1st International Electronic Conference on Machines and Applications

Maintenance strategy selection based on FMEA/FMECA approach using time dependent failure probability

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Maintenance strategy selection

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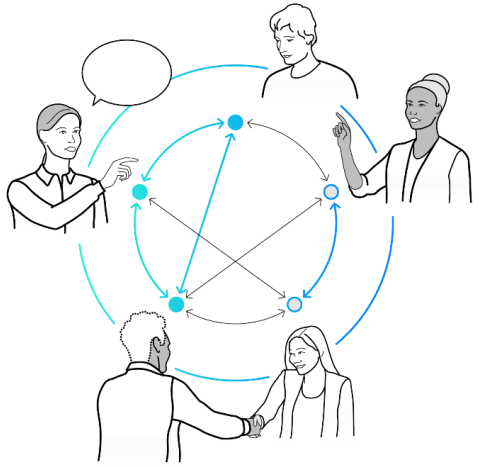
Maintenance strategy selection

- Industrial maintenance is playing an increasingly important role in production systems
- One of the most important factors that determines the use of resources and the resulting availability is the selection of the maintenance strategy for the production machines
- A lot of methods focus on reliability-centered approaches
- One of the reliability-centered approaches is the failure mode and effect analysis (FMEA)
- Exploring the possible failure modes and assessing the effects is at the center of the reliability-centered approaches, even if other names are used
- The exiting methods do not use time depended failure probabilities in their decision making process



Goal of this publication

- Introduce time dependency of failure probabilities into maintenance decisions
- Expand the original FMEA framework to allow for time dependency
- Validate the approach in a real life production environment

Time dependent failure and cumulative failure probability

Six possible failure curves for component wear with additional possibilities for other failure reasons

Calculating the cumulative failure probability

$$CFP_n = 1 - \prod_{i=1}^{n}(1 - FP_i)$$

- CFP_n: cumulative failure probability from now to n
- $(1 - FP_i)$: complementary failure probability at time interval I

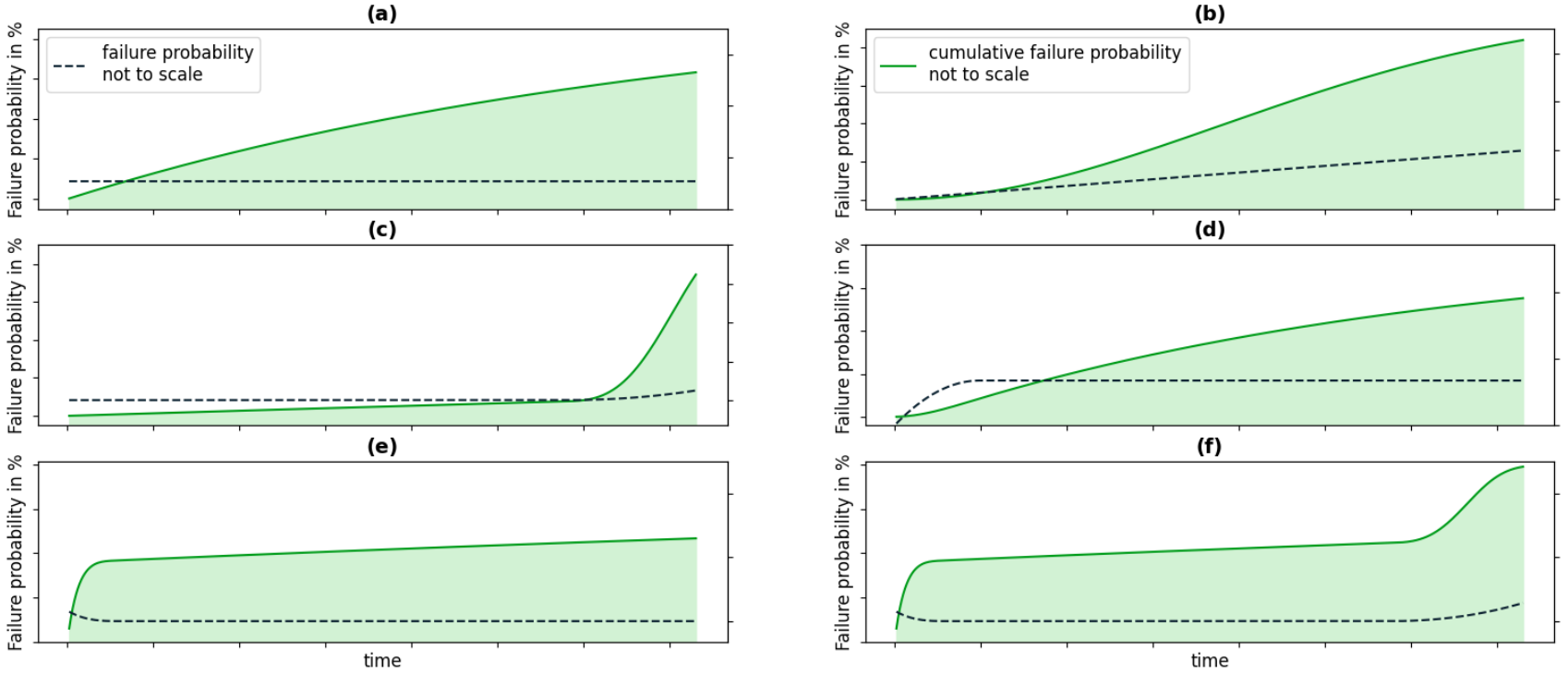


Figure 1. Failure probabilities (dashed lines) and cumulative failure probabilities (green lines) for the six component failure types. (**a**) Constant failure probability, (**b**) linear rising failure probability, (**c**) constant failure probability with a wear-out region, (**d**) rising failure probability to a constant level, (**e**) infant mortality of equipment followed by a constant failure probability and (**f**) infant mortality, followed by constant and then rising failure probability.

Using time dependent failure probabilities in FMEA

Leading to a time dependent risk priority number

Integrating time dependency into FMEA

- Instead of using the failure occurrence rate of failure probability, which consisted of one value for the component (a)
- using the cumulative failure probability (c), of the component.
- This allows the risk priority number to become time dependent as well
  - Either in ranges (b), if the cumulative failure probability is divided into ranges as well
  - Or as an consistent value over time (d), if the actual cumulative failure probability is used
- All other steps of the FMEA (or other reliability-centered method) for maintenance strategy selection can be done the same way

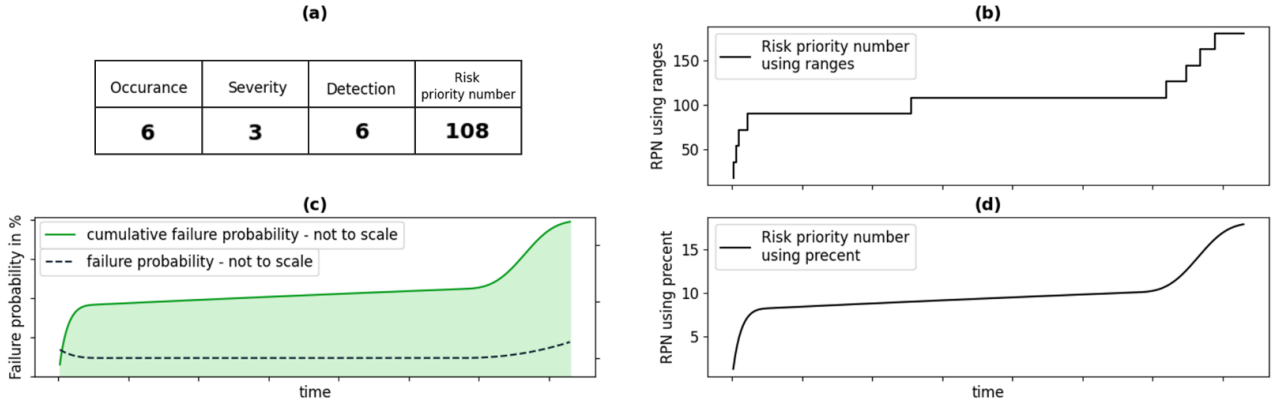


Figure 2. (**a**) Classic FMEA approach to determine the risk priority number; (**c**) time dependent failure probability of the component; (**b**) time dependent risk priority number using ranges; (**d**) time dependent risk priority number using ranges.

Validating the approach in a real production environment

Convincing results led to a change in maintenance actions

Investing into spare parts at the right time

- On the left the old method with fixed failure probabilities are shown. A component has about 50% chance to fail each year.
- On the right, the time dependence failure probabilities are shown
- Both approaches have the overall same failure probability at the end of the failure mode's expected lifetime (marked in the graph)
- Using the existing method, the risk of failure would have been calculated to be high, beginning at year one
- Using the time dependent approach shows, that the actual risk only rises at about year three
- Therefore the spare parts do not need to be stocked for the first years

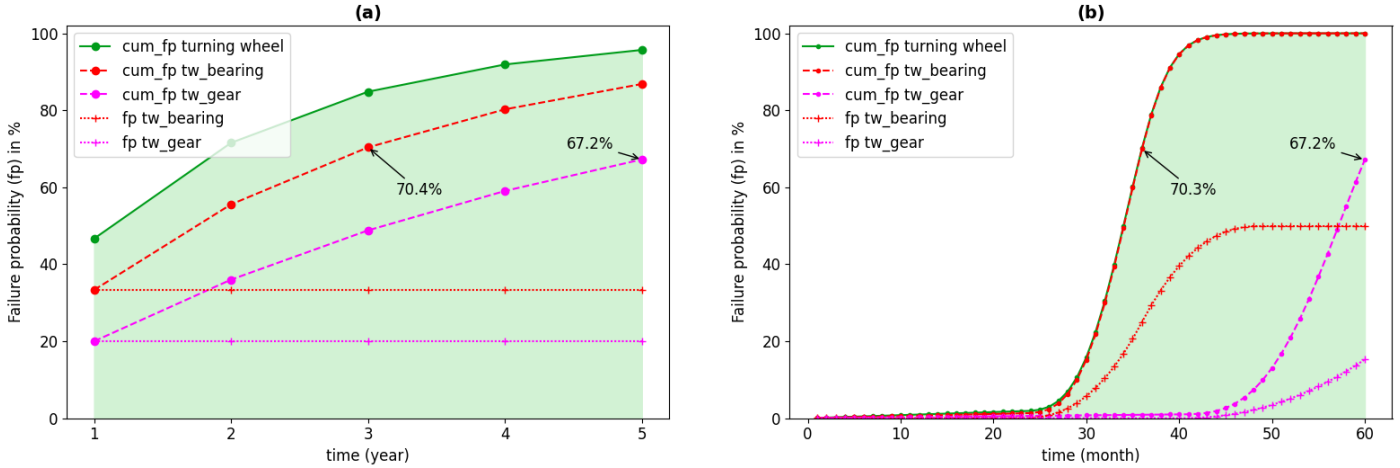


Figure 3. Using failure probability (fp) and cumulative failure probability (cum_fp) of a turning wheel (tw) to determine necessary maintenance actions (**a**) for constant failure probabilities, and (**b**) for time dependent failure probabilities.

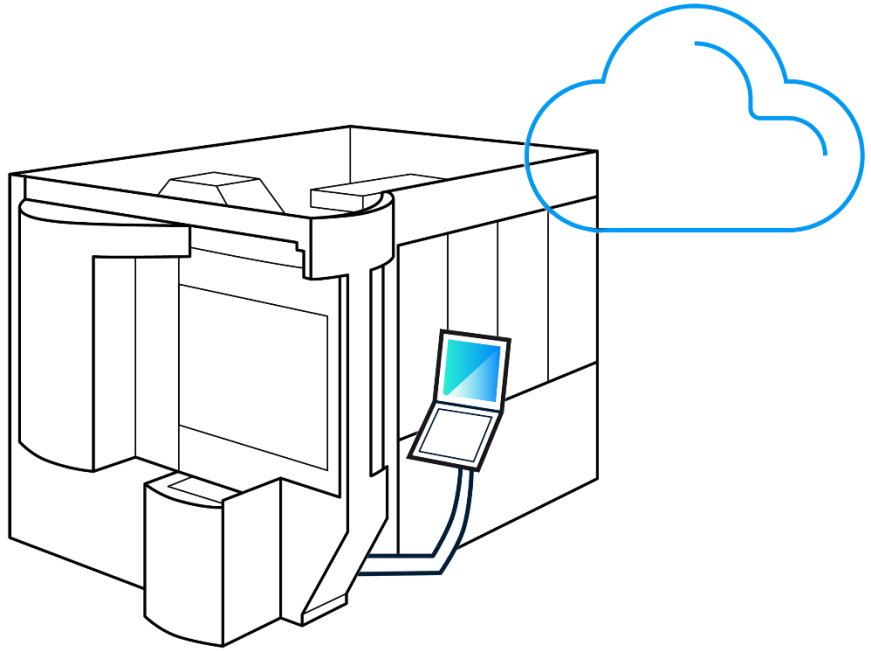
- The new approach was convinced the decision makers to change the buy order for the spare parts and the save money overall due to lower storage costs

Discussion of the expanded failure mode end effects analysis

Easy and intuitive to use for maintenance personal with only little more information needed

Discussion

- The additional information needed to introduce time dependent failure probabilities might seem very much.
- But in the real production environment, using historical data and failure template curves, the maintenance employees could very easily and intuitively produce those failure curves
- Even if the wrong template curve is used, the benefit of introduction time dependency still is better than the existing approaches
- The benefit of use time dependent data was clear not only to the maintenance employees but also to the decision maker
- Additional research into time dependency of other aspects of the FMEA approach should be undertaken



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