ETME 3120
Maintenance of Mechatronics Systems

Lesson 7: Total Productive Maintenance

Refer to Chapters 6 and 7 in Textbook

By: Khalid H. Tantawi

Email: Khalid-tantawi@utc.edu

Webpage: https://blog.utc.edu/khalid-tantawi/courses/etme-3120/

Department of Engineering Management & Technology

University of Tennessee at Chattanooga

Total Productive Maintenance

- Historical Evolution of Maintenance:
  - **Breakdown Maintenance**: oldest strategy, it is the repair of equipment. In 1957 it was renamed to **Corrective Maintenance**, to
  - **Preventive Maintenance**: introduced in 1951, its purpose is to increase equipment life by regular check ups.
  - **Predictive Maintenance**: Condition Based Maintenance
  - **Maintenance Prevention**: Introduced in the 1960's, it is the design of equipment so that they are maintenance-free as possible.
  - **Reliability-Centered Maintenance**: Introduced in the 1960's, uses a statistical and mathematical approach for maintenance
  - **Total Productive Maintenance**: A structured strategy Introduced by Nippon Denso in 1971

Overall Equipment Effectiveness (OEE)

- OEE is the quantitative tool that is used to measure the productivity of a manufacturing operation.
- **OEE = Availability x Efficiency x Quality**
- Where:
- $\textbf{Availability} = \frac{\textit{Operation Time}}{\textit{Net Available Time}}$
- $\textit{Efficiency} = \frac{\textit{Actual Production}}{\textit{Full Capacity Production}}$
- $\textit{Quality} = \frac{\textit{number of useful products}}{\textit{Total number of products}}$
- **Example:** A plant has the capability to produce 800 radio units per day, its actual production was 520 units. Of the units produced, 486 of them were good and the rest were faulty. The actual production time per day was 600 minutes out of a 12-hour available time for operation. What is the OEE for the plant?
- Solution: $OEE = \frac{600}{720} \times \frac{520}{800} \times \frac{486}{520} = 0.5063$

Some techniques used in TPM

Some maintenance techniques:

- **The Five S's (5S):** a method for organizing the workplace, which eventually leads to an increased efficiency and profitability.
- **The 5 Whys Technique:** an approach used for problem-solving training.
- **Graphical Troubleshooting Techniques:** such as the **Ishikawa** (Fishbone) technique and the check sheet.

Process Improvement Methods:

- **Kaizen:** Continuous Improvement such as adopting:
  - Increasing **Poka-Yoke** (Mistake Avoidance), such as interlocking of a motor forward and reverse contactors in the H-Bridge.
  - Reducing the **Seven Wastes (Muda):** Originated from the Toyota Production System of practices.
- **Six Sigma (6σ):** Invented by Motorola in 1986, focuses on product

The 5 S

- Sort
- Set in order
- Shine
- Standardize
- Sustain

The 7 Wastes

1) **Over production**
2) **Waiting:** cost of having the product waiting in a queue
3) **Transportation:** cost due to moving the products
4) **Inappropriate Processing:** for example, using expensive high-precision tools in place of simpler tools.
5) **Unnecessary Inventory**
6) **Defects**
7) **Excess Motion:** causes wear and tear on equipment used in the process

The 5 Whys

- **5 whys:** a method to determine the root cause of a problem by asking why five times.

- **Example:**
  - Why the workpiece stopped at station 3?
  - Why the eject cylinder did not extend?
  - Why the solenoid did not energize?
  - Why the PLC did not signal the solenoid to energize?
  - Why the sensor broke?

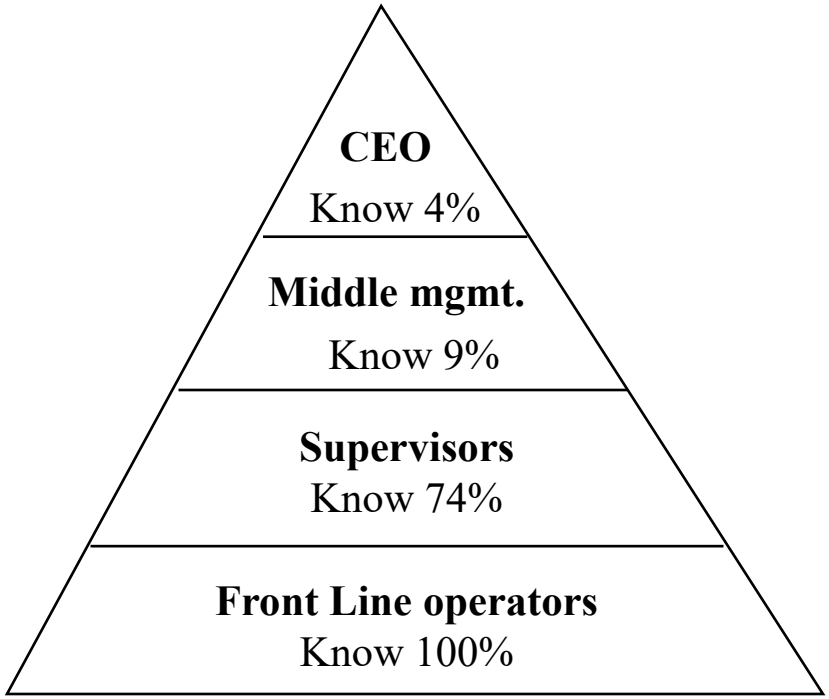
Paths to Process Improvement

- Process improvement can be achieved in three ways:
  - **Innovation:** the introduction of a new process.
    - Can be highly disruptive to the organization
    - Benefits can be remarkable, but drawbacks can cause a significant failure.
    - **Example:** The introduction of a new product that requires new processes.
  - **Change:** introduction of a new element in an existing process.
    - Benefits can be significant, but change can be slow and difficult.
    - **Example:** Introduction of a robot for material handling in place of manual labor.
  - **Imitation:** introduction of a process or an element of a process that is already being used somewhere else.
    - Highly predictable outcomes and low risk of failure
    - **Example:** Introduction of a tool in a manufacturing process that has been proven to be a successful addition on the same process in another plant.

Why do you need to involve the operators

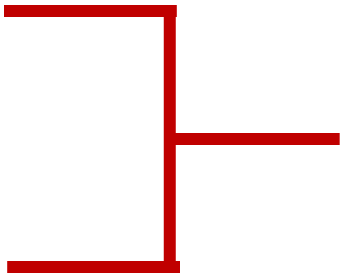
- Accurate description of the problem by the operators is essential in maintenance.
- Some companies provide educational and maintenance training to operators.
- According to S. Yoshida, the Iceberg of Ignorance shows who really knows the problems in a company:

"Iceberg of ignorance"

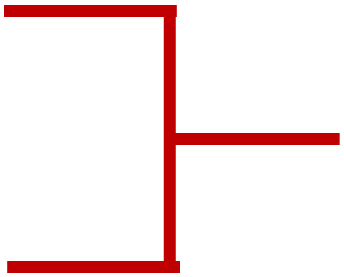


Maintenance Safety & Accident Prevention

- There are for ways of Hazard Avoidance (Batson, 1999):
  - Analytical approach
  - Engineering approach
  - Enforcement approach
  - Psychological approach



Form physical and procedural barriers that prevent accidents



Reduce human error and prevent unsafe acts

Maintenance Safety: Analytical Approach

- **Analytical Approach methods**:
  - **Accident Root Cause Analysis (RCA):** after an accident, a study is conducted to determine the root cause and how to prevent it in the future
  - **Failure Mode and Effect Analysis (FMEA):** identifies the possible failures that may occur and the results of the failure modes and their severity.
  - **Fault Tree Analysis**: A tree model that shows chains of causes and effects that lead to undesirable outcomes based on probability calculations.
  - **Hazard and Operability Analysis (HAZOP):** A study of an existing process to locate safety risks

Maintenance Safety: Engineering Approach

- Engineering Approach methods:
  - **Engineering controls:** design of equipment for safety, such as fail-safe mechanisms, overload and short circuit protection, E-stop requirements, ..etc.
  - **Safety Procedures:** Lockout- Tagout (LOTO), word order requirements, maintenance work procedures.
  - **Personal Protective Equipment (PPE):** such as gloves, safety glasses, helmets, safety shoes, ear plugs, respirators, and fire-resistant clothing.

Maintenance Safety: Enforcement Approach

- Enforcement Approach includes the safety legislation and plant rules and regulations.
- Some safety regulation bodies include:
  - Occupational Health and Safety Administration (OSHA)
  - International Labour Organization (ILO)
  - European Agency for Safety and Health at Work
  - Canadian Centre for Occupational Health and Safety (CCOHS)

Maintenance Safety: Psychological Approach

- Psychological Approach includes the safety culture in the place of work.
- Having a positive safety culture is necessary to avoid resistance to safety programs.
- Examples of safety culture include:
  - Safety is highly valued in all activities
  - Everyone from upper management to the operators are involved in ensuring safety and safe practice
  - Conducting regular safety trainings and exercises

Failure Mode and Effect Analysis (FMEA)

- Also called Process FMEA
- Focuses on single point of failure analysis
- Uses inductive reasoning
- Goal is to minimize failures, esp. catastrophic ones
- Analysis produces a **Risk Priority Number (RPN)**

- **RPN = Severity x Occurrence x Detection**
- Each factor has a scale from 1 – 10 (10 is worst)
- The smaller is the RPN, the better; the higher is RPN the worse.

Failure Mode and Effect Analysis (FMEA)

- After analysis is performed, an action plan is developed based on the RPN.
- The Action plan recommends fixes and/or modifications to reduce RPN.
- A new RPN is developed after fixes are applied.
- Typically management uses new RPN as basis for fixes/changes