Course Content

Day 1 - Machinery Health and Reliability Excellence - Introduction

COURSE OVERVIEW

First day – Cause of Rotating Machinery failures
Second day – Standards, condition monitoring and top-class maintenance
Third day – Shafts, bearings and seals for reliability excellence, Maintenance for reliability
Fourth day – Improving machinery reliability, reducing maintenance cost, sustaining RE integrity

What is ‘Rotating Machinery Excellence’?

PLANT AND MACHINERY DOWNTIME COSTS

The True Cost of Failure
Where Profit is Lost in Business Processes
The Purpose of Business
Maintenance is an Economic Decision
Impact of Defects and Failures
Defect and Failure True (DAFT) Costs go Company-wide
Failure Costs Surge thru the Company
Separate the True Downtime Costs so you can see them for what they are
Calculating the True Downtime Costs

MACHINERY RISK MANAGEMENT

Understanding Risk and Its Consequences
Risk Calculations
The Shape of Risk
Risk Relationships
What Risk Means
Determine Your Acceptable Failure Domain
Maintenance is Used to Manage Risk
Benefits of Reducing Operating Risk

VARIATION, DEFECTS AND FAILURES

Defects and Failures Enter Your Business Everyday
Normal Ways to Control Defects and Failures
Preventing Defects and Failures
The Trouble with Accepting a Defect
Defects Lead to Failures and High Costs
Act to Control the Defects and Risks
Problems, Defects and Failures start with Variation
Effects of Process Condition Disruptions
Special and Common Cause Variation
Preventing Process Condition Disruptions

MACHINERY DESIGN ISSUES

The Unforgiving Nature of Machine Design
Activity 1 - Design Shaft Rotor and Material Selection
The Slow Destroyers
Good Process Control Prevents Rapid Internal Equipment Changes
Supporting Structure and Foundation Strength and Rigidity
Vibration Basics
Course Content Continued

Forced Vibration
Natural Frequency
Attenuation of Vibration
Dissipating Loads and Forces
Preventing Equipment Deformation
Preventing Deformation from Pipe Stress
Activity 2 - Soft Foot Case Study
Soft Foot Case Study
Soft Foot Distorts Motor Armature Air Gap

ROTATING MACHINERY PARTS FAILURE

Causes of Shaft Failures
Causes of Roller Bearing Failures
Calculating L10 Lifetime
Effects of Fluctuating Loads and Forces
Lubrication Contamination
Lubrication Contamination Control
Tell-tale Bearing Failure Signs
Causes of Contact Shaft Seal Failures

ROTATING MACHINERY RELIABILITY

The Payoff is Reliability, Availability, Maintainability, Safety (RAMS)
Equipment Degradation Cycle
Equipment Life Extension
Valuable Precision Maintenance
Rotating Equipment Precision Maintenance
Precision Maintenance of Rotating Equipment is …
Activity 3 - Develop an ACE procedure

Day 2 - Machinery Health and Reliability Excellence - Introduction

MECHANICAL EQUIPMENT AND MACHINERY STANDARDS

6 Mechanical Equipment Care Standards to Set, Use and Keep Using
Balanced Rotors and Balancing Standards
Rotating Equipment Balancing
Shaft Coupling Problems
Appropriate Key Length for Assembly
Coupling Bolts and Washers
Specification for Coupling Assembly
Burred Shaft
Either on end or next to bearing face
Activity 1 Balancing Case Study
Effects of Shaft Misalignment
Causes of Shaft Misalignment
Coupling Flexing Points Locations
Accuracy and Limits for Alignment
Precision Alignment Practice
  . Pre-Alignment Checks
  . Rough-In Alignment
  . Precision Alignment

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Course Content Continued

- Alignment Records
- Off-line to Running (OL2R) Machine Movement
- Case Study 2 – Important Factors when Doing Shaft Alignments

CONDITION MONITORING METHODS FOR ROTATING MACHINERY

- Range and Choice of Condition Monitoring Methods
- Condition Monitoring Degradation
- Selecting Condition Monitoring using the Three Point Inspection Frequency
- Machine Shape Deflection

VIBRATION ANALYSIS

- Rotating Machinery Vibration
- Causes of Vibration
- Bearing Vibration Causes
- ISO Standards for Vibration Evaluation
- Allowable Vibration Severity
- Vibratory Condition Based Monitoring
- Rotating Shaft Vibration Measurement
- The Value of a Baseline Vibration Signature
- Rotating Bearing Vibration Displays

TRIBIOLOGY AND LUBRICATION ANALYSIS

- Wear Particle Analysis
- Analysing Properties of Lubricants
- Sustaining Lubricant Health
- Lubricant Management Programs

THERMOGRAPHY

ROTATING EQUIPMENT NON-DESTRUCTIVE TESTING

- Radiography (X-Ray, Gamma Ray)
- Magnetic Particle Inspections
- Dye Penetrant Procedures
- Ultrasonic Scanning (thickness, cracks, inclusions, etc)
- Visual Inspections (human eyes, borescope, etc)
- Performance Monitoring (human senses, temperature, pressure, pH, etc)

RELIABILITY AND MAINTENANCE STRATEGY MIX

- The Six Purposes of Maintenance
- Equipment Availability as a Function of Maintenance Costs
- Asset Management & Business Performance
- Reliability and Maintenance Best Practice Assessment
- Plant and Equipment Life Cycle
- When Operating Costs are Committed
- Component & System Reliability Modelling
- Reliability of Parts and Components
- Reliability of Systems of Parts and Components (i.e. Machines)
- Equipment Reliability Strategies
- Failure Mode and Effects Analysis (FMEA)
- Equipment Criticality
Course Content Continued

Rotating Equipment Maintenance Strategy PM - PdM - Replace - Breakdown Mix
Operator Driven Reliability
A Strategy for Equipment Reliability
Maintenance KPIs and Outcomes
Maintenance Quality Improvement
Use Visual Management for Feed Forward Control of Performance
Activity 4 – RE Life-Cycle Reliability Strategy

Day 3 - Machinery Health and Reliability Excellence - Advanced

LUBRICATION SELECTION

Physics of Lubrication
Properties Of Lubricants and Additives
Purpose Of Grease Additives
Use Grease or Oil?
Dry Lubricant
Lubricant Operating Environment for Oils and Greases
Wear Debris Analysis
Lubricant Life-extension with Lubrication Management

PROCESS CONTAINMENT SEALS

Methods, Types, Designs, Process Effects
Process Containment Seal Design Overview
Sliding Lip Seals
Seal Failure Modes
Long-life Seal Conditions
Seal Selection Issues

TRANSMITTED VIBRATION PREVENTION AND ISOLATION

Basics of spring/damper systems
Forced Frequency and Natural Frequency
Passive Machinery Vibration Isolation
Activity 1 – Vibration Isolation Calculation

STRENGTH OF MATERIALS FOR SHAFTS AND ROTORS

Metallurgy - Stress and Stress Raisers
Stress Concentration Effect
Metal Fatigue
Metal Fatigue Control
Bending and Deflection of Shafts
Horizontal and Vertical Shaft Design
Combined Axial, Radial and Torsional Loads
Controlling Axial, Radial, Torsional Loads
Shaft & Equipment Assembly Considerations
Shaft Manufacture, Diameter and Tolerance
Activity 2 – Life Considerations for a Shaft and Bearing Assembly

BEARING DESIGN AND SELECTION - RADIAL AND AXIAL

Roller Bearing Loads – Max and Min

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Course Content Continued

Roller Bearings and Plain Bearings – Uses and Limitations of Each
Bearing Lubrication Selection and Use
Value of Better Bearing Sealing
Bearing Housings and Construction
Activity 3 – Select a Roller Bearing for the Shaft

PRECISION MAINTENANCE

Explaining Precision Maintenance
Precision is a Serious Opportunity
Precision Standards to Set, Use and Keep
What we Know about the Business Benefits of Precision Maintenance
Journey to 6 Sigma – Minimizing Variability
The Solution starts when Management set standards, then promote and enforce them
Typical Precision Maintenance Program Content
. Accurate Fits and Tolerance at Operating Temperature
. Impeccably Clean, Contaminant-Free Lubricant Life-long
. Distortion-Free Equipment for its Entire Life
. Forces and Loads into Rigid Mounts and Supports
. Laser Accurate Alignment of Shafts at Operating Temperature
. High Quality Balancing of Rotating Parts
. Low Machine Vibration
. Correct Torques and Tensions in all Components
. Correct Tools in the Condition to do the Task Precisely
. Only In-specification Parts
. Failure Cause Removal to Increase Reliability
. A documented system to standardize work and use standards in a successful way
Improve Lubricant Condition
Alignment Tolerance Recommendation
Define Allowable Vibration Severity
Replace Unbalance with Balance
Correct Shaft and Hole Fits
Soft Foot
Using Precision Maintenance
. Creative Disassembly
. Creative Disassembly – Pre-shutdown of Equipment
. Creative Disassembly – At Shutdown
. Creative Disassembly – At Strip-down
Tell-tale Bearing Failure Signs
Set Standards for Condition and Use of Tools and Equipment
Typical Standards for Precision Maintenance Program
Developing Precision Skills
3Ts of Failure Prevention
The Accuracy Controlled Enterprise

Day 4 - Machinery Health and Reliability Excellence - Advanced

RISK REDUCTION STRATEGIES IN ROTATING MACHINERY DESIGN AND OPERATION

Understanding and Measuring Risk
Chance vs. Consequence Risk Reduction Methods
Applying Risk Reduction During Design
Understanding and Measuring Risk
Course Content Continued

What is a High Potential Incident?
Similarity between Safety Incidents and Equipment Failures
Applying Risk Reduction
Which Risk Reduction Methods are Best?
Risk Management Process

DESIGN AND OPERATING COST TOTALLY OPTIMISED RISK

Life Cycle Operating Cost
Failure Cost Impact Calculations
Design and Operating Costs Totally Optimised Risk (DOCTOR)
Life Cycle Risk Management Strategy

LIFTING LIFETIME RELIABILITY

Failure Mechanisms
Equipment Reliability Overview
Reliability Mathematics
Measuring Reliability for Components – Weibull Plot
Calculating the Reliability of Systems
Reliability of Series Systems (i.e. Machines)
Reliability of Parallel Systems (i.e. Machines)
Crow – AMSAA Reliability Growth Plotting
Reliability Implications for Maintenance
Failure Mode Effects Analysis (FMEA) Fundamentals
Failure Mode Effects Analysis
Reliability Centred Maintenance fundamentals
The RCM Process and Method
Choosing of Maintenance Type - Simplified RCM Method
Activity 1 – FMEA exercise

ROOT CAUSE FAILURE ANALYSIS (RCFA)

Root Cause Failure Analysis Process
  . RCFA fundamentals
  . Finding the Evidence and Proof
  . Applying RCFA in the Workplace
How RCFA Contributes To Improvement
RCFA is Fundamentally about Finding the Cause Behind the Cause
Cause Behind the Cause - Latent Thoughts
The Real Cause?... Latent Values
The RCFA Process
Data Gathering Following an Incident
Data Analysis to Release Information
Extra Clues for Causes
Developing and Implementing Solutions
Operating and Maintenance Records for Reliability Improvement
Importance of Keeping Accurate Records and History
Making RCFA ‘Live’ in the Workplace
Cross-functional Teams
For the Shopfloor – The 5 Whys method
Operator and Maintainer Buy-in for Improvement
Activity 2 - RCFA Exercise

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MANAGING ASSET INTEGRITY

Asset Management in a Nutshell
Rotating Equipment Asset Integrity
Control of Asset Integrity
Asset Integrity Means…
  . Design Integrity
  . Technical Integrity (mechanical integrity)
  . Operating Integrity
Threats to Technical Integrity
Commonly Reported Areas of Inadequate Process Safety Programs
Rotating Equipment Start-up Delays
Technical Integrity Assurance
Taking Integrity into Operations
Use Effective Asset Integrity Processes
Use Structured Review Audits
Structured Review Audit Objectives
Measuring and Rating Objectives
Machine Integrity Inspection Guide Notes
Example Model for a Plant Tour
Reciprocating Compressor Example
No Equipment Management Oversight
Activity 3 - Plans and Actions to Improve Rotating Machinery Reliability