TPK4450: Semester work 2020

Information:

- The semester work is mandatory. It counts 30% to the final grade in the course.
- The semester work is individual. You must submit report individually.
- It consists in 3 parts: Fault diagnosis, failure prognosis, maintenance modelling
- You must submit a report for each part. You should include figures that the exercise asks for, with your comments, explanations and/or analysis.

Description

A valve operates in an offshore oil platform. Looking at OREDA (Offshore and Onshore Reliability Data), the total failure rate (assumed constant in OREDA) is estimated: $\boldsymbol{\lambda = 17.8 \times 10^{-6}\ h^{-1}}$.

Then, the mean time of failure is approximately $\boldsymbol{MTTF = 5.6 \times 10^{4}\ h}$.

Time-based maintenance

Your job is to consider different preventive maintenance policies and to optimize replacements of the valve. (Perfect replacements in which the unit is considered “as-good-as-new”).

- Cost of preventive maintenance: c=50
- Additional cost due to failures (corrective maintenance): k=500

1. Assuming that the lifetime T is exponentially distributed with parameter λ, what is the optimal period of preventive replacement ?.

Assume now that the lifetime is Weibull distributed and the shape parameter $\boldsymbol{\beta = 3}$

2. Calculate or find the optimal period of replacement when considering a **clock-based maintenance** strategy. Write clearly the procedure you use to find this period and any assumptions you make.

Hint: you can use the MTTF to find the scale parameter of the Weibull distribution.

Condition-based maintenance

A condition monitoring program is performed in n=10 valves of the same type in similar application and operational conditions. By measurements of flow, pressure, temperature, a condition or health indicator based on deviations from the original flow coefficient CV is monitored.

The degradation $Y(t)$ is evaluated every 12 weeks (approximately 3 months). The observations are provided in the data set '**cmonitoring.txt**'. The monitored units have not been maintained (natural deterioration). In total, 30 observations of the degradation are taken for each unit.

Table 1. Structure of the data set

	Unit. 1	Unit. 2	…	Unit. 10
Y(0)	0	0	…	0
Y(τ)	Obs(1,1)	Obs(1,2)	…	Obs(1,10)
Y(2τ)	Obs(2,1)	Obs(2,2)	…	Obs(2,10)
…	…	…	…	…
Y(30τ)	Obs(30,1)	Obs(30,2)	…	Obs(30,10)

Table 1 shows the structure of the data. The columns correspond to histories for a unit and the rows to the observations (spaced $\tau = 12$ weeks from each other). In this sense, the last observation of the degradation corresponds to time $t = 30 * 12 = week\ 360$ since the unit is in operation.

The unit is considered to be in fail when the degradation $Y(t) \geq \boldsymbol{L} = \mathbf{100}$ (failure threshold).

It's your job to propose a condition-based maintenance model.

3. Make a plot of the data and based on your observations, choose a stochastic degradation model and write the reasons for your selection.

4. Estimate the parameters you need in your model and write a step by step guide to estimate this parameters from the given data set.

Now consider:

- As-good-as-new replacement.
- Failures are detected immediately and the unit is replaced.
- The deterioration of the valve is only known at inspection dates (unless a failure occurs).
- Time to replace the valve is neglected. (Instantaneous replacement)
- Cost of preventive maintenance: **c=50**
- Additional cost due to failures (corrective maintenance): **k=500**
- Cost of inspection: **ci = 10**
- The organization decides to keep the inspection interval as it is $\boldsymbol{\tau} = \mathbf{12}$ **weeks.**

5. Propose an objective function (based on cost) to optimize a preventive maintenance threshold M; such as when an inspection at time t finds the degradation $M \leq Y(t) < L$ a preventive replacement of the valve is carried. (Taking the assumptions listed)

To start evaluating the performance of a maintenance strategy, set the level **M=75**

6. Simulate 1000 (one thousand) trajectories of the process with the estimated parameters. Make a plot with the simulated degradation trajectories.

7. For each trajectory:
    a. Get the time of crossing the failure threshold L. You may use a linear interpolation to estimate the passage time when the failure occurs between two inspections, since we consider that the failure is detected immediately. Make a histogram of the passage time σ_L.
    b. Get the time of detecting the passage of level M, i.e. the time of the first inspection at which the degradation level is above M. Make a histogram of the detected passage time σ_M.

8. What is the estimated mean time of failure (MTTF) of the unit, in weeks and in hours ?

The renewal time for each trajectory then corresponds to the minimum between σ_M and σ_L , i.e. if the passage of the preventive maintenance threshold is detected (by inspection) before the failure occurs, then the unit is replaced at this inspection time. Otherwise, the unit is replaced at the failure time.

9. What is the MTBR (mean time between renewals)?

For each renewal you can calculate the cost, depending if it is preventive replacement or corrective and how many inspections were performed until the renewal.

10. What is the asymptotic cost per unit of time given that $\boldsymbol{\tau} = \mathbf{12}$ **weeks** and **M=75** ?

Finally, you want to challenge the threshold M and attempt to find the optimal value (by reducing the cost).

11. Try different values of M (e.g. between 75 and 95) and make a table or plot of the cost per unit of time as function of the level M.

12. What is the optimal value of M that you find?