

## ⇒ Intelligent Fault Diagnosis and Remaining useful life (RUL) Prediction of rotating Machinery

### Rotating Machinery

- ↳ A machine with a rotating component.
- ↳ Commonly used in mechanical system.
- ↳ operate under tough working environment.
- ↳ frequently subject to faults.
- ↳ importance in industrial applications.

### Types of rotating machinery

- \* Aeroengines
- \* Gas Turbines
- \* Wind Turbines
- \* Automobile Transmissions.

### Common Components:

- \* Rotors
- \* Bearings
- \* Gears.

### Rotors:

- ↳ rotating part of a machine.
- ↳ Generally supported by bearings.
- ↳ indispensable components in rotating machine.
- \* increased flexibility and complexity.
- \* operate under tight and harsh environment.

### Common fault types:

- 1) Mass unbalance
- 2) Bent
- 3) Rub
- 4) Misalignment
- 5) Resonance.

## Bearings :

- ↳ a component that carries loads by placing rolling elements between two races.
- ↳ relative motion of the rings causes the rolling elements to roll with little rolling resistance and little sliding.

- ↳ faults \* Flaking \* Spalling \* Peeling  
\* Abrasion \* Corrosion.

## Gears :

- ↳ machine components that function to transmit rotation or movement from one part to another (mechanical advantage).

- ↳ Two or more gears working in a sequence are called gear train.

- ↳ advantages :

- \* Torque transmission
- \* Speed Control
- \* Direction Change.

- \* Common Gear arrangement → one small and one big.

$$\left( \text{rotational speed} \propto \frac{1}{\text{Torque}} \right)$$

- \* Fault of the rotating machinery is the main cause of the failure.



# Health Management Strategies: (run-to-failure)

↳ Three development stages.

- 1) Reactive
- 2) Preventive
- 3) Predictive

## Reactive Maintenance:

- ↳ traditional strategy
- ↳ run it till it breaks
- ↳ machines running until they break down.
- ↳ advantage is low cost and less staff.
- ↳ disadvantage is increased cost due to unplanned downtime of equipment.
- ↳ Repair / Replacement of equipment.
- ↳ catastrophic and result in severe damages.

## Preventive Maintenance: (time based)

- ↳ more conservative than reactive maintenance.
- ↳ maintenance actions conducted at regular intervals. (Routine inspection, lubrication etc).
- ↳ shut down the machine immediately and replace the fault component.
- ↳ plan the maintenance strategy in advance to reduce huge failure.
- ↳ cons are
  - \* expensive to implement and maintain
  - \* Time intensive
  - \* More resources
  - \* Over maintenance.
- ↳ pros are
  - \* maintenance need is predicted in advance.
  - \* Reduce maximum amount of downtime.
  - \* improved automation of tasks.



## Predictive Maintenance: (condition based)

- ↳ maintenance actions based on the information collected through condition monitoring.
- ↳ degradation trend of the rotating machinery is first revealed through the analysis of condition monitoring data.
- ↳ Remaining useful life (RUL) is predicted.
- ↳ Pros \* maintenance done only as needed
- ↳ Cons \* High initial Costs (install, training etc).

## Prognostic and Health Management (PHM)

### ↳ Five Major Processes.

- 1) Data Acquisition
- 2) Signal Processing
- 3) Diagnostics
- 4) Prognostics
- 5) Maintenance Decision.

### Data Acquisition:

- ↳ process of capturing measurement signals using different tools (sensors) from monitored machines and storing a data into a computer.
- ↳ There are different types of measurement signals such as vibrational signals, acoustic signals, temperature and electric current.
- ↳ sensors (accelerometer, acoustic emission sensors, infrared thermometer, ultrasonic sensors).



## Signal Processing.

- ↳ Analyze the stored measurement signals using signal processing techniques and methods.
- ↳ Extract → useful information to reveal health condition of the machines. from signals.
- ↳ Three methods to analyze
  - 1) time-domain analysis
  - 2) frequency-domain analysis
  - 3) time-frequency-domain analysis

↳ time-domain analysis calculates statistic characteristics describing health conditions of machine such as mean, peak, root mean square, kurtosis and skewness.

↳ other time-domain analysis methods include time synchronous average (TSA), autoregressive model (AR), autoregressive moving average (ARIMA), Principle Component Analysis (PCA).

↳ frequency-domain analysis based on the transformed signals in frequency domain.

↳ Spectrum analysis by means of fast Fourier transform (FFT).

↳ Some useful tools (frequency filters, envelope analysis, side band structure analysis) → spectrum analysis tools.

↳ effective only in stationary measurement signals. unable to deal with non-stationary signals.



↳ time-frequency domain analysis  
↓ commonly used in short time Fourier transform (STFT)

## Diagnostic:

\* process of identifying and determining the relationship b/w information obtained in the measurement space and machine fault pattern.

↳ Three major steps.

- 1) Fault Detection (indicate whether fault occurred)
- 2) Isolation (find fault component and position)
- 3) Identification. (determine pattern and severity).

## Prognostic:

↳ detect fault presence in machinery as early as possible and identify kinds, position and degrees of faults.

\* forecast future performance of machinery using prediction methods.

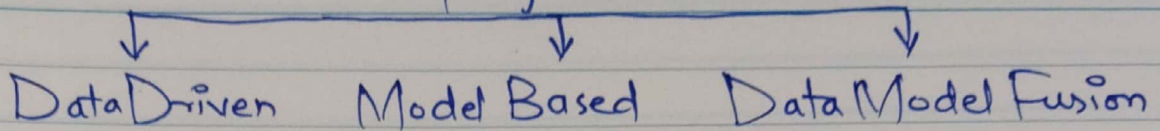
- \* State Estimation
- \* Prediction
- \* RUL Prediction.

\* Process of predicting the remaining useful life RUL of machinery.

\* three major approaches.



# Prognostics



(1)

- Data Driven prognostic derive degradation process from measurement signals.
- Rely on historical measurements and statistical characteristics of data.
- Examples (Relevance Vector Machine) RVM and Neural Networks-based models.

(2)

- Model-based method used mathematical or physical methods to describe degradation process.
- Need expert knowledge and real time information
- Examples are Markov-based models, Wiener process models, inverse Gaussian process model.

(3) → Data-Model fusion method integrate data driven and model based approaches.

- aim for more reliable RUL prediction
- These method enhance accuracy and robustness in complex scenarios.

## Maintenance Decision.

- ↳ determine optimal maintenance strategies & Replacement
- ↳ ensure effective asset management, minimize downtime and optimize maintenance.