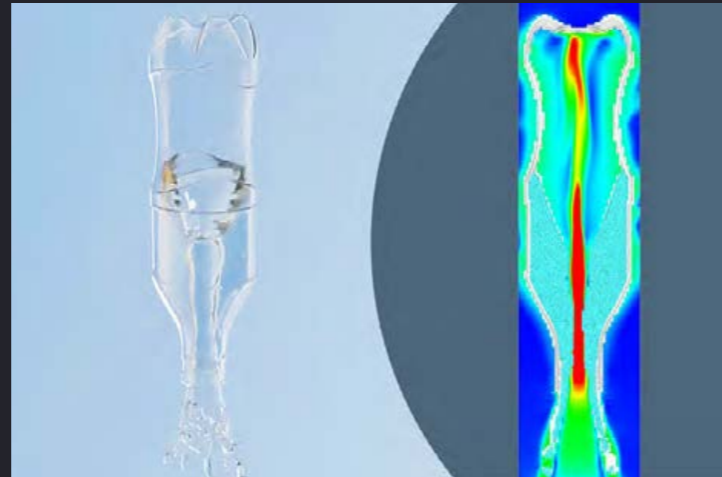
▌ Fluid - granular simulation

By coupling the Discrete Element Method (DEM) with the MPS method, complicated simulations such as mixing, stirring, and conveying granular materials and fluids can be performed. With the aeration function, you can model air bubbles in oil behavior simulations, mixing tank simulations in chemical processing, etc.

▌ Co-operating with other software

Simulation results of Particleworks can be imported to other simulation software such as; Abaqus, ANSYS, MSC Nastran, NX Nastran, LS-DYNA, and JMAG. The physical quantity data of particles can also be exported as CSV files, and converted to other formats so that you can use it as boundary conditions in other CAE software.

SIMUNIMA - The efficient visualization program for CAE results -

SIMUNIMA enables CG software to edit and render CAE results by converting them into a universal CG format. It supports Particleworks/Granuleworks natively, enabling efficient visualization, movie creation, and development of XR content.
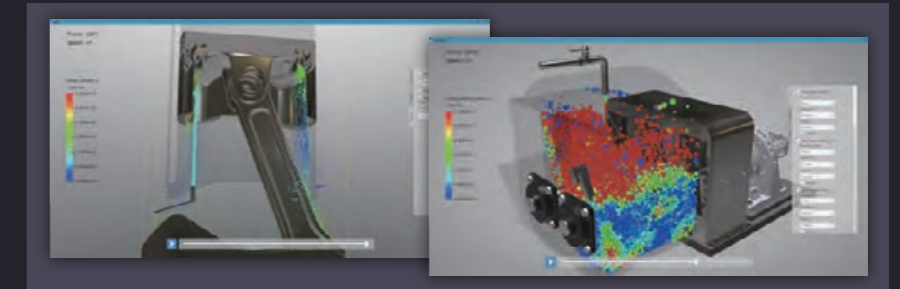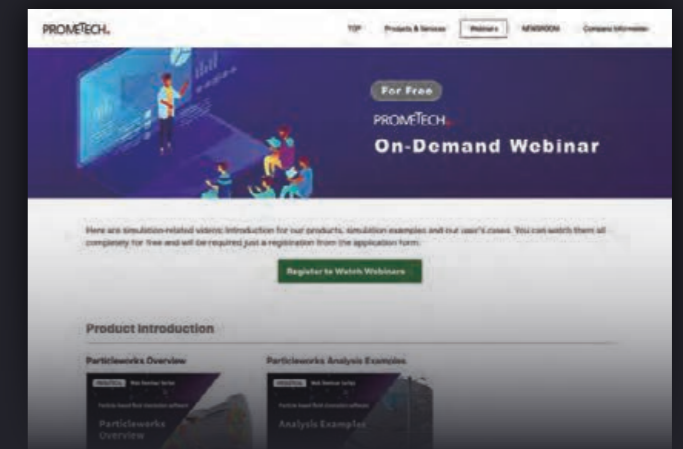
Webinars

You can see on-demand webinars such as introductions for our products, simulation examples and our user's cases. They are all completely for free and will be required just a registration from the application form.

Prometech on-demand webinar
https://www.prometech.co.jp/web_seminar_outline_en.html

Website

Our website offers a variety of useful content, including not only product introductions, but also a wealth of analysis case study videos and technical columns.

Particleworks Product Site
https://www.particleworks.com/home_en.html