IOCMA 2026 Conference
The 2nd International Online Conference on Mathematics and Applications
10–12 June 2026 | Online
MDPI

A Note on Reliability Analysis of Multi-Stage Manufacturing Systems with Controlled Capacity Release

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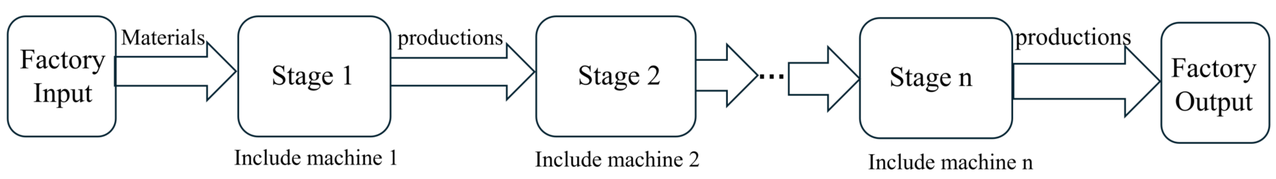
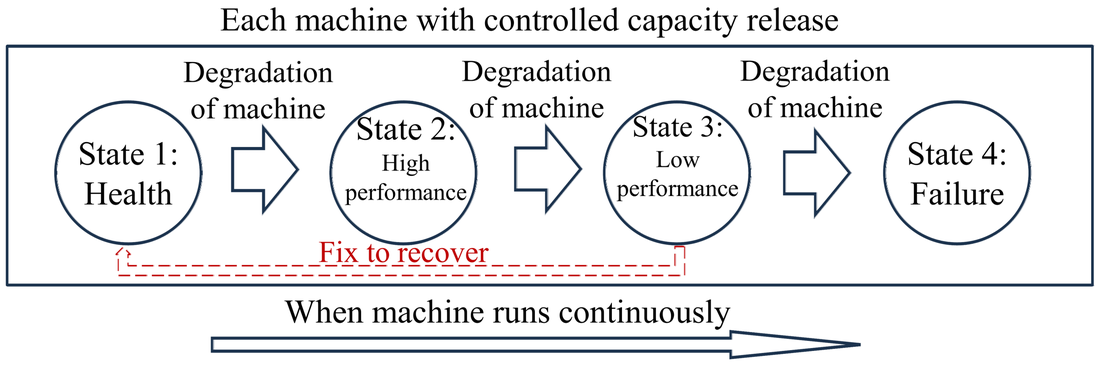
INTRODUCTION & AIM

Multi-stage manufacturing system



Why introduce controlled capacity release: avoid a purely destructive process

Each machine with controlled capacity release



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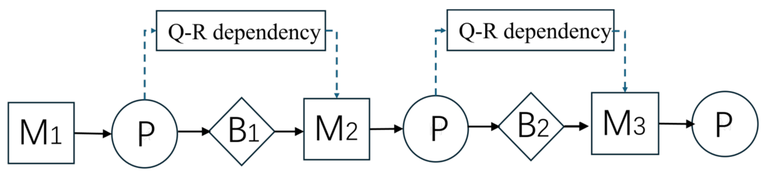
Objective of study

Evaluate and improve the reliability of a multi-state manufacturing system

METHOD

Multi-stage manufacturing with Q–R dependency(3 Stages)

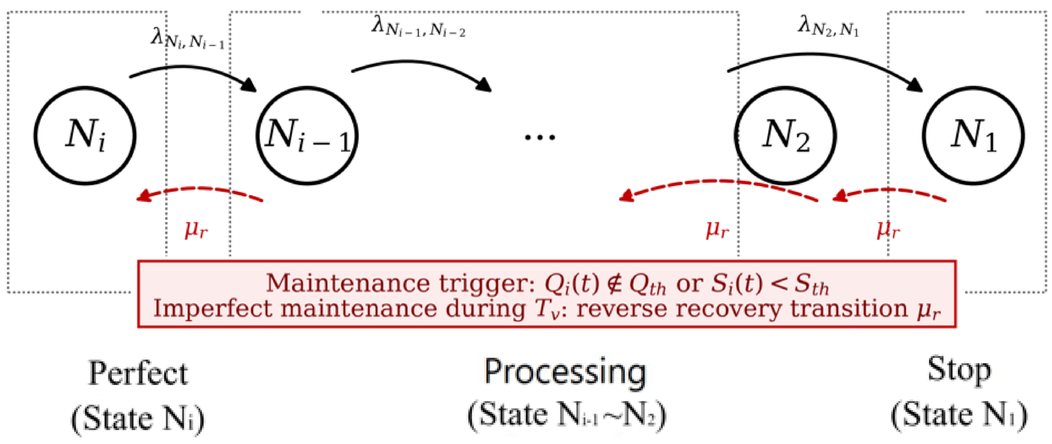


M:machine
P:prodcution
B:buffer

Fix mechanism in controlled capacity release

Parameter	Meaning	Approximate Source
S_th	Threshold for judging whether qualified capacity is below the required production level.	Determined by the production demand formula: S_th = D*k_s, where D = 60/day and k_s = 1.10.
Q_th	Threshold for judging whether the quality mean enters the warning control region.	Determined from the quality function Q_i(t) and quality control chart experience.
M_type	Indicates that maintenance only partially restores the machine state.	Determined by multi-state Markov recovery model and practical tool/drill replacement experience.
T_v	Downtime required for one maintenance action.	Calculated by the machining economics formula T_v = T_RPL + 60C_E / H_R and adjusted using maintenance experience.

CTMC model with controlled capacity release



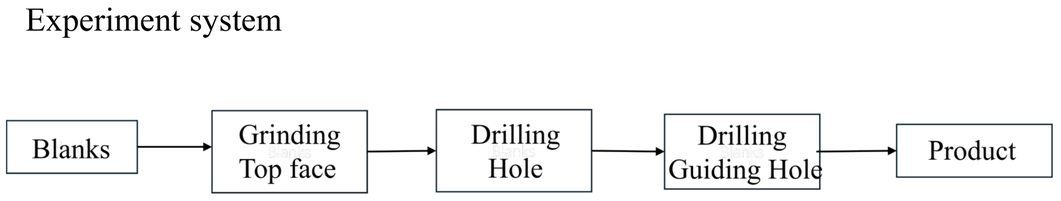
RESULTS & DISCUSSION

Reliability calculation formula

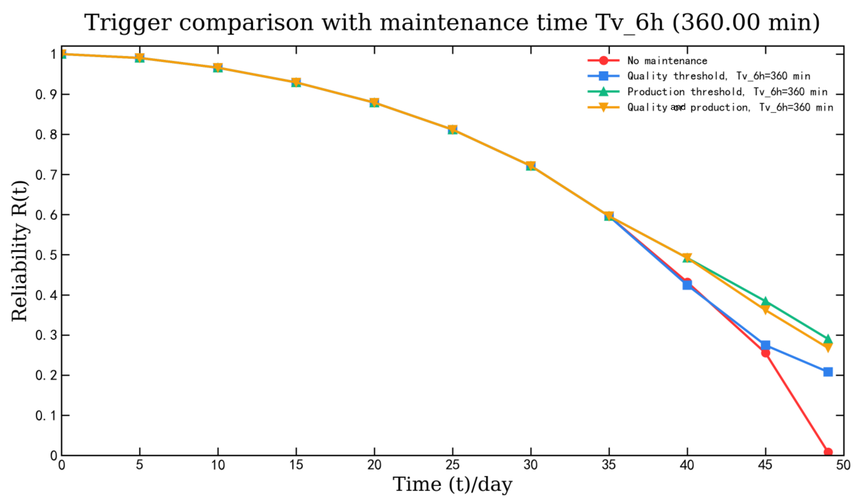
$$R(t) = \prod_{i=1}^{N} \sum_{j=1}^{N_i} \pi_{i,j}(t) \mathbb{I}(s_{i,j} \geq v_i) \cdot \sum_{j=1}^{N_i} \pi_{i,j}(t) \mathbb{I}(LSL_i \leq Q_i(t) \leq USL_i)$$

Symbol	Significance
$R(t)$	The probability that the system meets both quality and quantity requirements at time t.
$\pi_{i,j}(t)$	The probability that machine i is in state j at time t obtained by CTMC
v_i	The minimum required production capacity (demand level) for machine i
$Q_i(t)$	The quality characteristic (e.g., dimensional accuracy) of products from machine i at time t which is obtained by Q-R method
LSL_i	The lower specification limit of the quality characteristic for process i
USL_i	The upper specification limit of the quality characteristic for process i

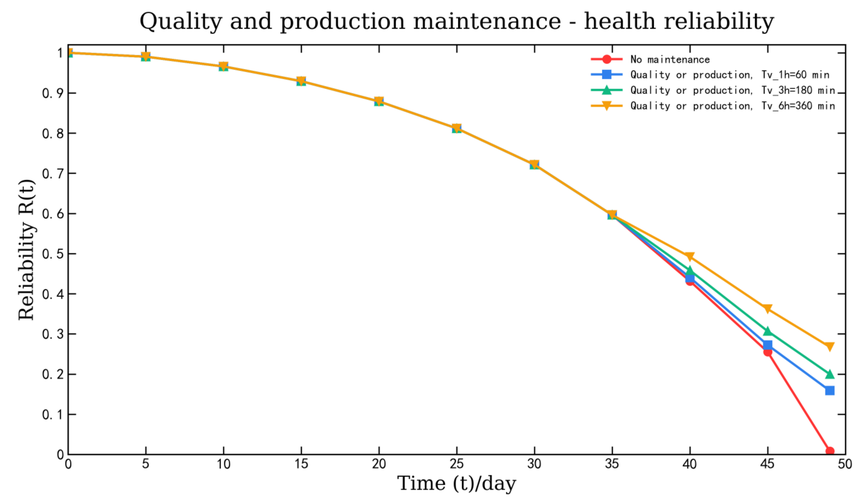
Experiment system



Experiment results



Quality-and-production maintenance improves system health reliability.



The maintenance-time comparison shows that longer maintenance improves health reliability more strongly.

CONCLUSION

1. Joint quality-and-capacity maintenance improves the reliability of the multi-state manufacturing system.
2. A moderate maintenance time best balances recovery improvement and downtime loss.

FUTURE WORK / REFERENCES

1. This study can use real manufacturing data to calibrate degradation rates, recovery rates, and maintenance thresholds.
2. This study can develop an optimization model that balances reliability improvement, maintenance cost, downtime loss, and production availability.