Week 10 - Lecture Nonlinear Structural Analysis

Product Lifecycle – Week 10



Goals of Simulation

- Validate Designs
- Predict Product Performance
- Optimize Designs



Replicate the Physical World

The more closely a simulation conforms to what happens in the physical world, the more value it has to offer.

- Model Geometry
- Analysis Type
- Materials
- Boundary Conditions
- Loading Conditions



- **Materials**
- The available material selection is vast and changes everyday.
- The material properties and material model determine the behavior under operating conditions.



Force Estimation Methods

Experience

 Engineers reply on past experience from similar projects to estimate forces.



Rigid-Body Dynamics

 Leverage the 3D design data to perform a motion simulation using rigid bodies to gain insights into force values.

Physical Experimentation

Experiment with prototypes or past products to obtain accurate force values.

Linear vs. Nonlinear Analysis

Linear

- Structure returns to original form
- No changes in loading direction or magnitude
- Material properties do not change
- Small deformation and strain

Nonlinear Focus for this week

- Geometry changes resulting in stiffness change
- Material deformation that may not return to original form
- Supports changes in load direction and constraint locations
- Support of nonlinear load curves





Nonlinear Analysis

Design Engineer Belief

- Too Complicated
- Time Consuming
- Specialized software packages

Reality

- Nonlinearities are common.
- Advances in FEA Software
- Advances in Computing Hardware





Types of Nonlinearity

Nonlinear Material

 Materials that do not have a complete linear stress strain curve as seen in plastic and rubber materials for example.

Nonlinear Geometry

 The changing shape of a model when large deformations exists provide nonlinear changes in the components stiffness.

Nonlinear Boundary Condition

 Boundary conditions that involve components in contact with one another often produce disproportionate changes in deformation.

Nonlinear Loading Condition

- Loading changes over time.

Materials Types



Polymeric Material Example



Nonlinear Boundary Condition

 Component contacts produce stresses and friction that result in disproportionate changes in deformation.



Nonlinear Geometry

 Changing shape triggers nonlinear changes in stiffness of the part model.



Event Simulation

- Event simulation allows for the entire event of a condition not just a static solution.
- In mechanical engineering the static case often does not dictate the design.
- Designs must consider the worst-case scenario which often occurs after loading.



Event Simulation Example



Linear static solution would have the entire load carried by vertical member.

Event Simulation Example



With an event simulation the horizontal members would carry some of the load.

Nonlinear Example

 Unbending and bending a paperclip back into position has nonlinear material and geometry effects.



Everyday Nonlinear Requirements



Autodesk Simulation

Autodesk Simulation helps designers and engineers make decisions earlier and predict product performance.

- Linear and Nonlinear Static Stress
- Fatigue Analysis
- Linear Dynamic
- Mechanical Event
- Heat Transfer
- CFD
- Multiphysics



The following are some of the element types available in Autodesk Simulation

- Beam
- Spring
- Brick
- Shell
- Truss
- Special (Actuator)
- Special (Membrane)
- Special (Slider)



Load Curves

Load curves control the load value through a multiplier over a time period. Each specific load can follow a different load curve.



Six Flags Theme Parks - Case Study



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Challenge

Maintain and renovate hundreds of thrill rides with minimal downtime.

Results

- New, in-house design of antirollback mechanism to modernize a wooden roller coaster, the Texas Giant
- Better collaboration with fabricators through use of high-quality drawings and documentation
- Improve quality by increasing reliability of high-wear parts.

"Our primary concern is safety. Inventor and Autodesk Simulation allow us to study real-world loading scenarios so we can be sure we have appropriate safety factors in our designs."

Mike Neuzil Corporate Engineer Six Flags Theme Parks, Inc. United States

Howden - Case Study





Challenge

Reduce the time taken to produce tenders with technically and economically competitive proposals, while taking account of increasingly detailed customer requirements

Results

- Substantial reduction in total design time.
- Faster response to customer design requirements.
- Simulation allows investigation and validation of new design approaches.
- Weight reduction through design optimization brings reduced costs.

"Flexibility, adaptability and reliability are the key benefits that we enjoy with Autodesk Simulation products."

Laurent Tisserand Technical Director Howden France

Computer-Cluster Projects (CP10)

Guided Lab Project 1

Guides instructions for completing a static stress linear simulation in Autodesk Simulation.



Guided Lab Project 2

Guided instructions for completing a mechanical event nonlinear analysis in Autodesk Simulation.



Guided instructions for completing a snap fit nonlinear analysis on a medical device in Autodesk Simulation.



Problem Set Assignment

Analyze the electrical switch snap fit mounting to determine force required and design quality.



Demo Topics

User Interface



Setup tab

Stress Analysis browser

Graphical display

Mesh Panel and Settings

MP	Mesh Dr	aw Setup	o Ana	alysis Sele	ection V	/iew To	ools Gettin	g Started	E3 •			
*				f_x	Bolt	151.11		A	3 Point Triangular	n Divide 1 Object		💣 Specify
Generate	3D Mesh	Generate	Joint	Inventor	Intern	nal Fluid	4 Point	Between	HP 4 Object 3D		Add to	His Automatic
3D Mesh	Settings	2D Mesh		Parameters	ሰ Exterr	nal Fluid	Rectangular	2 Objects	\overline 8 Point 3D		Selected Nodes	• _° Visibility
	Mesh 🔻			CAD Ac	dditions				Structured Mesh		Refineme	ent Points

Model Mesh Settings	Model Mesh Settings
Mesh type Mesh size Solid Silder not available since absolute mesh size was specified with automatic geometry-based mesh size function in effect. Options Options Defaults OK Cancel	General Options Surface Mesh size Size Solid Retries Number of retries Model Defaults OK Cancel

Simulation Browser





Assign Materials

Parts Parts Part 1 < beam:1 > Element Type < Brick > Element Definition Material < Aluminum 6061-T6; 6061-T651 > CAD Mesh Options Edit Material Surfaces	Element Material Selection		ି <mark>×</mark>
	Greate New Library Add Existing Library		
	Select Library	Aluminum 6061-T6; 6061-T651	
	Autodesk Simulation Material Library 👻	Current Material Information	
	Autodesk Simulation Material Library	Analysis Type:	MES with Nonlinear Material Models
	[Customer Defined]	Element Type:	Brick/Tetrahedral
	Euterina Sonnoaj	Material Model:	Standard
	E Brass	Material Specified:	Aluminum 6061-16; 6061-1651
	E Concrete	Material Identification	Autodesk Simulation Material Library
	🗄 🕀 🔂 Glass	In Library File:	C:\Program Files\Autodesk\Algor Simulation 20
		Date Last Updated:	28-0CT-2004 16:02:00
	E Riseria	Units System:	Metric mks (SI)
			None
	E Steel	Material Description:	
	E → AISI	Matchar Description.	
	🗄 🛅 ASTM		MatWeb
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	Carpenter 20-Mo6r Stainless Steel, Pl	Coloret Meteodol	Al minum CDC1 TC: CDC1 TCE1
	Carpenter 20Cb-3r Stainless Steel, Ba	D Material Properties	Auminum 6061-16, 6061-1651
	Camenter Custom 450r Stainless Stee	Damping (s)	0
	Stainless Steel (AISI 202)	Mass density (lbf·s²/in/in³)	2 52645876511496F-04
	Stainless Steel (AISI 302) Annealed	Modulus of Elasticity (bf/in ²)	9993100.13019664
	Stainless Steel (AISI 302) Cold-rolled	Poisson's Ratio	0.33
	Stainless Steel (AISI 309)	Strain Hardening Modulus (lbf/in²)	42513.2
	Stainless Steel (AISI 310)	Yield Strength (bf/in²)	40030.415615882
	Stainless Steel (AISI 317)		
	Stainless Steel (AISI 405)		
	4 III + I		
	Edit Properties Reset From	1 Model	OK Cancel Help

Assign Constraints

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Constraints 💌								

Creating 1 Surface Boundary Condition Object									
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Assign Loads







Contacts

Surface-to-Surface Contact

Contacts



Parameters		8
Contact problem type	Low Speed Contact (Press-Fit)	, -
Contact method	Frictionless Contact 🔹	Reset From Model
Contact type	Automatic 🗸	Reset From Default
Modeling Friction		
Static friction coefficient	0	Advanced
Sliding friction coefficient	0	
Tangential stiffness ratio	1	
Tied Contact Options	Slide / No Bounce Contact Options	
Tied contact initial interference	✓ No bounce	
Tied contact tolerance	No slide	
	OK Cancel Help	

Analysis Parameters

Analysis Parameters - MES with Nonlinear Material Models	Ouration
Description of model	O Capture Rate
MES Reset From Model	
- Reset From Default	3 Load Curves
Event	
Ouration 2 s 2 Capture rate 20 1/s	
⊘ Number of time steps 40 Initial time-step size 0.05 s	
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Data for Selected Load Curve	
Description Load Curve	
O Time Cookup Value	
Load curve selector Lookup Value Define/Edit Lookup Values_	
Add load curve_	
Add next load curve Load Curve Add Row	
2 0.5 0.06667 Delete Bow	
Import load curve 3 1 1 4 2 0	
Delete load curve	
3 Add Column Delete Column View plot_	
OK Apply Cancel Help Advanced	

Selection Panel











Run Simulation



MES with Nonlinear Material Models		
Analysis Description MES	Elapsed Time	e: 00:01:54
Analysis Duration	*	
Total 2 s Extend Total By 0	s	Resume
Analyzing:	Analysis in pro	ogress
Comparis Schedule Pause State	qq	Done
Analysis Configuration	Disk Space	
Target Computer	Started With	18841 MB
Monitor Rate 2 sec	Current	18817 MB
Number of threads/cores Automatic 💌		
Analysis Information View Statistics View Analysis Sum	nmary 🔘 View Solid	Meshing Summary
** 3-D surface contact element calculation (Initial)	,	*
<pre>number of element = 1788 ** Nonzero entries initially in upper triangle matri</pre>	x = 348088	
** BCSLIB-EXT Sparse Solver Solution		
Time Percent DT L Iter. Residual		
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Results User Interface



Results Contours / Results Inquire

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		Inquire				Probes	•			Graphs	Load Case Options 🔻	Captures 🔻

Graph Results

