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Optimal condition-based maintenance strategy under periodic inspections for traction motor insulations

Key words: Traction motor insulation, Condition-based maintenance, Preventive maintenance, Shock

PROBLEM DESCRIPTION

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Subject to the combination of fatigue and shocks

Key parts of high speed train

Lead to 37% traction motor failures

Insulation of Traction Motors

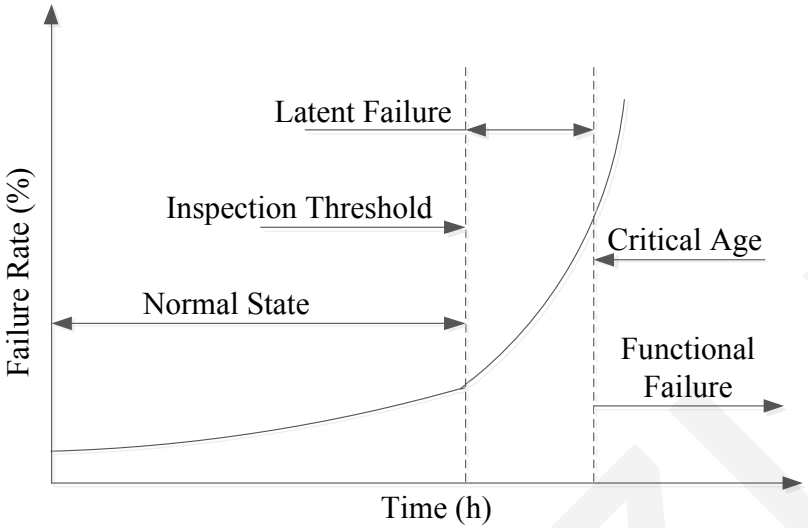
TBM leads to excessive or insufficient maintenance

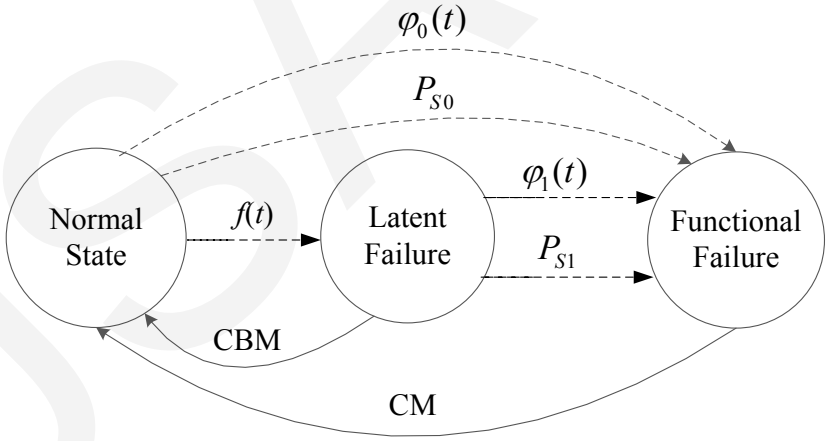
Lack of degradation process information for CBM

Optimal condition-based maintenance decisions under periodic inspections considering shocks

PROBLEM STATEMENT

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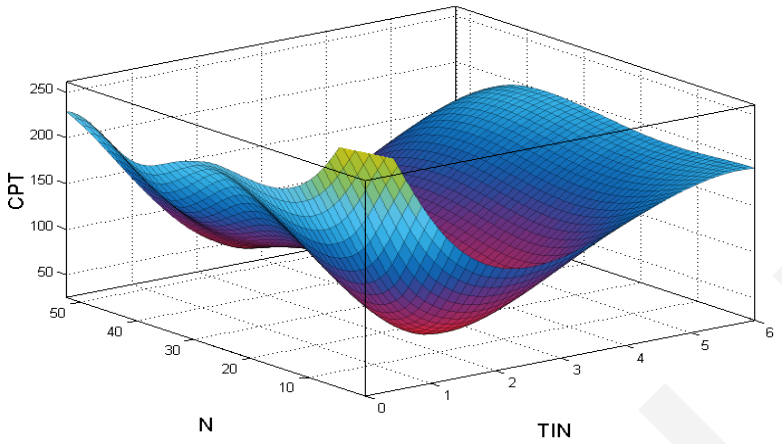




- Traction motor insulations can work in two states, normal state and latent failure state. Latent failure state is a transition state between normal state and functional failure state.
- The failure modes of traction motor insulations can be divided into two categories : the situation that functional failure occurs and the failure that inspection data reaches or exceeds the threshold value with no occurrence of functional failure.
- Functional failure calls for CM while latter triggers PM.
- The offline inspections on the performance indicator are performed periodically (assuming inspection is perfect).
- Insulation is subject to external random extreme high-voltage shock which occurs according to a Poisson process.
- minimal operation cost per time unit in an operation cycle is regarded as the optimization objective.

NUMERICAL INVESTIGATION

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No.	λ	P_{S0}	P_{S1}	N	T_{IN}	T_C	C%
1	0.01	0.0004	0.0007	14	1.60	22.40	0.74%
2	0.02	0.0017	0.0153	16	1.21	19.36	3.84%
3	0.02	0.0021	0.0029	13	1.58	20.54	4.03%
4	0.02	0.0150	0.0200	12	1.39	16.68	5.76%
5	0.05	0.0021	0.0057	12	1.48	17.76	5.38%
6	0. 2	0.0004	0.0007	13	1.57	20.41	1.65%
7	0.2	0.0170	0.0650	9	1.38	12.42	13.7%
8	1	0.1	0.12	4	1.31	5.24	40.7%

- The CPT of the proposed model is much higher with a small N, which results from the poor availability of traction motor insulations and excessively frequent PM. In this case, excessive maintenance occurs.
- For very large *N*, the maintenance strategy turns into a total CBM model. Furthermore, if T_{IN} is large simultaneously, both the life information and the condition monitoring information are given up. This maintenance transfers to a pure CM strategy and is inevitably costly.
- At the optimal point, operation cost and failure risk reach the best tradeoff. It can be observed that from this point, with the increase of T_{IN} and *N*, the risk of sudden functional failure increases greatly because of insufficient maintenance, which will finally lead to expensive CM.
- With an increasing difference of PS0 and PS1, more frequent inspections are demanded. shocks are more inclined to lead to functional failure and more frequent inspections should be performed to avoid the operation in state 1.
- With the increase of the frequency of shocks and failure rate, the optimal critical age decreases. More shocks may lead to the increase of the probability of high-cost CM, and therefore the critical age should be reduced to lower the probability of CM provoked by time-related internal factors.

CONCLUSIONS

- The primary contribution of this paper is to work out a feasible and practical CBM strategy for traction motor insulations based on their operating characteristics. Through periodic inspections, an operating mechanism comprising two failure modes and three operating states is proposed, which can make the best use of historic life information and inspection information. Moreover, it can overcome the drawbacks of excessive and insufficient maintenance of traditional time-based maintenance schemes.

- Another main contribution is to take extreme shock effect into account in the maintenance model. Traction motor insulation is different from normal deteriorating systems because of suffering random extreme shock load during operation. In the proposed model, extreme shocks following a Poisson process are integrated into the maintenance model, which ultimately increases the accuracy of the maintenance model.

- Numerical investigation validates that by taking shock effect into account, insulations can operate at a lower risk of catastrophic breakdown and the operating cost is reduced considerably.