BASICS OF MACHINE OPERATION

Laboratory · Exercise 6

Reliability analysis – Weibull and system reliability

Weibull · block diagrams · fault tree · spares

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1. Goal and organisation

Goal. Estimate the life distribution of a component from failure data, use it for a maintenance decision, and calculate and improve the reliability of a production line.

Organisation. Teams of 3–4 students. In class (about 80 min): Weibull analysis in a spreadsheet and the block diagram. At home: improvement options, fault tree, spare parts and the report. Files: BMO_Ex6_<team>.xlsx and BMO_Ex6_<team>.pdf.

2. Part A – Weibull analysis of hydraulic pump failures

Ten identical hydraulic pumps were observed. Eight failed; two were still working at 5 000 h (suspended).

Pump	Time [h]	Status
P1	820	failed
P2	1 350	failed
P3	1 900	failed
P4	2 300	failed
P5	2 750	failed
P6	3 200	failed
P7	3 900	failed
P8	4 600	failed
P9	5 000	suspended
P10	5 000	suspended

$$F_i \approx \frac{i-0.3}{n+0.4} \qquad \ln[-\ln(1-F)] = \beta \ln t - \beta \ln \eta \qquad R(t) = e^{-(t/\eta)^{\beta}} \qquad t_{B10} = \eta\,(-\ln 0.9)^{1/\beta}$$

1. In a spreadsheet calculate the median ranks for the 8 failures (n = 10), ln t and ln[−ln(1 − F)]; plot them, fit a straight line (LINEST or a trend line) and obtain β and η.
2. Calculate R(1 000 h), R(2 000 h) and the B10 life. What failure pattern does β show?
3. Repeat with n = 8 (ignoring the two suspended pumps). Compare and explain why ignoring survivors is a mistake.
4. A planned replacement costs 2 500 PLN; a failure in operation 15 000 PLN. Is age-based replacement justified? Suggest an interval.

3. Part B – Reliability of a bottling line

In series: feeder (R = 0.98), **two fillers in parallel** (R = 0.90 each; one is enough), capper (0.94), labeller (0.96), packer (0.97). Reliabilities for one week.

$$R_{\text{series}} = \prod_i R_i \qquad R_{\text{parallel}} = 1 - \prod_i (1 - R_i) \qquad R_{2\text{ of }3} = 3R^2 - 2R^3$$

5. Draw the reliability block diagram and calculate the line reliability.

6. One improvement is possible: (a) a second capper in parallel, (b) a third filler, (c) a labeller with R = 0.99. Calculate each and choose.
7. 10% of filler failures are common-cause (same product supply). Recalculate the filler group and comment.
8. Draw the fault tree for “line stops” (AND/OR gates) matching your block diagram and name the single points of failure.

4. Part C – Exponential components and spare parts

The line has 12 control units with constant failure rate $\lambda = 4 \cdot 10^{-5}$ 1/h, 6 000 h per year.

9. Calculate the MTTF, the probability that one unit survives a year, the expected number of failed units per year, and the number of spares for a 95% service level if the delivery time is 1 000 h (Poisson model).

5. Assessment

Criterion	Weight
Weibull analysis	35%
System reliability and improvement	35%
Fault tree	15%
Spare parts	15%