THE SPECIALIZED VIRTUAL PROTOTYPING ENVIRONMENT FOR RAILCAR ENGINEERING

"What used to take weeks, months, or years to physically model and test can now be done in just hours with ADAMS/Rail," says Gabriele Ferrarotti, MSC.Software's manager of rail industry marketing. "Users can quickly explore hundreds or even thousands of design variations, testing and refining their designs until optimizing railcar performance."

With ADAMS/Rail, engineers accurately model complete railway vehicles, then realistically simulate their design’s behavior in motion. This lets users study, refine, and optimize railcar performance - all on the computer, before running physical tests.

Using ADAMS/Rail — the specialized railcar simulation software from MSC.Software— an engineering team can quickly build a complete, parameterized model of a new railway vehicle, easily defining its suspension, wheelset, wheel-rail contact, and other vital characteristics.

Then, without leaving their engineering workstations, the team's members can run the model through a battery of kinematic, static, and dynamic simulations. They use these tests to determine the vehicle's stability, derailment safety, clearance, track load, passenger comfort, and more.

"What's key," says Gabriele Ferrarotti, manager of rail industry marketing for MSC.Software, "is that, with ADAMS/Rail, this is all done on the computer. An engineering team can refine and optimize the performance of its railcar design before cutting a single piece of metal or running a single physical test."

FAST "WHAT-IF" SIMULATIONS

According to Ferrarotti, "ADAMS/Rail users not only work faster, they work smarter. Simulation gives users immediate answers to their engineering questions. They quickly see and understand how any kind of design change will affect vehicle performance."

MSC ADAMS
Industry–Specific Product

APPLICATIONS

- Dynamic simulation of wheel-rail contact
- Suspension design
- Wear prediction
- Creep analysis
- Coupler design
- Bogie analysis
- Stability analysis
- Comfort analysis
- Curving analysis
- Track loads prediction
- Simulation of cargo tie-down effectiveness
- Design of material handling equipment
- Design and simulation of auxiliary equipment
- Event reconstruction

HIGHLIGHTS

COMPLETE SIMULATION SOLUTION

- Component-level
- Subsystem-level
- System-level

CONTACT ELEMENTS

- Linear
- Tabular (nonlinear with precomputed contact geometry)
- General (nonlinear with online calculation of contact geometry)

VIRTUAL MODELING

- Hierarchical structure
- Interactive in both standard-user and template-builder modes

FILE-BASED MODELING

- Through subsystem files
- Through property files

DATABASE

- Derived from ADAMS/Car
- Proven and commonly used

EASY CUSTOMIZATION

- Through dialog-box builder

MSC SOFTWARE
SIMULATING REALITY
ADAMS/Rail is built upon MSC.Software’s flagship MSC.ADAMS software, widely recognized as the world’s leading mechanical system simulation tool. ADAMS/Rail extends users’ ability to:

• Quickly build, test, and refine railcar designs, exploring many “what-if” alternatives. A user can, for example, change springs with only a few mouseclicks, instead of having to wait for a mechanic to install new springs, as required with physical testing.
• Easily vary the kinds of analyses being performed. With simulation, there’s no need to modify physical instrumentation, test fixtures, and test procedures.
• Work in a secure testing environment, without fear of losing critical data to instrument failure or falling behind schedule due to poor weather conditions for testing.

“In the past, the time and cost of physical testing made multiple railcar design iterations impractical,” Ferrarotti notes. “Now, with ADAMS/Rail, users can immediately see how their vehicle designs will move and where the potential problems are. They can plot their results in graphs or view them in high-speed animation. And the results they get are accurate — users can rely on simulation to guide them in railway vehicle design.”

DESIGNED FOR AND BY RAIL ENGINEERS
The development of ADAMS/Rail began in 1993 when engineers at NedTrain Consulting, an off-shoot of N.V. Nederlandse Spoorwegen (Dutch Rail), conducted an evaluation of commercially available mechanical system simulation tools. The specialized simulation packages offered at that time for rail applications were judged to be unsatisfactory, most commonly due to poor or non-existent graphical user interfaces, difficult interaction with other computer-aided design and engineering (CAD/CAE) tools, and problematic results from non-standard calculations.

The best solution was determined to be customization of MSC.Software’s general-purpose MSC.ADAMS software, which had been proven in use and progressively enhanced since its commercial introduction in 1980. Joint development of ADAMS/Rail was soon initiated. The
MODELING ELEMENTS IN THE ADAMS/RAIL LIBRARY

MODEL COMPONENTS

- Wheelset (single, double)
- Single element with symmetric building option
- Bogie frame with parameterized geometry
- Axle box (symmetric, anti-symmetric)
- Car body (engine, wagon)

INTERCONNECTIONS

- Suspension elements
- Bushings with linear or nonlinear characteristics
- Dampers with linear or nonlinear characteristics and with or without series stiffness
- Bumpstops, reboundstops
- Airsprings - linear or nonlinear and single or coupled
- Torsion springs

GENERAL MSC.ADAMS ELEMENTS

- Parts
- Flexible bodies
- Joints
- Friction

ADAMS/Rail's user interface is designed specifically for railcar simulation. Menu selections highlight functions already familiar to rail engineers, so they can quickly become proficient with the software. ADAMS/Rail can be further customized to support unique modeling and simulation approaches.

development drew heavily upon the theoretical work of Professors Kalker and de Pater of the Delft Technological University in the Netherlands. Embedded in the software were the specialized design expertise and analytical methods of rail engineers.

In 1996, ArgeCare e.V. — well known in the field of railway dynamics for its popular MEDYNA software — joined the ADAMS/Rail development consortium. ArgeCare's aim was to incorporate MEDYNA's capabilities within the frame of MSC.ADAMS, taking advantage of the latter software's state-of-the-art graphical user interface, fully nonlinear dynamic solver, and industry-proven interfaces to leading CAD/CAE packages.

TWO USER MODES FOR VEHICLE, TRACK, AND CONTACT MODELING

ADAMS/Rail users select from two operational modes:

- A standard interface, which allows users to enter data into existing design templates to run both standard and custom design tests; and
- Template-builder mode, enabling experienced users to create their own design templates from libraries of core and user-defined modeling elements.

In template-builder mode, the user defines model topology using the railway elements in the ADAMS/Rail library (wheelsets, bogie frames, dampers, suspensions, etc.). Defining hardpoints automatically parameterizes the model. Templates can be created for running gear, bodies, accessories, and other railcar subsystems.

Then, within the standard interface, the user can apply the new template and specify data to create a fully functional model of a railcar subsystem. Subsystems can be easily assembled into a complete railcar, or even a complete train including engine and cars. In vehicle modeling, users work at the system level, with a standardized platform, and the software's database structure allows easy data exchange.

In modeling tracks, the ADAMS/Rail user defines the centerline by specifying the analytic layout parameters: curvature, cant, and gauge. Track measured data are specified as irregularity
parameters: alignment, cross level, and gauge variation. Users define wheel-rail contact by specifying the type and properties of the contact elements for each wheel as a function of the track longitudinal coordinate. Parameters needed for each wheel-rail interconnection are automatically calculated according to wheel and rail parameters. Contact is modeled between one wheel and one rail with generalized force elements, and contact models can even switch along the track.

**EASY CAD/CAE INTEGRATION**

“ADAMS/Rail users can integrate applications with their existing engineering processes,” Ferrarotti says. “Two-way interfaces let them freely exchange data with their preferred CAD, finite element analysis, and control system design packages.”

**LINEAR WHEEL-RAIL ELEMENT**
- Designed for stability analysis
- Contact geometry and parameters are precalculated and linearized
- Left and right wheels/rails can be independent
- Includes gravitational stiffness effect

**NONLINEAR WHEEL-RAIL ELEMENT (WITH PRE-COMPUTED CONTACT GEOMETRY)**
- Designed for dynamic analysis with tabular description of wheel-rail properties
- Forces applied to each wheel
- Left and right wheel/rail can rotate independently
- Contact forces depend on relative position of wheel and rail
- Irregularities applied as contact table entry
- Contact table includes wheel and rail characteristics

**NONLINEAR WHEEL-RAIL ELEMENT (WITH ONLINE CALCULATION OF CONTACT GEOMETRY)**
- Designed for dynamic analysis with complex wheel-rail contact mechanics
- Online calculation of contact geometry and parameters during simulation
- Allows true 3D multi-point contact
- Left and right wheels/rails can be independent
- Wheel/rail profiles can change during simulation

**DIFFERENT CONTACT LEVELS SERVE DIFFERENT APPLICATIONS**
- The linear contact element permits stability studies for determining critical speed, as well as qualitative analysis of the vehicle's behavior. It will also soon support frequency domain response to power-spectra track description.
- The tabular contact element allows dynamic simulation involving nonlinear contact phenomena — such as comfort, stability, and curving — when there is no multi-point contact.
- The general contact element does not use tables, thereby offering the possibility of simulating multipoint contact and second-order effects such as the influence of track flexibility on contact mechanics.

The result, per Ferrarotti, is a complete virtual prototyping environment for building and testing railway vehicle designs. “Users not only save time and money by reducing the need for physical testing,” he says. “They also produce better designs because they can quickly optimize system performance on the computer.”

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