Z-BRE4K

Zero-unexpected breakdowns and increased operating life of factories

Veerendra C. Angadi[1] Alireza Mousavi[1]

[1]College of Engineering, Design and Physical Sciences, Brunel University London, Uxbridge - UB8 3PH, UK

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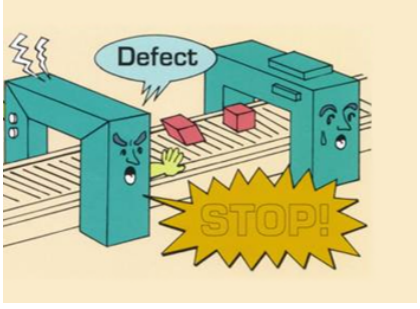

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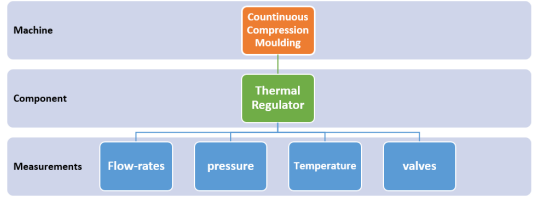
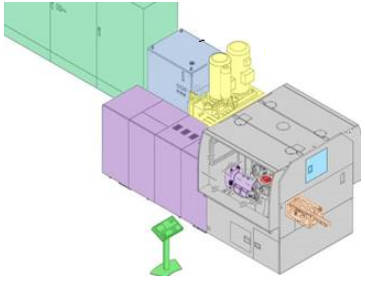
Introduction

- Estimated 26 - 50 billion “things” are connected to the Internet, - huge online data.
- Industry scenario: Fault detection, diagnostics & RUL
- Use case - Continuous Compression Moulding machine
- Manufacturing of plastic bottle caps (closures).
- The capacity of the production 1000 caps/min.





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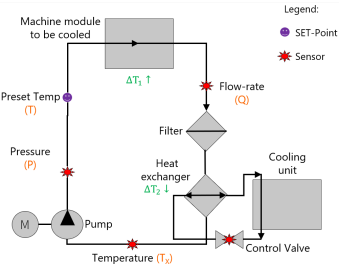
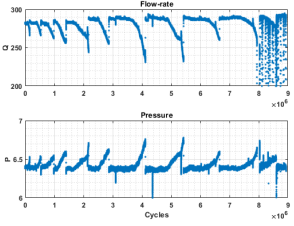
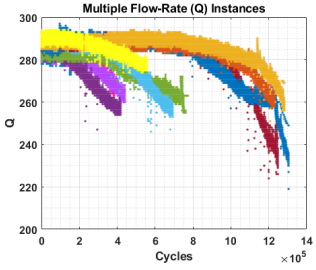
Thermal regulator







- Only the temperature is pre-set
- The set temperature is maintained by heat exchanger
- The particulates are built up in the circuit
- Flow-rate and pressure are inversely proportional
- Safety threshold 250 is introduced
- Time series data prediction is difficult: inherent uncertainty in the system

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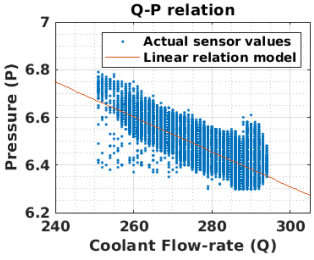
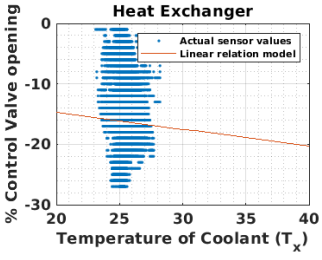
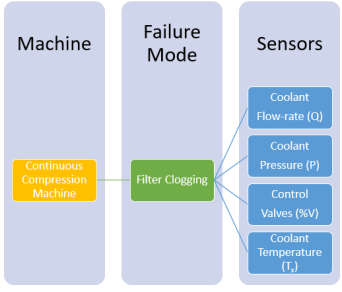
Failure mode







- The temperature is maintained despite reduced flow-rate
- The particulates causes decrease in flow-rate
- The decrease in flow-rate increases the pressure
- The latency in the control is due the filter-clog

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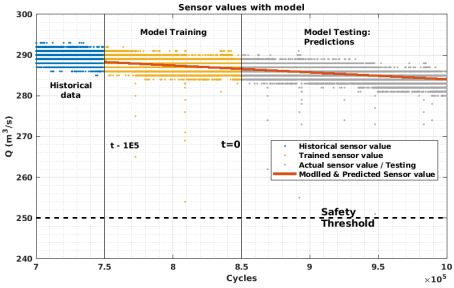
Regressive Trend-Tracker: Linear



- A model for the sensor to track the time-varying trend
- A linear model $= \phi(t) \cdot t$
- Provides an over-estimate of RUL when depreciating at faster rate

$$f(x) = \sigma + \phi(t) \cdot g(t) + \varepsilon(t)$$

$$R(t) = \left(\frac{S - \sigma}{\phi(t)} \right) - t$$

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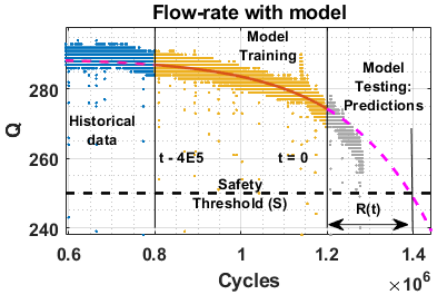
Regressive Trend-Tracker : Exponential



An exponential model $= \phi(t) \cdot t = \sum^{n} \exp(b_n t)$
A two term exp function has:

$$\phi(t) \cdot g(t) = \begin{bmatrix} a_1 & a_2 \end{bmatrix} \begin{bmatrix} \exp(b_1 t) \\ \exp(b_2 t) \end{bmatrix}$$

$$\forall \{b_1, b_2\} \in [0, 1]\,; a_1 \leq 0; a_2 > 0$$

1st exp function : gradual degradation
2nd exp function : faster degradation

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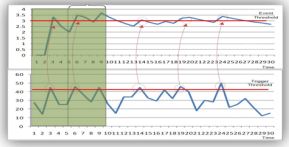
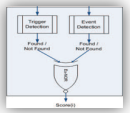
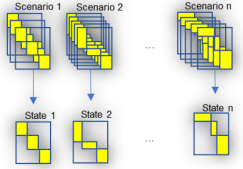
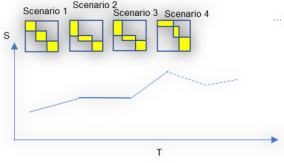
Event-clustering correlation discovery

Event-base correlation discovery is an unaware sensitivity analysis method to find system parameters correlation without requiring topology information.









Trigger Data and Event Data detection/ Two-way Matching → Build a coincidence matrix and Implement ROC algorithm → knowledge of systems / state change at specified time intervals (discretization)

- Rank Order Clustering (ROC) to cluster the scenarios.
- Correlation between performances and all sources of performances
- Real-time situation-awareness sensing
- Measure the sensitivity (effect)

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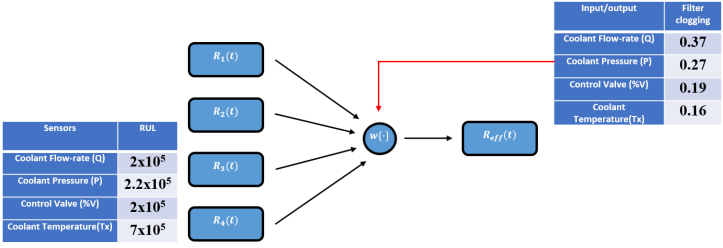
Effective RUL of Thermal Regulator



$$R_{eff}(t) = w^{\mathsf{T}} R_x(t)$$

- The effective RUL is estimated by weighted RUL of individual components
- The weights are estimated from event-clustering
- Event-clustering: Event-thresholds, Rank Order Clustering (ROC)
- The estimated effective RUL is $\sim 2.5 \times 10^5$ cycles
- The effective RUL provides an holistic maintenance plan

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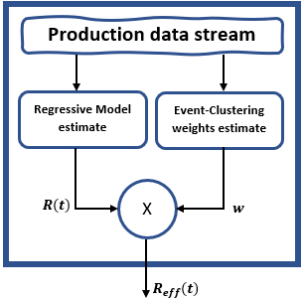
Conclusion

- The event-clustering evolves over time
- Hence the relevance of sensors for a failure may change. i.e. KPI may change for a particular failure mode
- The methodology provides a single health indicator of RUL for an entire module.
- The RUL for individual components provides the real-time preventive maintenance plans.
- Health indicator provides a holistic approach towards PdM with simpler predictions at micro-level.



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Acknowledgement

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