BASICS OF MACHINE OPERATION

Laboratory · Exercise 1

Machine life cycle and life cycle cost – CNC lathe

Life cycle · MTBF · MTTR · availability · LCC



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1. Goal and assumptions

Goal. Analyse the whole life of a CNC lathe over 10 years – purchase, use, maintenance, repairs and disposal – and find where the cost and the risk of failure can be reduced.

Assumptions. The lathe XYZ-TC500 works in a production plant for **10 years**, **160 h per month** (1 920 h per year). All costs are in PLN, net. Missing data (e.g. the electricity price) are assumed by the team and stated in the report.

Organisation.

- Teams of 3–4 students; one report per team.
- In class (about 80 min): data review, life cycle model (Task 1) and reliability indicators (part of Task 2).
- At home: cost analysis, optimisation proposals and the report.
- Report as PDF, file name: BMO_Ex1_<team number>.pdf.

2. Key terms

- **Life cycle** – design, manufacture, commissioning, use, maintenance and service, withdrawal, disposal (scrapping or recycling).
- **Preventive maintenance** – planned actions at fixed intervals or by operating hours (lubrication, filters, inspections).
- **Corrective maintenance** – actions after a failure to restore the machine.
- **MTBF** – mean time between failures; **MTTR** – mean time to repair (diagnosis + repair + restart); **A** – availability.

$$\mathrm{MTBF} = \frac{\text{total operating time}}{\text{number of failures}} \qquad \mathrm{MTTR} = \frac{\text{total repair time}}{\text{number of failures}} \qquad A = \frac{\mathrm{MTBF}}{\mathrm{MTBF} + \mathrm{MTTR}}$$

Life cycle cost (LCC) is the sum of all costs over the period of use, reduced by the resale value at the end. Costs of later years are discounted to the present value with the rate i (IEC 60300-3-3).

$$PV = \frac{C_t}{(1+i)^t} \qquad \mathrm{LCC} = C_{\text{purchase}} + \sum_{t=1}^{10} \frac{C_{\text{operation},\,t} + C_{\text{maintenance},\,t} + C_{\text{repair},\,t}}{(1+i)^t} - \frac{V_{\text{resale}}}{(1+i)^{10}}$$

3. Data

3.1 Technical data – CNC lathe XYZ-TC500

Parameter	Value
Year of manufacture	2020
Spindle	15 kW, 4 000 rpm
Positioning accuracy	± 0.005 mm
Max. turning diameter	500 mm
Control	Fanuc or Siemens CNC
Axis drives	servo drives, axes X and Z

Parameter	Value
Power demand at full load	20 kW (20 kWh per operating hour)
Average tool life	200 h
Mass	3 500 kg
Purchase price	200 000 PLN
Installation and operator training	10 000 PLN

3.2 Operating data and failures

Event	Frequency	Repair cost	Downtime
Spindle overheating	2 × per year	5 000 PLN each	3 days (24 h) each
Coolant pump replacement	every 2 years	1 500 PLN	8 h
Spindle bearing replacement (overhaul)	every 3 years	7 000 PLN	16 h

3.3 Preventive maintenance schedule

- **Every 500 h (about 3 months):** spindle oil change, lubrication of guideways and bearings, check of the coolant system and pump, check and adjustment of the machine geometry.
- **Every 1 000 h (about 6 months):** full diagnostics of servo drives and control, replacement of worn elements (e.g. filters).
- **Overhaul every 3 years:** spindle bearings, regeneration of ball screws, check and calibration of the CNC control.

3.4 Example annual costs

Item	Unit cost	Frequency	Annual cost
Lubricating oil	200 PLN	every 6 months	400 PLN
Turning tools	300 PLN	every 200 h	2 880 PLN (1 920 h : 200 h = 9.6 sets)
Coolant pump	1 500 PLN	every 2 years	750 PLN
Spindle bearings	7 000 PLN	every 3 years	2 333 PLN
Operator	40 PLN/h	160 h/month	76 800 PLN
Coolant system inspection	500 PLN	once a year	500 PLN
CNC calibration	1 200 PLN	once a year	1 200 PLN
Servo drive diagnostics	600 PLN	every 6 months	1 200 PLN
Oil filters	100 PLN	every 6 months	200 PLN
Drive belts	300 PLN	once a year	300 PLN
Electricity	price per kWh – assumed by the team	20 kW × 1 920 h	to calculate

Note: use the current electricity price for industrial customers (about 0.90 PLN/kWh net) and state the value you use.

3.5 Further possible failures (for Task 3)

Failure	Symptom	Repair cost	Note
Spindle head damage	required speed not reached	3 000 PLN	bearings may need replacement
Coolant system problem	insufficient tool cooling	1 500 PLN	pump replacement may be needed
Drive belt breakage	machine stops	500 PLN	belt replacement
Servo drive damage	loss of motion accuracy	4 000 PLN	service required
Sensor failure	wrong measurement data	1 000 PLN	sensor replacement
Control system fault	software does not respond	2 000 PLN	update may be needed
Guideway seizure	higher motion resistance	600 PLN	cleaning and lubrication
Tool damage	tools break	800 PLN	tool replacement
Power supply problem	unstable voltage	1 500 PLN	check the installation
Lubricating oil leak	faster wear of parts	700 PLN	seal replacement

3.6 Document templates

A. Inspection card

Date	Operating hours	Maintenance actions	Remarks	Operator
01.02.2024	500 h	oil change, guideway lubrication	slight wear on the spindle	Jan Kowalski

B. Failure report

Date	Failure type	Description	Repair cost	Repair time	Remarks
15.03.2024	spindle overheating	spindle overheated after 5 h of work	5 000 PLN	3 days	more frequent cooling checks recommended

C. Maintenance schedule – month · cumulative operating hours (160, 320 … 1 920 h) · planned maintenance actions · remarks.

4. Tasks

Task 1: Life cycle model

Draw the life cycle diagram of the lathe for 10 years: purchase and installation, commissioning and running-in, use with preventive maintenance, repairs and overhauls, withdrawal and disposal. Mark the 500 h and 1 000 h services, the pump replacements and the overhauls (years 3, 6 and 9) on a time axis.

Result: diagram of stages and a 10-year time axis.

Task 2: Reliability indicators and life cycle cost

1. For one year calculate MTBF, MTTR and availability A for the unplanned failures (spindle overheating).
2. Calculate availability including the planned stops for maintenance and overhauls; compare.

3. Summarise annual costs: purchase and installation, operation (operator, energy, tools), preventive maintenance, repairs and overhauls.
4. Calculate the 10-year LCC without and with discounting (i = 6% per year); resale value 10% of the purchase price.
5. Show the cost structure as a chart and name the dominant category.

Result: annual cost table, LCC (without and with discounting), cost chart, MTBF, MTTR and A.

Task 3: Optimisation

Propose at least four improvements – e.g. condition monitoring of the spindle (vibration, temperature), better cooling, a CMMS, operator training, an energy-saving mode, condition-based intervals. Estimate the effect of each on cost or availability and its implementation cost.

Result: table of measures: description, expected effect, cost, justification.

Task 4: Report

Max. 8 pages: machine description, life cycle model, reliability indicators, LCC analysis with chart, optimisation proposals, conclusions, assumptions and sources. Every calculation: formula → numbers → result with unit → one sentence of interpretation.

Watch out: tools 1 920 h : 200 h = 9.6 sets per year; 20 kW means 20 kWh per operating hour; preventive maintenance includes all items of table 3.4; separate planned and unplanned costs; proposals must follow from your analysis.

5. Assessment

Criterion	Weight
Life cycle model	25%
Reliability indicators	15%
LCC analysis	30%
Optimisation proposals	20%
Report quality	10%