Outline

Introduction
Benefits of Using ANSYS
Continual Enhancements
Analysis Types
Rotordynamics in ANSYS Workbench
Rotordynamics Documentation
Summary and Questions
Many industries use machines with rotating components

• Power generation, transportation, electronics, chemical processing

Comprehensive design of rotating components, using high-fidelity tools, is essential to achieve machine reliability, stable range of operation, low noise at desired speeds and loads etc.

• Turbomachinery, mixers, disk drives, generators etc.

ANSYS has expanded its rotordynamics capability to offer integrated solutions to all such industries and machine types
Benefits of Using ANSYS

Complete rotordynamics analysis with ANSYS, enabled by:

- CAD import and automatic meshing
- Library of elements
- All analysis types (including pre-stress)
- Dedicated post-processing
- Multi-spool dynamics simulation
- Direct connection to bearing codes
- Account for the flexibility of the supporting structure and/or the disks

Connect directly to other ANSYS tools via Workbench.
Continual Enhancements
## Release 10.0 Enhancements

<table>
<thead>
<tr>
<th>Feature</th>
<th>Command(s)</th>
</tr>
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<tbody>
<tr>
<td>Activate gyroscopic effect at solver level</td>
<td>CORIOLIS</td>
</tr>
<tr>
<td>Specify rotational velocity for full model and components</td>
<td>OMEGA, CMOMEGA</td>
</tr>
<tr>
<td>Develop Campbell diagram</td>
<td>PRCAMP, PLCAMP</td>
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<tr>
<td>Include gyroscopic effect with LINE and MASS elements</td>
<td>MASS21, BEAM188, BEAM189</td>
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## Release 11.0 Enhancements

<table>
<thead>
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<th>Feature</th>
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<tr>
<td>Include gyroscopic effect with SOLID elements</td>
<td>SOLID185, SOLID186, SOLID187</td>
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<tr>
<td>Perform a harmonic response to synchronous and asynchronous excitations</td>
<td>SYNCHRO</td>
</tr>
<tr>
<td>Perform Campbell analysis of a pre-stressed structure</td>
<td>CAMPBELL</td>
</tr>
<tr>
<td>Visualize and printout the orbits characteristics</td>
<td>PLORB, PRORB</td>
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<tr>
<td>New variable bearing element</td>
<td>COMBI214</td>
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# Release 12.0 Enhancements

<table>
<thead>
<tr>
<th>Feature</th>
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<tr>
<td>Include gyroscopic effect with SHELL elements</td>
<td>SHELL181, SHELL281</td>
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<tr>
<td>Replace damped eigensolver with faster and more accurate solver</td>
<td>MODOPT, DAMP</td>
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<tr>
<td>Improve performance for large models (1 MdoF) in reduced damped eigensolver</td>
<td>MODOPT, QRDAMP</td>
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<tr>
<td>Include gyroscopic effect with new generation axi-harmonic elements</td>
<td>SOLID272, SOLID273</td>
</tr>
<tr>
<td>Add dedicated Rotordynamics Guide</td>
<td><strong>Documentation</strong></td>
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</tbody>
</table>
## Release 13.0 Enhancements

<table>
<thead>
<tr>
<th>New APDL Math extends APDL scripting capabilities</th>
<th><strong>EIGEN</strong></th>
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</thead>
<tbody>
<tr>
<td>Damped (MODOPT,DAMP) extraction method supported in Distributed ANSYS</td>
<td><strong>MODOPT, DAMP</strong></td>
</tr>
<tr>
<td>QR damped (MODOPT,QRDAMP) eigensolver now reuses existing undamped modes</td>
<td><strong>MODOPT, QRDAMP</strong></td>
</tr>
<tr>
<td>Linear Perturbation enables a modal analysis to use the tangent stiffness matrix at any point in a previous analysis</td>
<td><strong>PERTURB</strong></td>
</tr>
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</table>

*SMAT, K, D, IMPORT, FULL, file.full, STIFF
*SMAT, M, D, IMPORT, FULL, file.full, MASS
*SMAT, G0, D, IMPORT, FULL, file.full, DAMP

*Smat, zMG0, Z, COPY, M
*AXPY,, alpha, G0, 1,, zMG0
*SMAT, zK, Z, COPY, K

/SOLU
ANTYPE, MODAL
MODOPT, UNSYM, 6

Reduced processor time for large models

Better performance for Campbell Diagram generation

More general method for rotordynamics pre-stress modal analysis
Release 14.0 Enhancements

Support in Workbench Mechanical for:
• Campbell Diagrams
• Full Damped, Reduced Damped solvers
• Animation with Decay
• Rotational Velocity with Coriolis Effect
• Post-process Multi-step modal analysis
Analysis Types
Specify the rotational velocity and activate the Coriolis effect.
Modal Analysis – Campbell Diagram

Frequencies - Whirls - Stability

Critical Speeds

Set up a Multiple Load Step Modal Analysis

Logarithmic Decrement
Harmonic Analysis – Unbalance Response

Specify the Unbalance Force on Inner Spool

Orbit Plot

Unbalance Response
Transient Analysis 1

Specify the Rotational Velocity vs. Time

Start-up and Stop Simulation

Transient Response
Transient Analysis 2

Stability Verification

Specify a Short Duration Force

Transient Orbits
Rotordynamics in ANSYS Workbench

Initial 3D geometry

Disk added

Model consists of
- Shaft
- Disk
- Bearings

Final axisymmetric model

Bearings
Rotordynamics in ANSYS Workbench

Project view in ANSYS Workbench

Simulation process

Geometry
Mesh
Simulation

Parameters: geometry & bearing stiffness

Design Exploration Tools

Parameters:

Geometry

Mesh

Simulation

Design

Exploration

Tools

Simulation process

Geometry

Mesh

Simulation

Parameters:

Geometry & bearing stiffness

Design Exploration Tools

Simulation process

Geometry

Mesh

Simulation

Parameters:

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Simulation process

Geometry

Mesh

Simulation

Parameters:

Geometry & bearing stiffness

Design Exploration Tools

Simulation process

Geometry

Mesh

Simulation

Parameters:
Mesh & Model

- Mesh
- Expanded view

Axisymmetric model with boundary conditions
Simulation & Results

Campbell Diagram

Critical speeds

Mode visualization (animation with decay)
Design Exploration

Outline of All Parameters

<table>
<thead>
<tr>
<th>ID</th>
<th>Parameter Name</th>
<th>Value</th>
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<td>Input Parameters</td>
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<td>2</td>
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<td>3</td>
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Automated parametric investigation

Sensitivity plots

- Input parameters
  - Disk radius
  - Shaft radius
  - Bearing stiffness

- Output parameters
  - Critical speeds
## Multi-objective Optimization

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
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<td>P2 - D8_Radius</td>
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Specify “Seek Target” for Optimization

![Graph showing Multi-objective Optimization results](image-url)
Chapter 7: Rotordynamic Analysis

The following example analysis samples are available:

- Example: Campbell Diagram Analysis
- Example: Campbell Diagram Analysis of a Prestressed Structure
- Example: Modal Analysis Using ANSYS Workbench
- Example: Harmonic Response to an Unbalance
- Example: Mode-Superposition Harmonic Response to Basal Excitation
- Example: Mode-Superposition Transient Response to an Impulse
- Example: Transient Response of a Startup
- Example: Campbell Diagram Analysis of a Simple Rotor Supported by a CMS Superelment
Technology Demonstration Guide

Figure 21.12 Bonded Contact Pairs at Bearing Locations (3-D Solid Model)

To model an orthotropic bearing, an additional node is created at the center of the cross section of the rotor at the bearing location. This node is then connected to plot node using COMBIN14 elements. To visualize this element, offset the node along the Y-direction without altering the results as shown in the figure below and in Figure 21.11.
Summary

The previous slides have described the elements of complete rotordynamics analysis, with ANSYS.

Key enabling features:

- CAD import and automatic meshing
- Library of elements
- All analysis types (including pre-stress)
- Dedicated post-processing
- Multi-spool dynamics simulation
- Direct connection to bearing codes
- Account for the flexibility of the supporting structure and/or the disks
- Connect directly to other ANSYS tools via Workbench (DesignXplorer)

The result: Faster, more complete and accurate machine analysis... with ANSYS.
Questions?