BASICS OF MACHINE OPERATION

Laboratory · Exercise 7

FMEA, root cause analysis and maintenance plan

Pareto · Ishikawa · 5 Whys · FMEA · KPIs



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1. Goal and organisation

Goal. Use one year of failure history of a packaging machine to find the most important losses (Pareto), analyse the main problem to its root cause, carry out an FMEA, and write a maintenance plan with a strategy for each assembly, KPIs and spare parts.

Organisation. Teams of 3–4 students. In class: Pareto, root cause analysis and team presentations (5 min per team). At home: FMEA, maintenance plan and the report (max. 8 pages). File name: BMO_Ex7_<team number>.pdf.

2. Machine

A horizontal flow-wrapping machine packs 120 products per minute on two shifts (16 h/day, 250 days/year = 4 000 h/year). Assemblies: infeed conveyor, film unwind with tension control, forming box, heated longitudinal sealing rollers, heated cam-driven cross-sealing jaws, servo drives, PLC with HMI and sensors, outfeed conveyor. Lost production margin: 600 PLN per hour of downtime.

Failure history (work orders, last 12 months)

Assembly	Failure	Count	Downtime [h]	Parts cost [PLN]
Cross-sealing jaws	poor seal / jaw heater failure	14	42	5 600
Film unwind	film tears / tension fault	31	26	900
Infeed conveyor	product jam	58	19	300
Sensors	photocell misread	22	11	1 800
Servo drives	drive fault alarm	4	16	9 500
Longitudinal sealing	roller wear / temperature	6	12	3 200
Outfeed conveyor	belt slip	9	5	700
PLC / HMI	software freeze	3	4	0

Notes from the work orders: most jaw failures happen in the first hour after a product changeover; jaw temperature setpoints are changed by operators “by feel”; film tears are more frequent with a new film supplier since month 7; jams happen mainly with products from one line.

$$\mathrm{RPN} = S \times O \times D \qquad \mathrm{MTBF} = \frac{\text{operating time}}{\text{number of failures}} \qquad \mathrm{MTTR} = \frac{\text{total downtime}}{\text{number of failures}}$$

3. Tasks

1. **Pareto analysis.** Pareto charts by number of failures **and** by downtime – do they show the same priorities? Calculate MTBF and MTTR of the machine and the annual cost of downtime.
2. **Root cause analysis.** For the assembly with the highest downtime build an Ishikawa diagram (6M) and a 5 Whys chain; name the physical, human and latent root causes and the corrective actions. Use the notes from the work orders.

3. **FMEA.** For at least four assemblies: function, failure mode, effect, S, cause, O, current controls, D, RPN, action, and S/O/D/RPN after the action. Mark high-severity modes regardless of RPN.
4. **Maintenance strategy.** For each assembly choose run-to-failure, time-based, condition-based, failure-finding or redesign, using the criticality matrix and the Weibull/RCM logic. Write tasks, intervals and who does them (operator, maintenance team, external service).
5. **KPIs and spare parts.** 4–5 KPIs with targets (e.g. availability, MTBF, planned work ratio, OEE) and a list of critical spare parts with recommended stock (ABC/VED).
6. **Benefit estimate.** Expected reduction of downtime and annual savings against the cost of the plan.

Deliverable: report with Pareto charts, Ishikawa diagram, 5 Whys, FMEA table, maintenance plan, KPIs, spare parts list and benefit estimate.

4. Assessment

Criterion	Weight
Pareto and indicators	15%
Root cause analysis	25%
FMEA	25%
Maintenance plan, KPIs and spare parts	25%
Presentation	10%