CHAPTER 2: Mechanism and Failure modes

2.1. INTRODUCTION

Mechanisms and failure modes are critical concepts in engineering and reliability analysis, serving to identify how and why systems or components fail. for this, two major factors are necessary to take into consideration:

- **Failure Mode**: This refers to the specific manner in which a failure occurs. It describes the observable consequences of a failure event. For instance, a pump may fail due to an impeller coming loose, which is a clear failure mode.
- **Failure Mechanism**: In contrast, the failure mechanism is the underlying cause that leads to the failure mode. It encompasses the physical, chemical, or operational processes that result in failure. For example, if an impeller comes loose due to a worn mounting nut, the lack of maintenance on that nut represents the failure mechanism

2.2. THE NOTION OF FAILURE

The notion of failure is a multifaceted concept that can be viewed from various perspectives, and its interpretation often depends on cultural, personal, and situational factors. At its core, failure refers to the inability to achieve a desired goal or outcome, whether that be in personal aspirations, professional endeavors, or other areas of life. However, the way people define, experience, and respond to failure can vary significantly.

2.2.1. Traditional Understanding of Failure

In a traditional sense, failure is often seen as an undesirable and negative outcome. It represents a setback or defeat in pursuit of a specific objective. People may associate failure with feelings of inadequacy, embarrassment, or disappointment. This view is often grounded in external expectations, such as societal standards of success, which may define success in terms of wealth, status, academic achievement, or career milestones.

2.2.2. Philosophical and Psychological Perspectives

- **Growth Mindset:** Psychologist Carol Dweck introduced the concept of the "growth mindset," which suggests that failure is not a final verdict but a stepping stone to improvement. People with a growth mindset see failure as an opportunity to learn, adapt, and refine their abilities. This contrasts with a "fixed mindset," where failure is seen as a reflection of one's inherent limitations.

- **Failure as Feedback:** From a psychological perspective, failure can be reframed as valuable feedback. It provides insight into what didn’t work, what assumptions were wrong, and what adjustments are needed. This reframing helps reduce the emotional sting of failure and allows for a constructive approach to future attempts.

2.2.3. Cultural and Societal Influences

Different cultures have varied attitudes toward failure. In some cultures, failure is stigmatized and seen as something to be avoided at all costs, while in others, failure is more accepted as a part of the learning process. For example, some Western cultures may prioritize individual success and view failure as personal inadequacy, while certain Eastern cultures may emphasize collective well-being and the process of perseverance through failure.

2.2.4. Personal Experience and Subjectivity

The notion of failure is deeply personal and subjective. What one person considers a failure, another may see as a temporary obstacle or a minor setback. For instance, someone might view not getting a promotion as a failure, while another person might consider it an opportunity to seek a role that better aligns with their passions.

Furthermore, personal values and goals influence how failure is perceived. A person who values personal growth and exploration might be more accepting of failure in pursuit of a creative endeavor, while someone who prioritizes security and stability might find the same outcome more distressing.

2.2.5. Types of Failure

- **External Failures:** These are failures that happen due to factors beyond one's control, such as a business venture collapsing due to an economic recession or losing a competition due to an unfair decision.
- **Internal Failures:** These occur when an individual doesn't meet their own internal standards or expectations, such as feeling like they failed to achieve their own personal goals, despite external success.

- **Moral or Ethical Failures:** These refer to situations where an individual fails to live up to their own ethical standards or violates the values that they hold dear.

2.2.6. The Role of Resilience

Resilience is key to how we deal with failure. Those who can bounce back after setbacks are often able to transform failures into opportunities for future success. Resilience doesn't mean avoiding failure, but rather learning how to cope with it, adapt, and move forward with a renewed sense of purpose.

2.2.7. Success and Failure Are Relative

Success and failure are often seen as binary opposites, but in reality, they exist on a spectrum. Some individuals redefine success by embracing small wins and focusing on incremental progress. For example, someone who struggles with mental health might define success as managing their daily routine, which could seem minor to others but is a significant achievement for them.

2.3. CAUSE OF FAILURE

Causes of failure can vary widely depending on the context, whether in project management, engineering, or personal endeavors. Here are some key causes identified across different domains:

2.3.1. Project Management Failures

1. **Lack of Planning**: Insufficient planning is a primary cause of project failures, often leading to undefined scopes and roles, which can result in wasted time and resources.
2. **Scope Creep (Kitchen Sink Syndrome)**: Changes in project deliverables without proper control can stretch resources and lead to missed deadlines.
3. **Unrealistic Deadlines**: Setting overly ambitious timelines without considering the complexity of tasks can result in failure to meet objectives.
4. **Lack of Transparency**: Poor communication and visibility among team members can hinder collaboration and lead to misunderstandings.

2.3.2. Mechanical and System Failures

1. **Common Cause Failures**: These occur when multiple failures stem from a single source, such as abnormal temperatures or pressures affecting several components simultaneously.
2. **Mechanical Causes**: Factors like excessive stress, impact, or vibration can lead to mechanical failures in systems.
3. **Electrical Causes**: Issues such as high voltage or current can cause electrical components to fail.

2.3.3. Organizational and Personal Failures

1. **Poor Communication**: A lack of clear communication can lead to misunderstandings and mistakes within teams.
2. **Lack of Leadership**: Insufficient guidance can leave employees unsure about their tasks, increasing the risk of failure.
3. **Not Learning from Past Mistakes**: Failing to address root causes of previous failures can lead to repeated issues over time.

2.3.4. General Causes of Failure

1. **Ill-Discipline or Negligence**: Failure to adhere to established procedures can result from individual negligence or lack of motivation.
2. **Complex Systems**: Highly complex systems are inherently more prone to failures due to their intricate interdependencies.

2.4. FAILURE MODE

A **failure mode** refers to the specific manner in which a system, component, or process fails to perform its intended function. It is crucial in reliability engineering and is often documented in methodologies like Failure Mode and Effects Analysis (FMEA) and Failure Reporting, Analysis, and Corrective Action System (FRACAS).

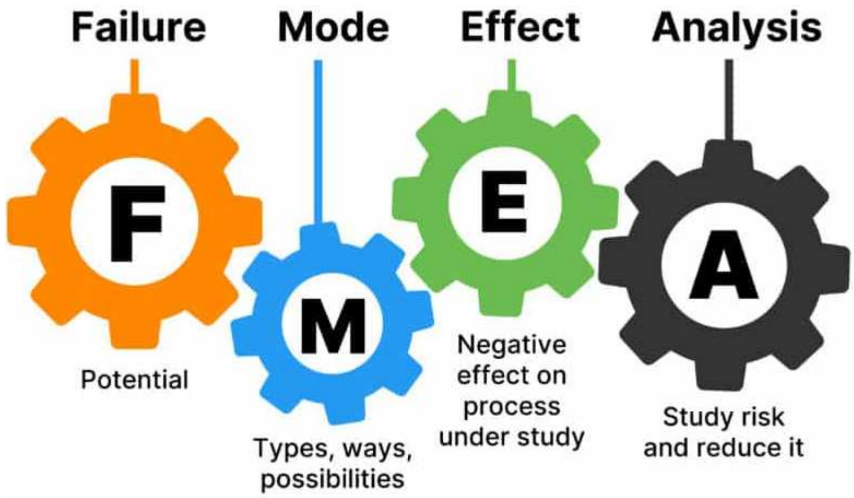

Figure 2.1. Failure mode scheme (FMEA).

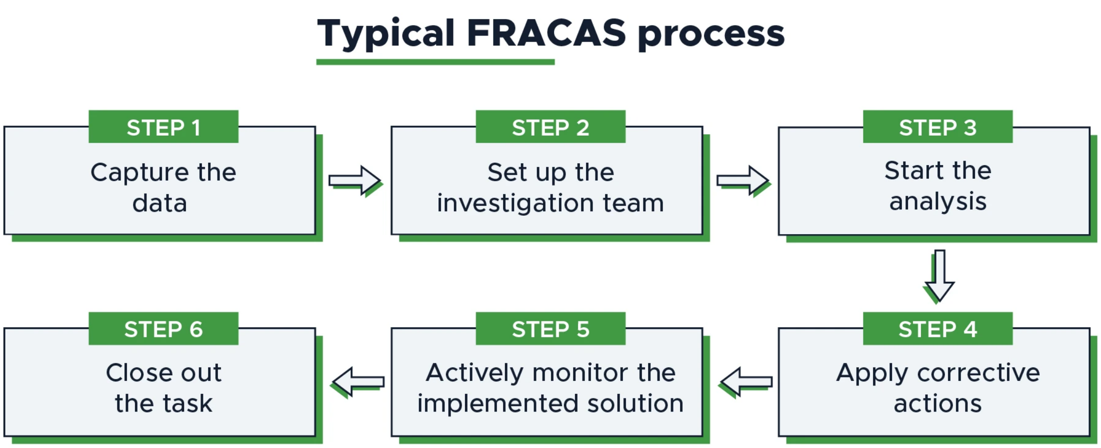

Figure 2.2. Failure mode scheme (FMEA).

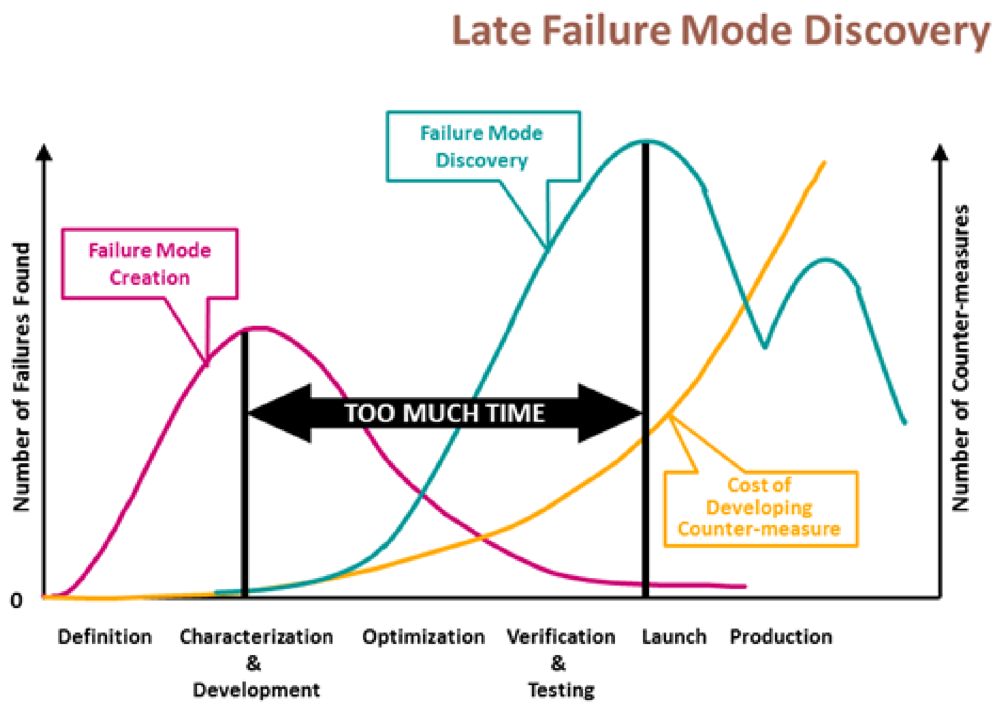

Figure 2.3. Failure mode discovery scheme.

2.4.1. Types of Failure Modes

Common types of failure modes include:

- **Loss of function**: The system ceases to operate entirely.
- **Degradation of function**: The system operates but below its intended capacity.
- **Intermittent function**: The system functions sporadically.
- **Partial function**: The system performs some but not all intended functions.
- **Unintended function**: The system operates in a manner not intended by the design.

The table below illustrates the different types of failure mechanisms with their affecting components in addition to their contributing and mitigating factors:

Table 2.1. Failure mechanisms with relative affecting components and their characteristics.

Failure mechanisms	Affecting components	Contibuting factors	Mitigating factors	Oil Analysis	Vibration Analysis	Stress Wave Analysis	Thermal Imaging	Inspection

Abrasion (hard cutting soft, polishing, grinding, machining)	Mechanical Items	Dust contamination, defective breather	Contamination control, clean, dry, fit for use	x		x		X
Adhesion (boundary, sliding, metal-to-metal)	Mechanical Items	Lubricant misapplication, slow speed, excess load, low viscosity	Lubrication, speed, load, viscosity	X	x	x	x	x
Rolling Fatigue (cyclic rolling line-load, sub-surface fatigue)	Bearings Gears	High dynamic load, improper fit	Minimize resonance, misalignment & imbalance	x	x	x		x
Corrosion (Oxydation or other chemical attack)	Mechanical Items Electrical Items	Corrosive fluid contamination, non-desiccating breather	Contamination control, clean, dry, fit for use	x		x		x
Cavitation Fatigue (Cyclic void	Impellers, pumps, valves, piping	Speed, pressure, flow extremes	Speed control, fluid dynamics,		x	x		x

implosions, sub-surface fatigue)			surface treatment					
Erosion (Surface impacts, particulate blasting)	Valves, pipes, windows, baffler, screens, throttles, impellers, sensors	Exposure to streaming particulates	Protective coating			x		x
Electric Discharge (Spark, track, arc, plasma, surface erosion)	Electric powered Items Static Charged Items	Moisture, ground faults, deterioration, looseness, corrosion	Contamination control, clean, dry, fit for use	x	x	x	x	x
Deposition (Physical, electrostatic, or chemical attachement)	Flow controls, filters, screens, valves, fans	Fibers, temperature cycles, polar constituents, static charge	Awareness & prevention	x	x			x

2.4.2. Examples of Failure Modes

To illustrate, consider a laptop computer:

- **No display**

- **Inoperable**
- **Damaged case**
- **Overheating**
- **Loss of data**
- **Wobbly hinge**

Each of these represents a different way the laptop can fail, and they can also be viewed as causes or effects depending on the context.

2.4.3. Importance of Clarity in Definitions

Understanding the distinctions between failure modes, effects, and causes is essential for effective analysis. This clarity helps prevent confusion during documentation and analysis processes. For instance, a vague statement like "the pump fails" is less useful than specifying "the impeller comes adrift due to lose mounting nuts".

2.4.4. Application of failure mode in Engineering

Failure modes are critical for developing robust systems. By identifying potential failure modes during the design phase, engineers can implement preventive measures to enhance reliability and safety. This proactive approach is fundamental in various industries, including manufacturing, aerospace, and electronics

2.5. FAILURE MECHANISM

A **failure mechanism** refers to the underlying physical, chemical, or other processes that lead to a failure mode. While a failure mode describes the observable event of failure (e.g., a component not functioning), the failure mechanism explains *why* that failure occurred. For example, if a bearing seizes (failure mode), the lack of lubrication can be identified as the failure mechanism. The keys aspects of failure mechanism are:

- **Relationship to Failure Mode**: The failure mechanism is often linked to one or more failure modes. A single failure mode can arise from multiple mechanisms, highlighting the complexity of failure analysis.
- **Importance in Analysis**: Understanding the specific mechanisms behind failures is crucial for effective root cause analysis and for developing strategies to prevent future

occurrences. This involves identifying the materials, environmental conditions, and operational stresses that contribute to degradation and eventual failure.

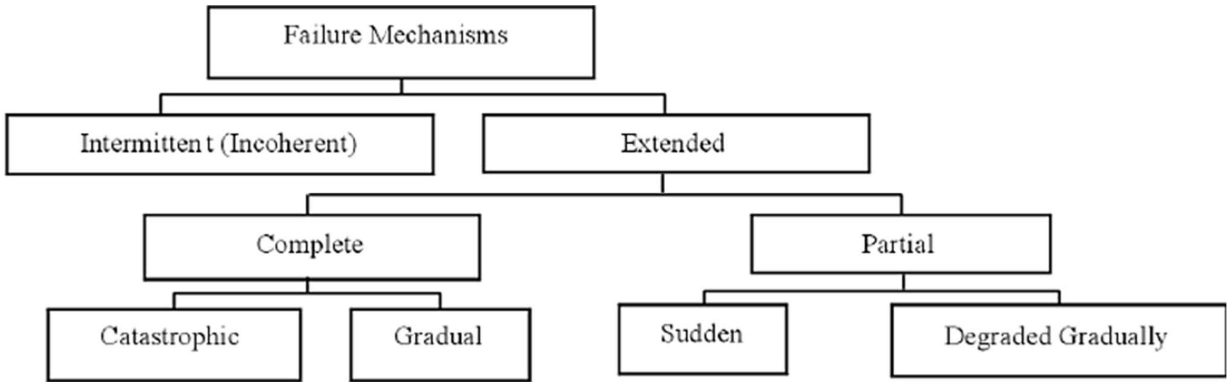

Figure 2.4. General failure mechanism scheme .

2.5.1. Examples of Failure Mechanisms

Common examples of failure mechanisms include:

- **Corrosion**: Chemical degradation due to environmental exposure.
- **Fatigue**: Material weakening due to repeated stress cycles.
- **Wear**: Gradual removal of material from surfaces in contact.
- **Thermal Stress**: Damage caused by temperature fluctuations leading to expansion and contraction of materials.

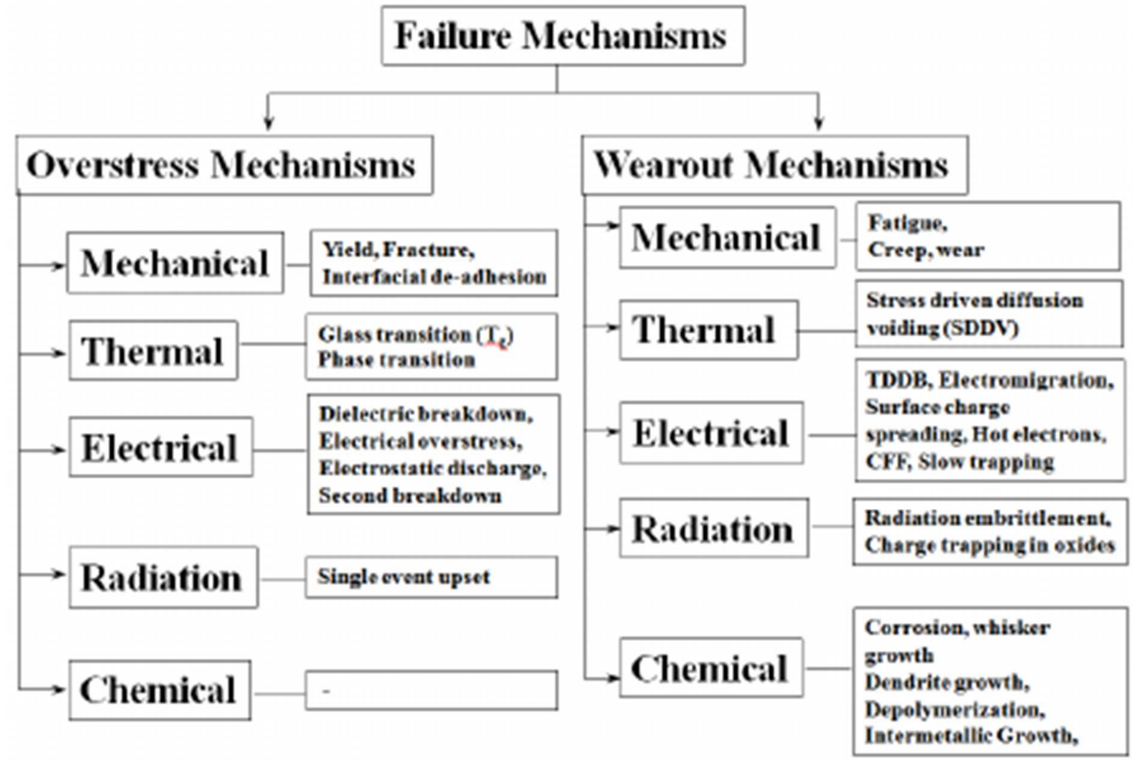

Figure 2.5. Diagram of failure mechanisms in various areas.

2.5.2. Application of failure mechanism in Engineering

In engineering contexts, recognizing both failure modes and mechanisms is essential for designing reliable systems. Tools like Failure Modes and Effects Analysis (FMEA) help teams systematically identify potential failures and their causes, allowing for informed design decisions and preventive measures.

By clearly articulating the relationship between failure modes and mechanisms, engineers can enhance product reliability and safety, ultimately reducing costs associated with failures in the field.

2.6. CONCLUSION

This chapter discussed the relationship between failure modes and failure mechanisms is crucial in understanding how systems fail and how to prevent such failures. A failure mode refers to the specific way in which a system or component fails, such as a "bearing seizing" or "pump failure." In contrast, a failure mechanism is the underlying cause that leads to this failure mode, such as "lack of lubrication" or "wear and tear." Recognizing that a single failure mode can have multiple mechanisms allows for a more nuanced approach in reliability engineering and maintenance strategies. This distinction is essential for effective analysis and intervention, enabling engineers to target root causes rather than just symptoms of failure.

The next chapter will explain Quantitative Mode Analysis (QMA) is an analytical approach used to assess the reliability and performance of systems by quantifying the likelihood of various failure modes and their impacts. Unlike qualitative analyses, which focus on identifying potential failures and their causes, QMA employs statistical methods and mathematical modeling to provide numerical estimates of failure probabilities and consequences. This approach allows organizations to prioritize risks based on data-driven insights, facilitating informed decision-making regarding maintenance schedules, design improvements, and resource allocation. By integrating quantitative analyses into the reliability assessment process, engineers can enhance system resilience and ensure better operational performance over time.