⇒ 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.
- indespensible components in rotating machines

* 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 arangment → one small and one big.

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

* 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 conduted 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.
↳ Remaing 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 Aquisition
2) Signal Processing
3) Diagnostics
4) Prognostics
5) Maintenance Decision.

Data Aquisition:

↳ 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 heath 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 heath conditions of machine such as mean, peak, root mean square, kurtosis and skewness.
↳ other time-domain analysis methods include time synchronous average (TSA), autogressive model (AR), autoregressive moving average (ARMA), 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 occured)
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

Data Driven | Model Based | Data Model Fusion

(1)
- → Data Driven prognostic derive degradation process from measurement signals.
- → Rely on historical meaurements and statistical characteristics of data.
- → Examples (Relevance Vector Machine) RVM and Nueral 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, Winner process models, inverse Gaunian 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.

Maintanence Decision.

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