MSC Software
Simulation Solutions Overview

Daniele Catelani - MSC Software

June 14, 2012
49 years in Simulation for Engineering

1963
MacNeal-Schwendler Corporation founded

1969
First MSC Nastran Installation

1973
MSC goes Global

1994
Addition of Pre/Post Processing

1999
Addition of Nonlinear Simulation

2002
Addition of Multibody Simulation

2009
STG Acquires MSC

2010
Multidiscipline Innovation in MSC Nastran Solver

2011
Addition of CFD and Acoustics
MSC Software: A Global Team

Corporate talent assets
1200 people WW

Ann Arbor
Pune

Corporate Headquarters

Munich
Tokyo
Beijing
Paris
MSC Software: The Italian Team

- Italy talent assets
  - 40 people + external consultants / partners

- Offices Location
  - Roma
  - Torino
  - Udine
  - Genova
MSC.Software Customers
Trusted by over 10,000 Manufacturers
MSC Simulation Portfolio
Build, Manage, Solve

Brodest Range of CAE Solutions for Engineers

**Simulate** range of structural and multiphysics problems

**Create, build and simulate** mechanical systems and controls performance

**Model and simulate** acoustics and CFD problems to optimize designs

**Study** durability and design life predictions to improve quality

**Manage** simulation process and track pedigree of all data
Structures & Multiphysics
**MSC Nastran**

Integrated CAE Solver

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What is MSC Nastran?

- **A Unified Multi-Discipline solver**
  - The new MSC Nastran combines the traditional power of classic MSC Nastran plus the incorporation of multi disciplinary solutions in contact, nonlinear analysis, NVH and acoustics, crash analysis, optimization, assembly modeling, high performance computing, and rotordynamics all within the familiar Nastran interface.

- **A Combination of Best In Class solver technologies**
  - MSC Nastran, Dytran, LSDYNA and Marc

- **A Common Model Data for all disciplines**
  
  - Improved correlation with real world conditions due to interactions between disciplines
  
  - Eliminates redundancies (multiple models for each discipline)
  
  - Simplified IT support
    - CAE functions can maintain one solver solution instead of more
MSC Nastran
Large Model, Systems and Assembly Modeling

- Complex structural systems and large assemblies require special capabilities for efficient and accurate simulation
  - MSC Nastran contains industry proven, high performance technology and methodologies for correctly and efficiently modeling and simulating these types of models
- Techniques for correctly modeling welded, glued and fastened assemblies, as well as jointed connections
- ACMS – Automathed Component Mode Synthesis for faster, parallelized modal analysis of large models
- External Superelements for use in assembly process
  - Superelements enable logical partitioning of a full-vehicle and reuse of component information helping reduce a solution time
- 3D Contact simulation to account for complex assembly interaction
Advanced integrated nonlinear analysis
What is SOL 400?

- **New advanced nonlinear solution process**
  - Combines capabilities of multiple solution sequences and software components into a common solution
  - Allows for analysis Chaining
    - Automatically chaining together sequences of analyses with output state of one used as input state for another
    - Model complete processes in a single simulation through analysis chaining
MSC Nastran – Advanced Nonlinear Analysis

Contact Analysis

- Study multi-body contact for 2D or 3D scenarios
- Model contact between pure deformable bodies or a combination of deformable and rigid bodies
- Include friction in your analysis
- Two type of contact conditions are available
  - General Contact (Touching)
  - Glue Contact

- Linear Glue Contact
  - Glued Contact available for all Nastran linear solutions including
    - Linear Statics
    - Normal Modes
    - Frequency Response Analysis
    - Transient Dynamics
    - Optimization
  - It allows connecting mismatching mesh
MSC Nastran – Advanced Nonlinear Analysis
Material Modeling

- Large Strain Elastic-Plastic Material
- Nonlinear Elastic Material
- Advanced Hyperelastic Material
- Composite Failure
- Gasket Material
- Crack Materials
- Creep Material
- Shape Memory Alloy
You can perform design optimization to assess the effects of design changes, improve existing designs and ensure that your designs meet all requirements.

- With the help of Sizing (also Topometry option), Shape (also Topography option) and Topology Optimization you can choose the appropriate methodology for your studies.
- MSC Software’s multi model optimization technology also integrates models from different disciplines and simultaneously optimizes the complete design to meet the high level objectives such as performance, cost, life and weight.
- A Design Optimization based on NonLinear Responses is also available.

**MULTI-MODEL OPTIMIZATION Example**

**Gauge Thickness Discrete Optimization**

- **Full Vehicle NVH:**
  - 5.0M dof / 50 design var
  - Analysis = **MFREQ** (w ACMS)
- **Trim Body Stress:**
  - 4.6M dof / 47 design var
  - Analysis = **STATICS** (Inertia Relief)
- **BIW Stiffness:**
  - 2.8M dof / 31 design var
  - Analysis = **MODES** (w Modtrak)

**Objective (Min Wt)**

-60 -40 -20 0

**Delta Wt (lb)**

0 1 2 3 3D

53.5 lb wt reduction (full vehicle model)
Example: Topology optimization
Combined Sizing/Topology optimization

- Topology can be combined with other types of optimization classes

Design model
- Maximize the 15th natural frequency
- **Red**: topology design region with extrusion + mirror symmetry constraints
- **Green**: sizing (thickness) variables
- Topology mass saving 50% & sizing mass no change

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Optimization using different design models
Test Case using three different input models

Model 1 – Built for Torsional Stiffness Analysis
- Grids = 5613
- Elements = 5970
- Design Variables = 10

Model 2 – Built for stress Analysis
- Grids = 19411
- Elements = 19640
- Design Variable = 9

Model 3 – Built for Acoustic Analysis (FRF)
- Grids = 13761
- Structural Elements = 5970
- Fluid Elements = 7829
- Design Variables = 10

- Each model is built according to the request of the specific type of analysis
Optimization using different design models
Test Case using three different input models - Results

- The design overcame a violated constraint while reducing the weight from 643. to 573.
STRUCTURAL OPTIMIZATION and its application in AUTOMOTIVE INDUSTRY

VECOM training
“Simulation methodologies for vehicle structure”
9-10 February 2012, Firenze, Italy

Ing. Mauro Linari
Project Manager
MSC Software S.r.l.
• Product development teams need to verify and optimize their designs for multiple disciplines, including those with various physics like thermal, acoustics and fluids.
  • How thermal history state affects structural behavior?
  • How vehicle trims influence cabin acoustics?
  • How flow induced stresses or deformation affect a system’s behavior.

• Using a chained, uncoupled approach and a coupling method, MSC Nastran gives you the flexibility to include the influence of multiple physical phenomena on your designs.

• Scalability of MSC Nastran also enables you to conduct full vehicle studies without sacrificing accuracy.

• A few examples of the problems that can be addressed by MSC Nastran are:
  – Interior and exterior acoustics
  – Brake squeal analysis
  – Fluid filled bottles
  – Hydroplaning
  – Brake heating
  – Plastic heat generation during forming
MSC Nastran – Advanced Nonlinear Analysis
Nonlinear explicit

- Analyze dynamics of short duration with severe geometric and material multiple nonlinearities including, but not limited to, crash, drop test, and impact.
- Simulate complex fluid structure interaction problems
- Use the smooth-particle hydrodynamics (SPH) method to model fluid flow problems for crashworthiness on water or soft soil, high velocity impact, and penetration and perforation problems
- Simulate crash, impact and similar scenarios

Bumper Pendulum Impact Test
- Bumper Made of Thermoplastic Material
- Pendulum Impact Speed: 7 km/h
- Bumper Substructure Contains Energy Absorbing Box
- Mesh Size: 7500 Shell Elements

Inside Airbag:
- Detailed gas flow
- Multiple compartments
- Heat convection
- Holes and porous areas
Nonlinear, Thermal, and Multiphysics Analysis

Marc

- **General large sliding contact**
  - Deformable and rigid bodies
  - Line contact
  - 2D and 3D contact
- **Nonlinear materials**
  - Nonlinear material behavior of metals, composites, plastics, elastomers
- **Multiphysics**
  - Coupled electrical-thermal-structural
  - Joule heating
  - Electromagnetics, electrostatics, magnetostatics

Benefits
- Easy nonlinear model setup
- Solves complex problems involving contact and nonlinear material effects
- Reduce time and cost of physical test

Industries
- Biomedical
- Wind Energy
- Oil & Gas
- Automotive
- Heavy Equipment
- Aerospace
Marc Application on Engine Analysis

- Contact areas
- 3D Engine Head mesh
  1750838 elements
The implementation of a robust procedure for the cyclic application of subsequent mechanical, thermal, and thermo-mechanical loads to the model is essential, since the accuracy of these data directly affects the quality of the structural response and of the numerical predictions.

Loading strategy

Many different consecutive load cases are subsequently implemented in order to take into account both high frequency-cycles and low frequency cycles:

1: press fits and bolt tightening only  \[\text{head assembling}\]
2: press fits, bolt tightening and combustion pressure  \[\text{engine cold start}\]
3: including all mechanical and thermal loads  \[\text{h.c.f. operation}\]
4: including all loads except for combustion pressure  \[\text{engine stop}\]
5: same as 4 but thermal loading is removed  \[\text{l.c.f. operation}\]
6: same as 5 but thermal loading is re-applied  \[\text{engine start}\]
Marc Application on Engine Analysis

High-cycle fatigue regions: standard HCF stress-based criterion can be adopted

Low-cycle fatigue regions: stress-strain hysteresis cycle should be adopted

A: Initial State
B: Components assembling
C: First engine warm up
D: First engine cool down
E: Second engine warm up
F: Second engine cool down
G: Third engine warm up

Stress-strain hysteresis cycle energy density distribution
Systems & Controls
Build Functional Virtual Prototypes with Adams

Accurately simulate product performance and optimize virtual prototypes

Perform design of experiments to examine more design variations

Predict performance of systems & mechanisms with integrated controls

Study the dynamics of moving parts, how loads and forces are distributed throughout mechanical systems, and improve & optimize product performance
Quickly create high-fidelity system models with pre-built, ready-to-use blocks in several Application Libraries

- **Broad & Powerful Analysis Capabilities:**
  - Steady-state tool
  - System stability via linear analyses tools
  - Control system analyses
  - DOE
  - And More!

- **CAE Tool Integration:**
  - Multibody dynamics via Adams
  - DOE, optimization via Adams/Insight
  - Flexible bodies via Nastran
  - 3\textsuperscript{rd} Party codes
Examples of controlled chassis systems

ABS, ESP, EHB, ASR, EDS, BA, ACC

4CL, CDC, ABC

Controlled differential Clutches/Locks

EPAS, EHPAS, Servotronic, Active Steering

Controlled Stabiliser

Reference: Dr. Gies, Audi AG
Acoustic
Nastran and Acoustic: Interior vs. Exterior

• **Interior Acoustics**
  - Fluid domain is bounded.
    • Automotive interiors
    • Aircraft cabins
    • Acoustic devices

• **Exterior Acoustics**
  - Domain is unbounded (or “infinite”).
    • Radiated engine noise
    • Exhaust pipe system
    • Acoustic devices
      - Loudspeakers
      - Microphones
Full Vehicle Acoustics

- **Model Descriptions**
  - Total nodes: 421,000
    - External acoustic: 58,800
    - Internal acoustic: 3,300
  - Total elements: 708,000
    - External acoustic: 329,000
    - Internal acoustic: 2,500
    - Infinite elements: 7,700

- **Analysis Conditions**
  - Modal Frequency (SOL 111)
    - 2646 structural modes (0 ~ 375Hz)
  - 100 Forcing frequencies
  - HPia2 2.53GHz
  - MEM=6GB, SMEM=1GB

- **Performance Results**
  - DMP=4 (ACMS)
  - Elapsed time = 12.6hr
  - CPU time = 12.5 hr
ACTRAN for NASTRAN

- Contains all advanced features for mixing ACTRAN and NASTRAN models
  - Import of NASTRAN super-elements in ACTRAN Vibro-Acoustics
  - Large trimmed body modeling
    - Updated Modal Approach
    - Reduced Impedance Approach
  - Export of ACTRAN impedance matrices to NASTRAN

- Purpose: when performing vibro-acoustic simulation on local component, take account of influence of the whole structure to which the component being studied is connected
- Method: import of super-elements. These elements carry structural information which is to be applied to local component and to modify their vibro-acoustic behavior under loading
  - Applications: Acoustic transmission through components in real-life mounting conditions.
Modeling of the Trim and the Dashboard

Patch N°1

Patch N°2

Patch N°3

Multi-layered trim: foam + heavy layer

Super-element

Model courtesy of Audi

Super-Element Reduction - NASTRAN

Vibro-acoustic simulation - ACTRAN

ACTRAN for NASTRAN
ACTRAN for NASTRAN

SPL at driver’s ear

Conf1 = patch 1 + patch 3
Conf 2 = patch 2 + patch 3

SPL distribution at 120 Hz

Average dashboard vibration

Patch N°2

Patch N°3

Patch N°1

patch 1 + patch 2
Multidiscipline Simulation
Multidiscipline Parts & Systems
Controls-MBD-FE Integration

MBS + Fatigue

MBS + CFD + Fatigue

MBS + CFD + Fatigue + EE + Controls
Multi Discipline Value
CASE STUDY - 1

Multibody, DOE & Fatigue Simulation for new Track Suspension Design

Courtesy By Iveco
CFD-FEM-Multibody Integrated Simulation for System-Level Dynamic Performance Including Aerodynamic Profiles
Optimize Designs by Simulating Multidisciplinary Problems

**Model** and analyze structural, thermal, motion, and systems simulations in a single, fully integrated user environment

**Access** native CAD features for defeaturing and faster meshing & pre-processing

**Use** a common data model across discipline simulations for higher accuracy and faster results

**Automate** standard and repeatable simulations so simplify simulations and reduce costs
Simulation Data & Process Management
Innovation Framework
Managing, Integrating, and Automating Simulation

• Manage diverse simulation content
  – Models, files, inputs and outputs
  – Instructions, Scripts, Macros, Templates
  – Simulation Processes & CAE workflow
  – Classify, Store, Protect, Distribute

• Manage & automate simulation processes
  – Manually repetitive tasks
  – Standard procedures
  – Multiple method execution sequences
  – Schedule management on HPC

• Document simulation audit trail
  – Enable “SEARCH/FIND”
  – Satisfy regulatory compliance
  – Protect against liability
Thank you

www.mscsoftware.com