

Chapter 4: Diagnosis in maintenance and reliability.

4.1. INTRODUCTION

Diagnosis in maintenance and reliability involves the systematic identification, analysis, and resolution of issues affecting the performance and integrity of assets. Diagnosis is a critical process in maintenance that systematically identifies the root causes of equipment failures and performance issues. It serves as a fundamental approach to understanding and addressing system problems before they escalate. It encompasses a range of techniques and methodologies aimed at understanding the root causes of failures, deviations, or inefficiencies in equipment, processes, or systems.

4.2. METHODOLOGY OF THE DIAGNOSIS

Diagnosis in maintenance is a systematic approach to identifying and addressing equipment failures through several key methodological steps:

1. Initial Problem Detection: in this case some points must be taken into consideration citing:
 - Visual inspection
 - Sensor data analysis
 - Review maintenance logs
 - Operational data examination

2. Diagnostic Tool Application: this step requires some important devices and database such as:
 - Use multimeters
 - Employ vibration analyzers
 - Conduct specialized testing
 - Analyze historical performance data

Here in figure 4.1 below are some key aspects of diagnosis in maintenance and reliability:

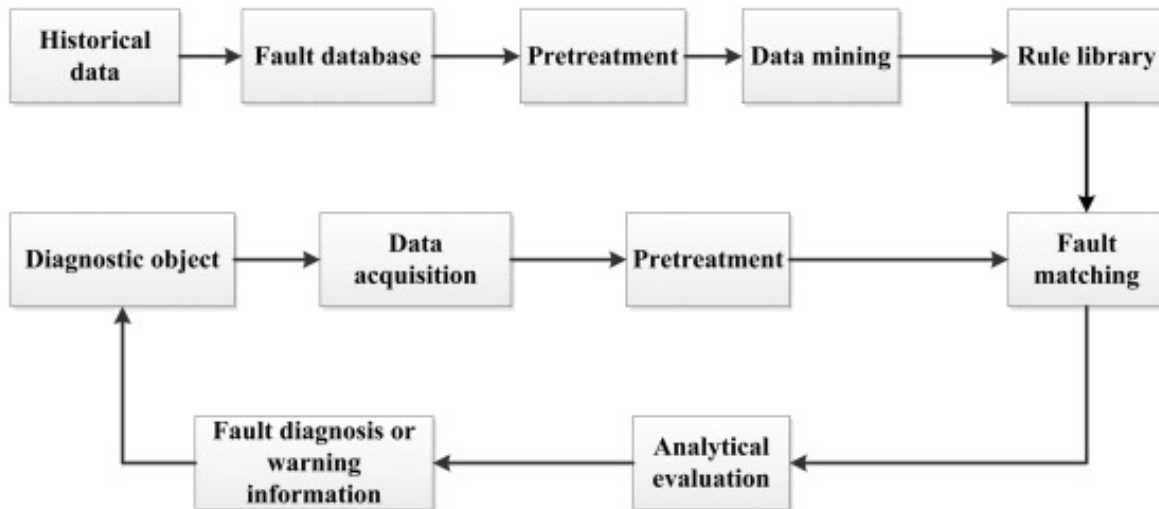


Figure 4.1. Synoptic scheme of the diagnosis.

4.2.1. Failure Identification

Diagnosis begins with the recognition of failures or abnormalities in equipment or processes. This can include unexpected downtime, reduced performance, abnormal noises or vibrations, leaks, or other signs of malfunction.

4.2.2. Data Collection and Analysis

Gathering relevant data is essential for effective diagnosis. This may involve collecting information from sensors, monitoring systems, historical records, maintenance logs, and input from operators or maintenance personnel. Analyzing this data can provide insights into the behavior and condition of assets.

4.2.3. Root Cause Analysis (RCA)

Root cause analysis is a critical step in diagnosis, aiming to identify the underlying factors contributing to a failure or issue. Techniques such as fishbone diagrams, 5 Whys, fault tree analysis, and failure mode and effects analysis (FMEA) are commonly used to systematically explore potential causes and their interrelationships.

4.2.4. Condition Monitoring

Condition monitoring involves the continuous or periodic assessment of equipment health and performance. Techniques such as vibration analysis, thermography, oil analysis, ultrasonic testing, and performance metrics monitoring are used to detect early signs of deterioration or impending failures.

4.2.5. Predictive Analytics

Predictive analytics leverages historical data and advanced algorithms to forecast future equipment behavior and performance. By analyzing trends, patterns, and anomalies in data, predictive analytics can identify potential failures before they occur, allowing for proactive maintenance interventions.

4.2.6. Diagnostic Tools and Technologies

A wide range of diagnostic tools and technologies are available to aid in the diagnosis process. This includes handheld diagnostic devices, portable analyzers, software applications for data analysis, remote monitoring systems, and more sophisticated technologies such as machine learning and artificial intelligence.

4.2.7. Expertise and Experience

While tools and technologies play a crucial role, expertise and experience are also invaluable in diagnosis. Skilled maintenance technicians, engineers, and reliability specialists bring domain knowledge, intuition, and problem-solving abilities to the diagnostic process, enabling them to interpret data, prioritize issues, and make informed decisions.

4.2.8. Continuous Improvement

Diagnosis is not a one-time event, but an ongoing process aimed at continuous improvement. Organizations should establish feedback loops to capture lessons learned from diagnostic activities, implement corrective actions, and refine their diagnostic methodologies over time.

4.3. DESTRUCTIVE TEST

Destructive tests play a crucial role in materials testing, quality assurance, research and development, and failure analysis across various industries, including manufacturing, aerospace, automotive, construction, and materials science. While destructive tests involve the permanent alteration or destruction of test specimens, the valuable insights gained from these tests are instrumental in ensuring the safety, performance, and reliability of materials and components in real-world applications. A destructive test is a type of test or analysis that involves the physical alteration or destruction of a test specimen in order to assess its properties, performance, or behavior under specific conditions. Unlike non-destructive testing (NDT) methods, which allow for the evaluation of materials or components without causing damage, destructive tests typically involve the permanent alteration or destruction of the test specimen. Here are some common types of destructive tests and their applications demonstrated in figure 4.2 :

Unicist Destructive Tests

Ontogenetic Map in Unicist Standard Language

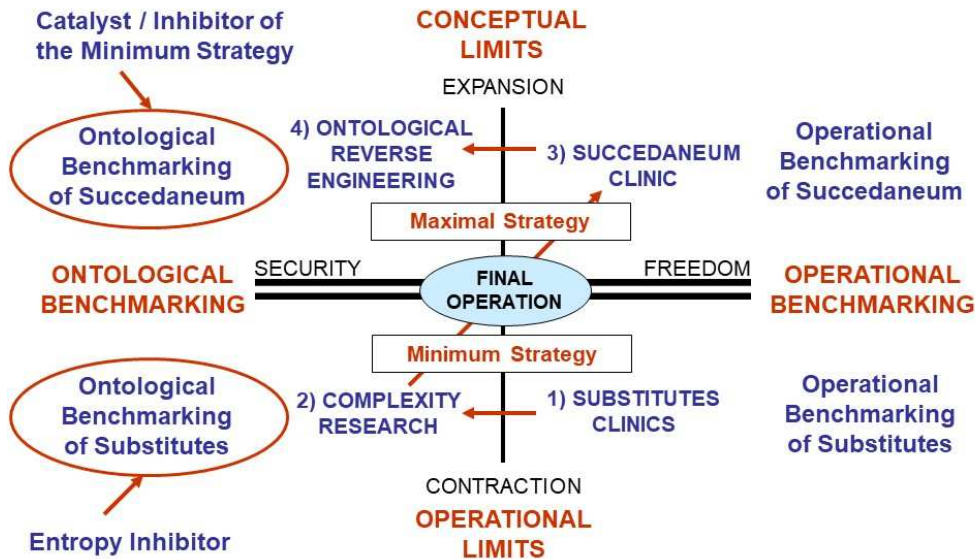


Figure 4.2. Destructive test in diagnosis scheme.

4.3.1. Tensile Testing: Tensile

Testing is a widely used destructive test that measures the mechanical properties of materials under tension. A test specimen is subjected to a controlled pulling force until it fractures, allowing for the determination of parameters such as ultimate tensile strength, yield strength, elongation, and modulus of elasticity. Tensile testing is commonly used in materials testing, quality control, and research and development.

4.3.2. Compression Testing

Compression testing involves applying a compressive force to a test specimen to evaluate its resistance to crushing or deformation. This type of test is used to determine parameters such as compressive strength, modulus of elasticity, and deformation characteristics of materials. Compression testing is commonly used in the characterization of materials such as concrete, metals, plastics, and ceramics.

4.3.3. Bend Testing

Bend testing is used to assess the ductility and fracture behavior of materials by subjecting a test specimen to bending forces until it fractures or undergoes significant deformation. Bend tests are often performed on materials such as metals, plastics, and composites to evaluate their ability to withstand bending or flexural loads.

4.3.4. Impact Testing

Impact testing evaluates the toughness and impact resistance of materials by subjecting them to sudden, high-energy impacts. Test specimens are typically struck with a pendulum or falling weight, and the amount of energy absorbed during fracture is measured. Impact tests are commonly used to assess the behavior of materials under dynamic loading conditions and to characterize their resistance to fracture and impact.

4.3.5. *Hardness Testing*

Hardness testing measures the resistance of a material to deformation, indentation, or scratching. Various methods, such as Rockwell, Brinell, Vickers, and Knoop hardness tests, are used to assess the hardness of materials across a range of scales. Hardness testing is commonly used to evaluate material properties, assess material suitability for specific applications, and monitor material degradation over time.

4.3.6. *Fracture Toughness Testing*

Fracture toughness testing evaluates the ability of a material to resist crack propagation and fracture under stress. Test specimens are typically subjected to controlled loading or crack propagation tests, and parameters such as critical stress intensity factor (K_{IC}) or fracture toughness (K_{IC}) are determined. Fracture toughness testing is essential for assessing the safety and reliability of structural components and engineering materials.

4.4. NON DESTRUCTIVE TEST

Non-destructive testing (NDT) refers to a wide range of techniques used to evaluate the properties, integrity, and quality of materials, components, or structures without causing damage to the test specimen. NDT methods are invaluable in various industries for detecting defects, flaws, discontinuities, or irregularities that could compromise the safety, reliability, or performance of materials and components. Here are some common non-destructive testing methods and their applications illustrated in figure 4.3 and figure 4.4 respectively:

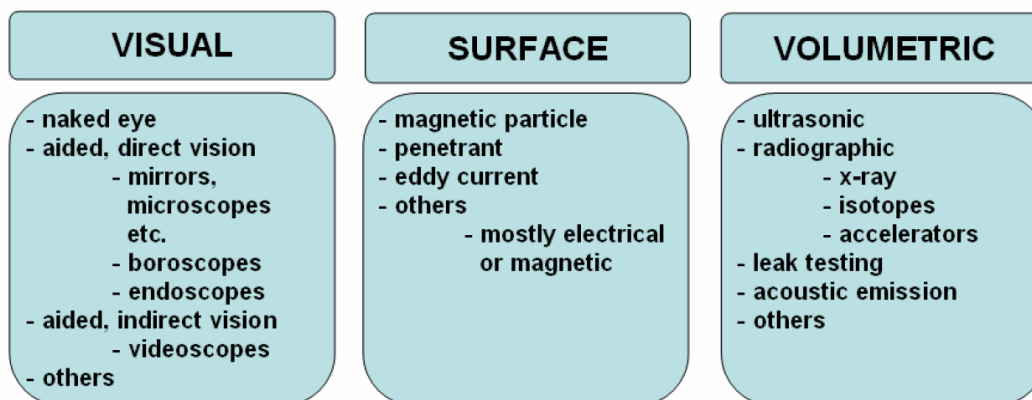


Figure 4.3. Non-destructive test scheme in diagnosis.



Figure 4.4. Example of Non-Destructive-Tests Methods.

4.4.1. Visual Inspection

Visual inspection is one of the simplest and most widely used NDT methods. It involves visually examining the surface of a test specimen for signs of defects, such as cracks, corrosion, weld discontinuities, surface roughness, or dimensional irregularities. Visual inspection is commonly used in manufacturing, construction, maintenance, and quality control across a wide range of industries.

4.4.2. Ultrasonic Testing (UT)

Ultrasonic testing utilizes high-frequency sound waves (ultrasound) to inspect the internal structure of materials and detect defects or discontinuities. A transducer generates ultrasonic waves that propagate through the material, and the reflected waves are analyzed to identify defects such as cracks, voids, inclusions, or thickness variations. UT is widely used in industries such as aerospace, automotive, manufacturing, and oil and gas for flaw detection, thickness measurement, and material characterization.

4.4.3. Radiographic Testing (RT)

Radiographic testing involves exposing a test specimen to X-rays or gamma rays and capturing images of the internal structure on a radiographic film or digital detector. Radiographic images reveal internal defects such as cracks, porosity, inclusions, voids, or internal geometry. RT is commonly used in industries such as aerospace, construction, petrochemical, and pipeline inspection for detecting hidden defects in welds, castings, and composite materials.

4.4.4. Magnetic Particle Testing (MT)

Magnetic particle testing is used to detect surface and near-surface defects in ferromagnetic materials. A magnetic field is applied to the test specimen, and iron particles (either dry or suspended in a liquid) are applied to the surface. Defects disrupt the magnetic field, causing the particles to accumulate at defect locations, making them visible under ultraviolet (UV) light or fluorescent light. MT is commonly used in industries such as automotive, aerospace, rail, and manufacturing for detecting cracks, laps, seams, and other surface defects in welds, forgings, and castings.

4.4.5. Liquid Penetrant Testing (PT)

Liquid penetrant testing is used to detect surface-breaking defects in non-porous materials such as metals, plastics, and ceramics. A liquid penetrant is applied to the surface of the test specimen and allowed to penetrate into surface discontinuities through capillary action. Excess penetrant is removed, and a developer is applied to draw out the penetrant from the defects, making them visible under white or UV light. PT is commonly used in industries such as aerospace, automotive, and manufacturing for detecting cracks, porosity, laps, and other surface defects.

4.4.6. Eddy Current Testing (ET)

Eddy current testing uses electromagnetic induction to detect surface and near-surface defects in conductive materials. A coil or probe generates alternating electrical currents that produce induced eddy currents in the material. Changes in the eddy currents caused by defects are detected and analyzed to identify defects such as cracks, corrosion, or material thickness variations. ET is commonly used in industries such as aerospace, automotive, and electronics for detecting defects in aircraft structures, automotive components, and electronic circuits.

4.4.7. Infrared Thermography (IRT)

Infrared thermography involves using thermal imaging cameras to detect temperature variations on the surface of a test specimen. Temperature differences can indicate defects such as delaminations, voids, moisture ingress, or thermal gradients. IRT is commonly used in industries such as building inspection, electrical maintenance, and predictive maintenance for detecting defects in building envelopes, electrical systems, and mechanical equipment.

4.4.8. Leak Testing

Leak testing is used to detect the presence of fluid or gas leaks in sealed components or systems. Various methods, such as pressure decay testing, vacuum testing, bubble testing, and tracer gas testing, can be used to identify leaks in pipes, vessels, valves, seals, and other components. Leak testing is commonly used in industries such as automotive, aerospace, pharmaceuticals, and HVAC for ensuring the integrity and safety of pressurized systems and fluid containment systems.

4.5. LEO APPROACH

The LEO approach you've provided seems to be a framework for assessing or addressing certain aspects within a system or process. Let's break down each component:

L: Level of Critical Parameter (e.g., Shocks/Vibrations): This component refers to the measurement or evaluation of a critical parameter within a system or process. In this case, it seems to focus on factors such as shocks or vibrations, which can be crucial indicators of the health and performance of machinery, equipment, or structures. Assessing the level of shocks or vibrations can help identify potential issues, determine the severity of the problem, and inform decision-making regarding maintenance, repairs, or operational adjustments.

E: Experience Factor: The experience factor likely relates to the level of expertise, knowledge, or familiarity that individuals or teams possess regarding the system or process being evaluated. Experience can significantly influence decision-making, problem-solving, and the ability to interpret data or observations accurately. Individuals with extensive experience may have a deeper understanding of potential risks, best practices, and effective solutions, while those with less experience may require additional training or support to make informed decisions.

O: Operation Efficiency Factor: The operation efficiency factor likely pertains to the overall efficiency and effectiveness of the system or process under consideration. This component may encompass various factors such as productivity, resource utilization, cost-effectiveness, and compliance with performance standards or requirements. Assessing the operation efficiency factor can help identify areas for improvement, optimize processes, and enhance overall performance and competitiveness.

4.6. FAILURE MODE EFFECT AND CRITICAL ANALYSIS (FMECA)

Failure Mode Effect and Criticality Analysis (FMECA) illustrated in figure 5.4 is a systematic

method used to identify and prioritize potential failure modes of a system, component, or process, analyze their effects, and assess their criticality. FMECA is widely used in various industries, including manufacturing, aerospace, automotive, healthcare, and telecommunications, to proactively manage risks, enhance reliability, and improve safety. Here's how FMECA works:

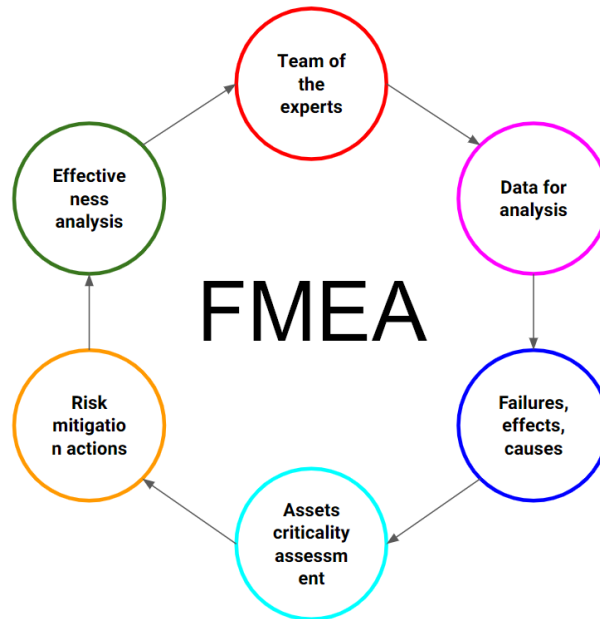


Figure 4.5. FMEA scheme.

4.6.1. *dentification of Failure Modes*

The first step in FMECA is to identify all possible failure modes that could occur within the system, component, or process being analyzed. A failure mode is defined as the way in which a component or system may fail to perform its intended function. This step typically involves brainstorming, literature review, historical data analysis, or consultation with subject matter experts to identify potential failure modes comprehensively.

4.6.2. *Determination of Effects*

Once the failure modes are identified, the next step is to assess the potential effects or consequences of each failure mode on the system, component, or process. This involves considering the impact of the failure mode on safety, performance, reliability, functionality, environmental impact, regulatory compliance, and other relevant factors. Effects can range from minor inconveniences to catastrophic failures with severe consequences.

4.6.3. Assessment of Criticality

After determining the effects of each failure mode, the criticality of each mode is assessed based on factors such as severity, likelihood of occurrence, and detectability. Criticality is typically evaluated using a scoring system or matrix, where each failure mode is assigned a numerical value based on its severity, occurrence probability, and detectability. These scores are then used to prioritize failure modes and focus resources on addressing the most critical risks.

4.6.4. Risk Mitigation and Control Measures

Once the critical failure modes are identified, appropriate risk mitigation and control measures are developed to reduce the likelihood or severity of these failures. This may involve implementing design changes, improving maintenance procedures, enhancing monitoring and inspection processes, introducing redundancy or backup systems, or providing training and education to personnel. The effectiveness of these measures is evaluated, and adjustments are made as necessary.

4.6.5. Documentation and Continuous Improvement

Throughout the FMECA process, documentation is essential to capture the results, findings, recommendations, and action plans. This documentation serves as a reference for future assessments, audits, and reviews and helps ensure accountability and transparency in risk management efforts. Additionally, FMECA is an iterative process, and organizations should continuously review and update their analyses to account for changes in technology, operations, regulations, or other factors.

By systematically analyzing failure modes, effects, and criticality, FMECA enables organizations to proactively identify and mitigate risks, enhance reliability, and improve safety and performance across various systems, components, and processes.

4.7. CONCLUSION

In the present chapter Predictive failure analysis has been presented in different points and in the next chapter diagnosis in maintenance will be represented. Diagnosis focuses on identifying the root causes of current malfunctions, while predictive failure analysis anticipates potential future failures based on current system conditions. These techniques are highly correlated, with diagnosis determining the set of faulty components explaining observed malfunctions, and prognosis determining the future state of those components. By integrating diagnostic insights with predictive modeling, organizations can develop

sophisticated maintenance strategies that not only identify existing issues but also forecast potential failures before they occur. This approach leverages advanced techniques including physics-based models, statistical data analysis, and machine learning methods to assess the health and residual lifetime of system components.