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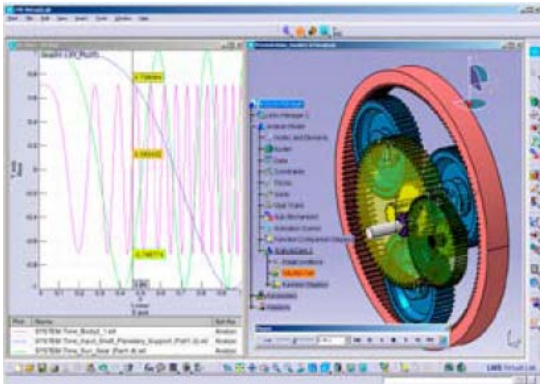

# Rotating Machinery Testing and Source Path Receiver Models

When engineering quiet, efficient and reliable products, mastering the sound and vibrations produced by engines, compressors, electrical motors, pumps and shafts, is a highly complex process. Engineering teams that focus on vibro-acoustic troubleshooting and product refinement require a comprehensive array of tools: waterfall mappings, order tracking, time data, processing functions and specialized modules to analyze and visualize the vast amounts of data that are generated. Whether you are performing measurements in an engine test cell, a vehicle on the proving ground, a helicopter in flight or on a pump in the field, rotating machinery testing and angle domain processing is a critical part of the functional performance engineering.

- First, the basic key elements of rotating machinery which relate to noise and vibration testing. The course is intended as an introduction or review of the acquisition and analysis of rotating machinery harmonics through real-life exercises.

- Next, participants will focus on The Source-Path-Receiver Model is introduced and Transfer Path Analysis (TPA) is used as investigative or troubleshooting tool. Transfer Path Analysis is a procedure which allows you to trace the flow of vibro-acoustic energy from a source, through a set of known structure- and air-borne pathways, to a given receiver location.

- Lastly, participants will be shown how to run the model and interpret output results on LMS software products. A thorough understanding of what these results mean and how to use them to improve the product design will be discussed.

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# Course Syllabus

## I IDENTIFYING INFORMATION

| | |
|---|---|
| **Course:** | Rotating Machinery Testing and Source-Path-Receiver Models |
| **Prerequisite:** | Digital Signal Processing in Noise and Vibration Testing |
| **Time Frame:** | 40 total contact hours |
| **Instructor:** | A technical specialist with LMS International<br>BS in Mechanical Engineering<br>5 years of experience with LMS software and hardware<br>5 years of industrial experience with rotating components |
| **Phone:** | (248) 952-5664 |
| **E-mail:** | testsupport.us@lmsintl.com |

## II REFERENCE MATERIALS

1. The Fundamentals of Signal Analysis (Hewlett Packard App Note 243)
2. The Time Variant Discrete Fourier Transform as an Order Tracking Method Jason R. Blough and David L. Brown, Structural Dynamics Research Laboratory, University of Cincinnati. Harvard Vold, Vold Solutions.
3. Multi-Tachometer Order Tracking and Operating Shape Extraction, J.R. Blough, Ph.D. Michigan Technological University, Mechanical Engineering-Engineering Mechanics Department
4. The Qualification and Quantification of Vibro-acoustic Transfer Paths, LMS International.

## III COURSE GOALS AND OBJECTIVES

1. Understand the differences between a resonance and an order
2. Use real life exercises to explain the analysis of rotating machinery harmonics via order tracking analysis
3. Interpretation of waterfall and colormap plots
4. Understand the resulting vibrations via operating deflection shapes
5. Understand the concepts behind source-path-receiver models
6. How to use operational test data to estimate operational forces
7. How to complete a transfer path analysis and interpret the results
8. Understand the need for principal component analysis and its use in transfer path analysis
9. Understand the advantages and disadvantages to operational transfer path analysis methods

## IV METHODOLOGY

This course is an introduction to the techniques that are used in the measurement and processing of noise and vibration data of rotating components and the techniques that are used during a transfer path analysis. Each module will introduce new material that the student will be allowed to experience for himself with the associate In-class Tutorials.

### Lectures

Each detailed subject will be presented in a lecture format outlining the theory and standardized accepted methodology. A printed copy of the lecture material will be provided for the student's personal in-class use and as a reference material.

### Specific Industry Examples

Real life examples will be covered that explain the application of the theory to various industries such as automotive, aerospace, home appliance. This will give the students a clear understanding of how and why these techniques are utilized in different industries and the value they add to noise and vibration enhancement.

### In-Class Assignments

The student will conduct several hands-on tutorials to reinforce the theoretical concepts. These tutorials will increase in complexity as the students further develop their skills.

## V COURSE OUTLINE & ASSIGNMENTS

**Module 1 – Digital Signal Processing Review**

Time – Frequency Domain Comparison
Terminology, tools and rules
Leakage
Aliasing
Windows
Linear Spectra
Auto Power Spectra
In-Class Tutorial – Time – Frequency Domain Comparison, Leakage, Aliasing, Linear vs. Autopower spectra

**Module 2 – Signature Theory Introduction**

Non-Stationary Operating Conditions
Analyzing Signatures
What is an Order?
In-class Tutorial – Signature Theory

**Module 3 - Signature Testing**

Measuring tachometer signals
FFT Fixed Sampling Signal Data Acquisition
In-class Tutorial – Signature Testing Data Acquisition

**Module 4 – Order Tracking Testing**

Order Tracking Signal Data Acquisition
In-Class Tutorial – Order Tracking Testing and Analysis

**Module 5 – Data Visualizing and Reporting**

Common Displays for Presentation of Results
Single Page Reports
Multiple Page Reports
In Class Tutorial – Advanced Reporting

**Module 6 – Geometry and Operating Deflection Shapes**

Creating a Geometry for Testing
Associating the Test Geometry to the Acquired Signature Data
Time Animation
Operating Deflections Shapes
In-class Tutorial – Creating a Test Geometry and using that in an Operating Deflection Shape Analysis

**Module 7 – Throughput Processing**

Selecting Throughput Time Data for Analysis
Specifying a Time Segment for Analysis
Processing Time Data for Run Up / Run Down Analysis of Rotating Components
In-class Tutorial – Throughput Processing of Run Up data for Order Tracking
In-class Tutorial – Automated reporting of results

**Module 8 – Run Data Comparison**

Comparison of Repeated Runs of a Signature Testing
Average, Max and Min Envelopes and Standard Deviation
Post Processing of Signature Testing Results
In-class Tutorial – Post-Processing of Results and Run Data Comparison

**Module 9 – Off-Line RPM Extraction**

Methods of Extracting an RPM-time Curve When One is not Available
Calculation of a Vibration or Acoustic Colormap
Selection of a Known Dominant Order
RPM Time Trace Derivation from the Selected Order
In-class Tutorial – Off-Line RPM Extraction and Analysis

**Module 10 – An Introduction to Source-Path-Receiver Models**

The Source-Path-Receiver Model
Structure Born Paths and their Contributions
Airborne Paths and their Contributions

**Module 11 – Single Reference Transfer Path Analysis**

Single Reference vs. Multiple Reference Transfer Path Analysis
The TPA model and its Definition
Load Identification via the Dynamic Stiffness Method
Load Identification via Single Point Inversion
Load Identification via Matrix Inversion
Interpretation of TPA Results
In-class Tutorial – Single Reference Transfer Path Analysis

**Module 12 – Singular Value Decomposition**

- Matrix Inversion
- Condition and Rank of the Matrix
- Singular Values
- Improving the matrix condition
- A-priori known loads
- Over determination
- In-class Tutorial – Single Reference Transfer Path Analysis #2

**Module 13 – Principal Component Analysis and Multi Reference TPA**

- Principal Component Analysis
- Singular Value Decomposition
- Principal Component Autopowers and Virtual Spectra
- Multi Reference Transfer Path Analysis
- In-class Tutorial – Principal Component Analysis #1
- In-class Tutorial – Principal Component Analysis #2

**Module 14 – Operational Transfer Path Analysis and OPAX**

- An Introduction to Operational Path Analysis
- A Critical Review of Operational Path Analysis
- OPAX Load Estimation Method
- Transfer Path Analysis using OPAX results
- In-class Tutorial – Operational Path Analysis
- In-class Tutorial – OPAX Load estimation and Transfer Path Analysis

**Module 15 – Component Editing**

- Editing the TPA Model
- Comparing different TPA models
- In-class Tutorial – TPA Component Editing