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PHM for safety barriers in infrastructures: opportunities and challenges

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Content

Background

- Safety barriers applied widely
- The failure of components follow exponential distribution
- The item is `as good as new` after a repair

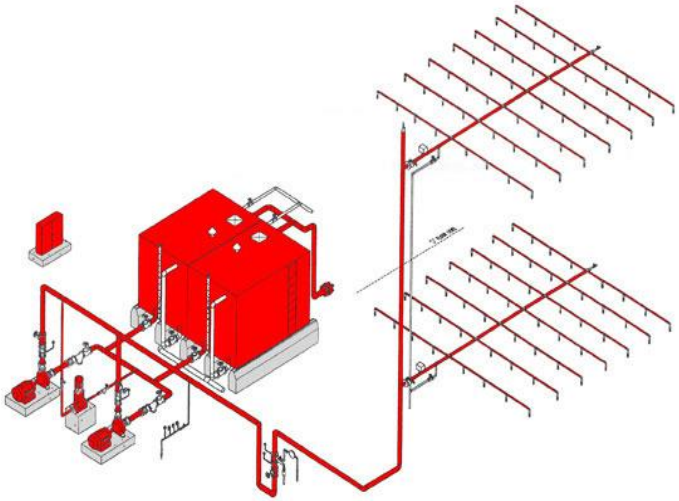


Figure: Automatic fire sprinkler system

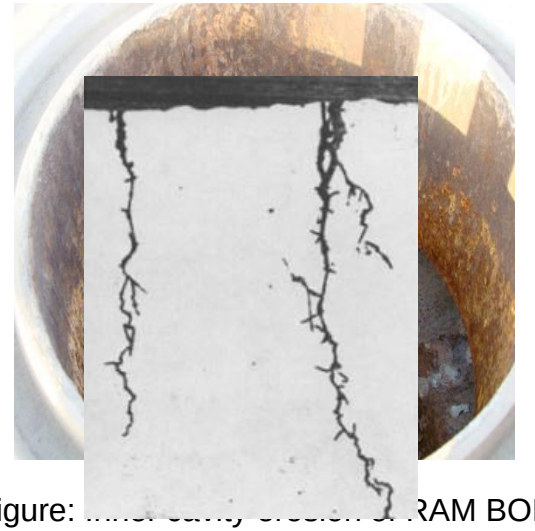


Figure: RAM BOP

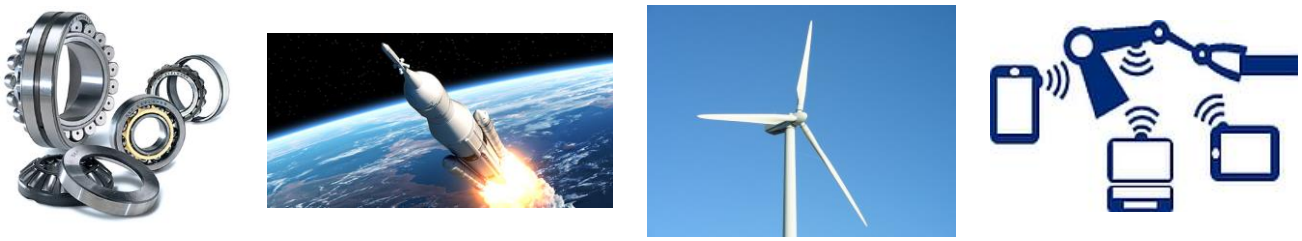
Figure: Cracks in mechanical device

Can we predict degradation and failures of safety barriers?

PHM

PHM can used for: (Haddad et al. 2012)

- evaluating the reliability of systems of their life cycle;
- determining the possible occurrence of failures and risk reduction;
- highlighting the remaining useful lifetime(RUL) estimation.



Figure：Examples of PHM application

PHM process

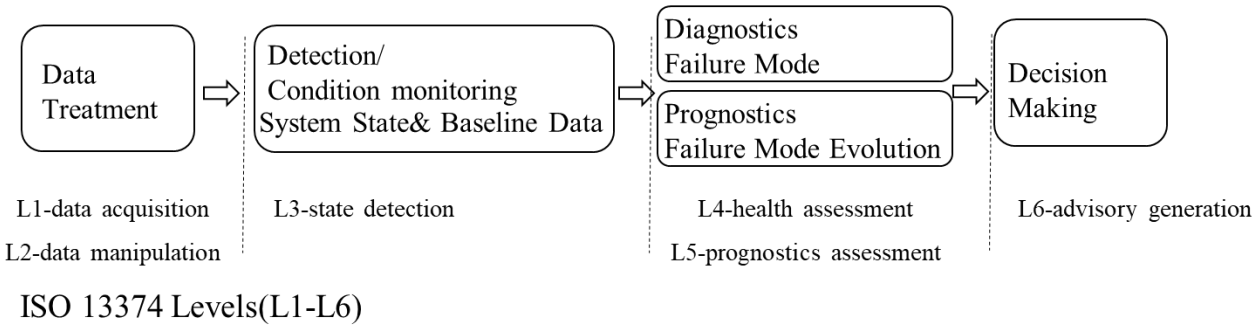


Figure: General process of PHM. Correlation with ISO 13374 (Guillen,2016)

PHM attempts to answer several questions:

- How is the status of system now?(Performance assesment)
- When will the system fail?(Remaining useful lifetime)
- What will the primary faults that cause system failue?
- Why does the incipient fault occur?

Safety barriers

Classification

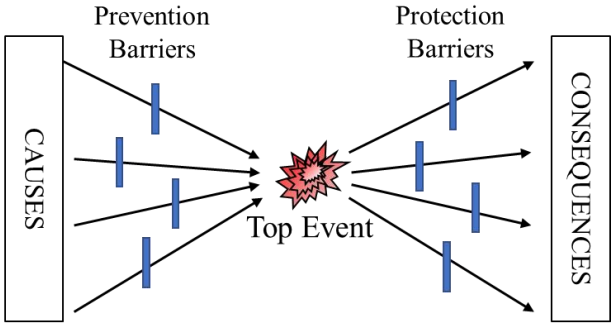


Figure: Bowtie diagram for a Top Event with prevention and protection barriers

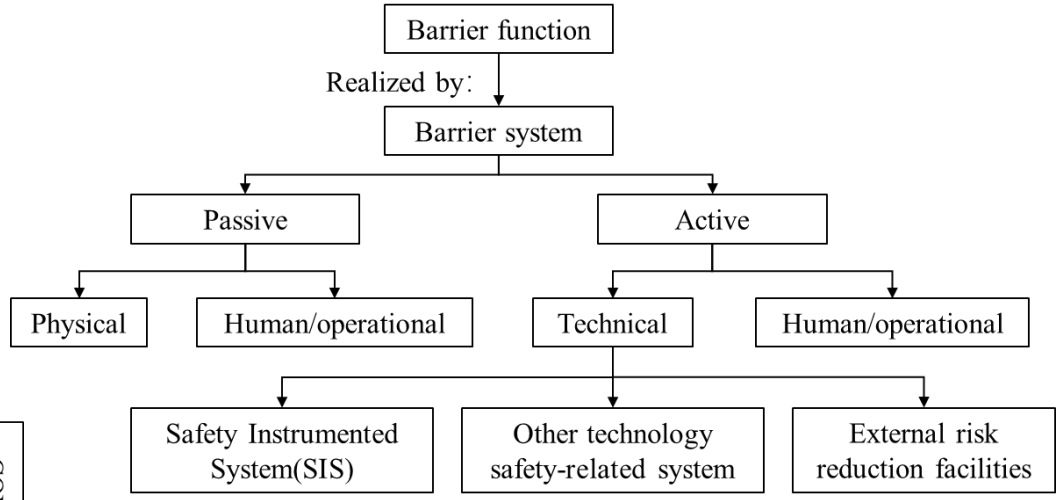


Figure: classification of safety barriers(adopted from Sklet,2006)

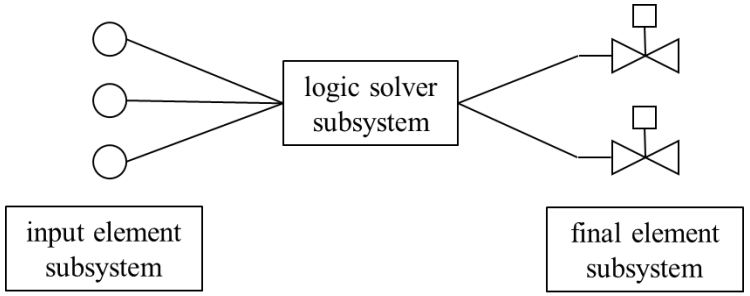


Figure: Main parts of a technological barrier

Application PHM for Safety barriers

Main function and potential benefits:

- Advance warning of failures
- Optimized maintenances
- Logistic support and cost reduction

Application PHM for Safety barriers

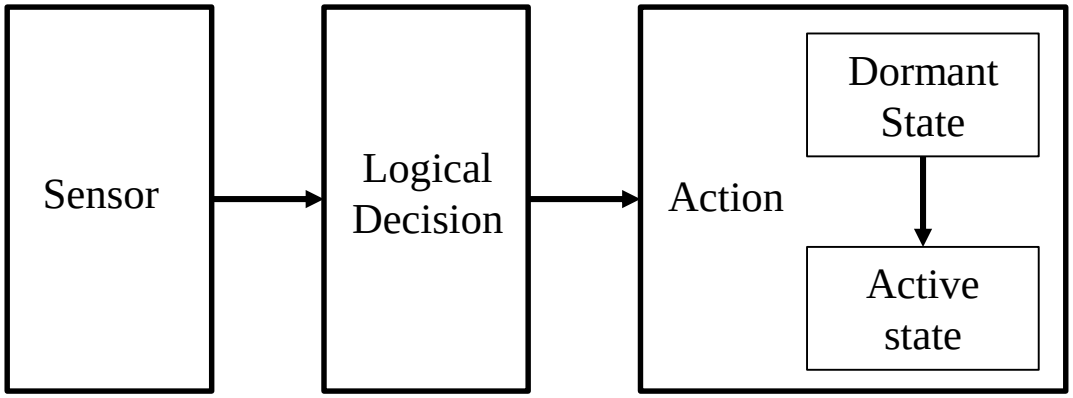
Challenges of PHM on barriers:

design and operational characteristics of barriers

1 Operational modes of barriers

Operational modes:

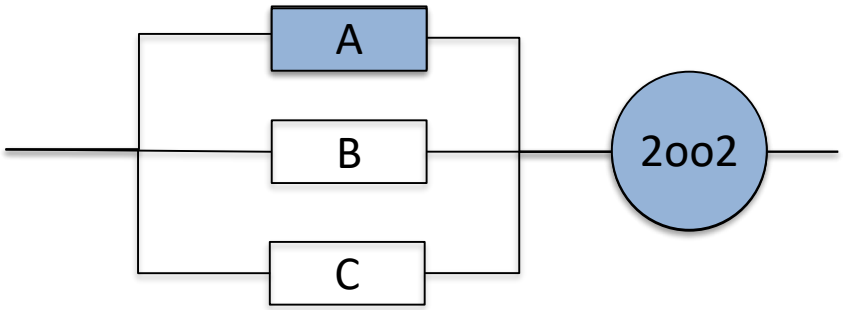
Low-demand mode
High-demand mode
Continuous mode



- Degradation mechanisms in different states are varied
- Degradation prediction with state transitions
- Parameters to predict the performance during the durations of demands

Application PHM for Safety barriers

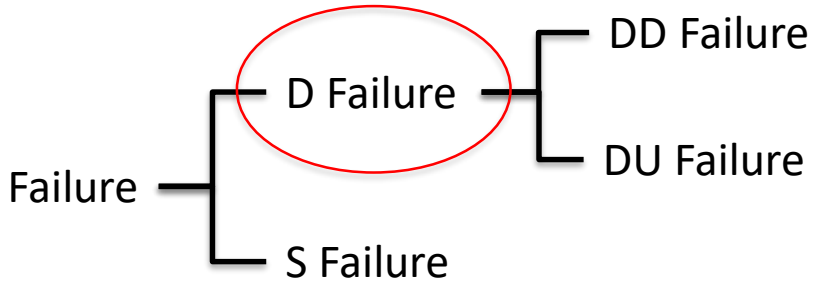
2 Structures of barriers: *K*-o-o-*N*



- effects of degradation in one channel on the entire barrier system

Application PHM for Safety barriers

3 Failure modes and tests of barriers



- Link the incipient failures or deviations with dangerous(D) failures

Data-driven → historical/training data

Model-driven → DU failures

Hybrid Approaches??

- Identify the causes and potential influences of common cause failures(CCF)

Application PHM for Safety Critical systems

4 Measures of technological barriers

Safety Integrity Level	low-demand operation mode	high-demand operation mode
4	$> 10^{-5}$ to $< 10^{-4}$	$> 10^{-9}$ to $< 10^{-8}$
3	$> 10^{-4}$ to $< 10^{-3}$	$> 10^{-8}$ to $< 10^{-7}$
2	$> 10^{-3}$ to $< 10^{-2}$	$> 10^{-7}$ to $< 10^{-6}$
1	$> 10^{-2}$ to $< 10^{-1}$	$> 10^{-6}$ to $< 10^{-5}$

(Reference IEC 61508)

- Build a relationship between SILs and indicators of PHM

5 Cost-benefit analysis of PHM

Cost: sensors, re-design the host product

Benefit: decrease of proof tests and maintenance, downtime loss

- choose the indicators to calculate the ROI of a PHM program

Conclusion

Researcher topics in the future:

- New approaches for predicting degradations of a component with state transitions;
- Mechanism of incorporating redundancy structures and varied configurations in degradation modelling and analysis;
- Models to link the effectiveness of PHM with SILs;
- Methods to optimize tests and maintenance activities under the constraints of SIL requirements.

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Thanks for your attention!