Applied Mechanics and Materials
ISSN: 1662-7482, Vol. 575, pp 935-938
doi:10.4028/www.scientific.net/AMM.575.935

Submitted: 2014-04-28
Accepted: 2014-04-28
Online: 2014-06-25

Equipment Aging, Aging Detection, and Aging Management: a Review

K.H. Hui[1,a], Lim Meng Hee[2,b], and M. Salman Leong[3,c]

[1,2]RAZAK School of Engineering & Advanced Technology, Universiti Teknologi Malaysia, Malaysia

[3]Faculty of Mechanical Engineering, Universiti Teknologi Malaysia, Malaysia

[a]huikarhoou@gmail.com, [b]mhlim@ic.utm.my, [c]salman@ic.utm.my

Keywords: Aging; Equipment Aging; Aging Detection; Aging Management.

Abstract. It is becoming increasingly difficult to ignore the importance of equipment aging in critical industries such as power generation plants, oil and gas plants, etc. since many system components are approaching the end of their designed operational lifetime. New installations of system components in these critical industries will be extremely costly whilst any increase in demand will be too small to warrant totally new facilities. Aging management can be an alternative for this aging equipment to ensure its safety and reliability. This review aims to provide a brief understanding of equipment aging, aging detection and recent research into aging management.

Introduction

In recent years, there has been an increasing interest in equipment health prediction that recognises aging effects. The aging of a technical system is a degradation process caused by a number of different factors such as strain, stresses, fatigue, environmental factors, etc. [1] Many critical and advanced machines such as gas turbines, pumps and compressors in power generation plants, oil rigs, etc. are facing the end of their designed operational lifetime. The increases in demand are too small to warrant totally new installations. Knowledge about the residual life of a technical system ensures that it can be operated up to or even beyond its designed operational life. Operational life of a technical system is assessed in two steps which are (a) computing based on design values for the load effects (e.g. material, dimension) and (b) accounting for the effects of time on these load effect (i.e. production increase) in order to predict actual operational life [2]. Therefore, data of actual condition may assist in determining the actual residual life of a technical system. Actual residual life not only gives an idea to the owner about the safety and reliability of the operating technical system but also provide an overview on when the system components should be replaced. By understanding the actual residual life of a technical system, extending the useful life is possible [1]. Various concepts have been introduced to extend the useful life of a technical system such as replacement, overhauling and modification of the system, or keeping the system in operation without any changes [3]. This review aims to provide a brief review of the subject of equipment aging, aging detection and aging management.

Equipment Aging

Conventional analysis tends to classify equipment health condition into two states, namely working state and failure state [4]. However, most mechanical equipment works in an aging condition. Aging is generally understood to mean the degradation processes before the failure of a technical system, as illustrated in Fig. 1. In the literature, the term ‘aging’ tends to be used to refer to the degradation of the performance of mechanical equipment or technical systems [5]. The broad use of the term ‘aging’ in manufacturing and production engineering is sometimes equated with longer processing time due to the fact that the production facility becomes less efficient [6]. The degradation or aging processes of equipment are often dependent on their loads and working environment. For instance, excessive loads due to increases in productivity will shorten the operational lifetime of equipment. In most situations, the increases in demand are too small to justify investment in new installations. Then, running the equipment at maximum capacity might be the only alternative solution to fulfil the demand. In addition, the equipment operating under extreme conditions such as high temperature, humidity and dusty and corrosive environments will accelerate the aging processes of the equipment. Thus, many researchers are now aware that aging effects have to be taken into consideration for equipment health prediction or even maintenance scheduling in order to achieve higher levels of safety and efficiency.

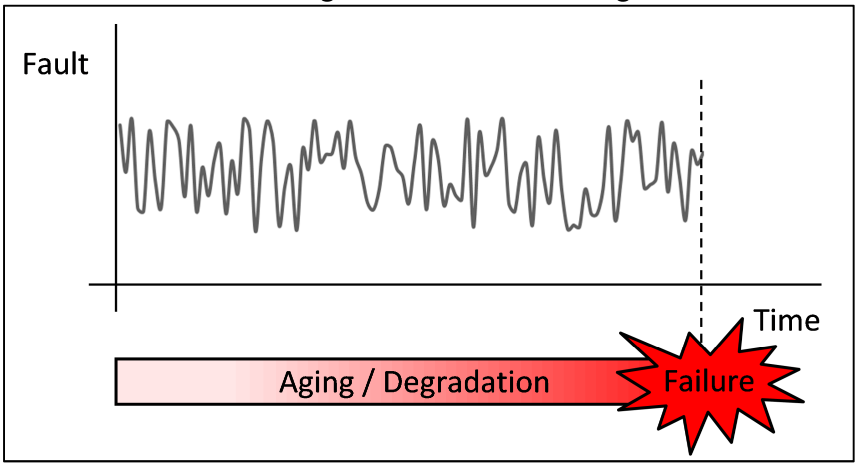

Fig. 1. Illustration of Equipment Aging or Degradation Processes [7]

Aging Detection

As was mentioned in the previous section, aging of equipment has to be taken into account to ensure the safety and efficiency of mechanical equipment, thus a brief review on the detection methodologies has been carried out. Equipment performance can be evaluated based on electrical, mechanical and thermal parameters such as voltage, current, torque, strain, noise, vibration, temperature, thermal stress, etc. Mechanical failures of rotating equipment are often related to bearing, balance and alignment defects. Researchers claimed induction motor aging effects and defects can be detected by analysing low-frequency vibration signals from the electric motor [8]. The low and high frequency bands of the vibration signals can be decomposed by applying Multi-Resolution Wavelet Analysis (MRWA). Defects like broken rotor bars and abnormal air gap eccentricity of induction motors can also be detected by analysing a motor's current by motor current signature analysis (MCSA) [9]. Kunz *et al.* [10] confirmed that wear behaviour of the vane pump can be identified by analysing the temperature distribution of the pump. Aging of a steam turbine rotor like cracks (i.e. rotor surface cracks) can only be detected using vibration monitoring [11]. Lim *et al.* [12] claimed that gas turbine blade faults like rubbing, cracks, deformations and looseness can be detected using vibration analysis. Wear of gears can be identified by utilising oil analysis to detect anomalies in the lubricant of machines [9]. In addition, oil analysis is also employed to discover wear, contamination and chemical changes. Bearing degradations can be determined by analysing vibration signals [13]. In summary, equipment aging detection methods are around vibration, current, temperature and oil analysis.

Vibration signals analysis obviously is the most common detection method for aging, degradations, defects, etc. Aging is a time-dependent problem, thus, it usually employs time-frequency signals analysis methods such as Short Time Fourier Transform (STFT), Wavelet Transform (WT), Empirical Mode Decomposition (EMD), Hilbert-Huang Transform (HHT), etc. The reviews on time-frequency signals analysis are widely available. Recently, many researchers integrated signals analysis with decision-making strategies to enable real-time diagnosis and prognosis of equipment health conditions [14]. Decision-making strategies widely used for equipment aging-related research include Condition-Based Maintenance (CBM) [14], the Bayesian approach [15], Artificial Neural Networks (ANN) [16], etc. Better understanding of the subject of equipment aging leads to efficient aging management and aims for all equipment to be utilised for its designed operational lifetime.

Aging Management

As described in the previous section, equipment aging can be detected using various methods, thus, aging management can be employed to ensure that equipment operates for its designed operational lifetime. The aging management begins with performance assessment then follows by predicting the remaining useful lifetime and, finally, feasible life extension alternatives [7]. If equipment aging is confirmed, the problem is then to determine what corrective measures will best help to delay the occurrence of a failure [15]. Life extension alternatives for aging equipment included preventive maintenance, design change, component replacement, overhauling and keeping the system as it is. Preventive maintenance can be carried out by monitoring the parameters related to the condition of the machinery therefore significant change can be identified in order to schedule for maintenance. Design change will enhance the reliability of equipment and avoid frequent failure. Replacing a component with later or better technology can extend the operational lifetime of a technical system. Through perfect overhauling, the equipment can be recovered to an 'as good as new' condition [16]. Lastly, some of the aging equipment can be kept as it is if it does not threaten the safety issues. Aging management processes have been summarised in Fig. 2. Therefore, knowledge of equipment aging makes life-extension possible on aging equipment.

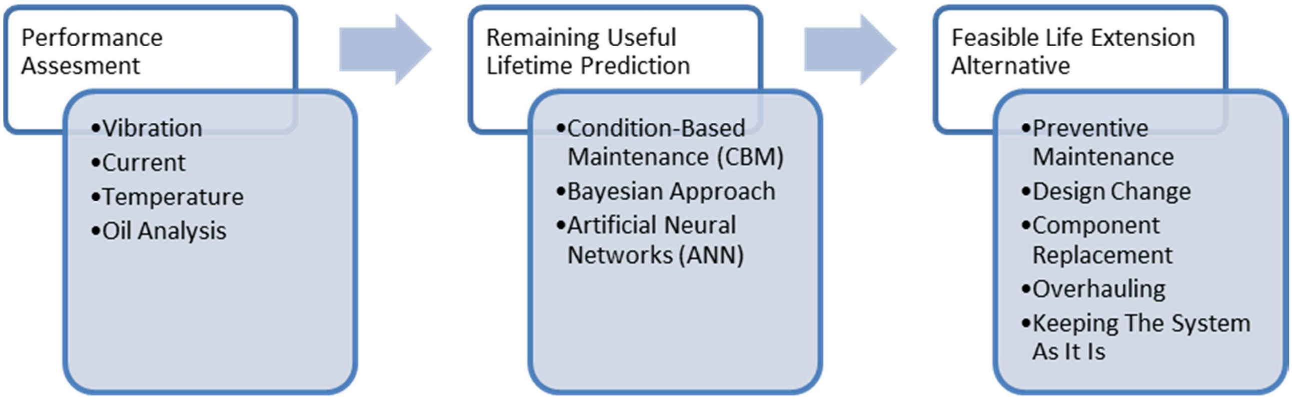

Fig. 2. Aging Management Processes

Conclusion

Equipment aging has become increasingly important since many system components are approaching the end of their designed operational lifetime. Performance of a technical system can be evaluated by various data, then, theory of evidence can be considered as a promising approach to address the aging detection problems. Aging management can be an alternative to new installations that can require considerable expenditure. On the other hand, extensive further research is needed into equipment aging since equipment aging predictions are using aging statistics from the same or similar components. Therefore, aging statistics for every critical mechanical device are required to shed new light into equipment aging management.

Acknowledgements

This work is supported by the Exploratory Research Grant Scheme (ERGS-R.K130000.7840.4L089) financed by the Ministry of Education, Malaysia. The main author is joint-funded by the Ministry of Education and Universiti Tun Hussein Onn Malaysia for his PhD study.

References

[1] R. Reinertsen, “Residual life of technical systems; diagnosis, prediction and life extension,” *Reliab. Eng. Syst. Saf.*, vol. 54, pp. 23–34, 1996.

[2] N. M. Okasha, D. M. Frangopol, and A. D. Orcesi, “Automated finite element updating using strain data for the lifetime reliability assessment of bridges,” *Reliab. Eng. Syst. Saf.*, vol. 99, pp. 139–150, Mar. 2012.

[3] P. A. Pérez Ramírez and I. B. Utne, “Decision support for life extension of technical systems through virtual age modelling,” *Reliab. Eng. Syst. Saf.*, vol. 115, pp. 55–69, Jul. 2013.

[4] R. Moghaddass and M. J. Zuo, “A parameter estimation method for a condition-monitored device under multi-state deterioration,” *Reliab. Eng. Syst. Saf.*, vol. 106, pp. 94–103, Oct. 2012.

[5] A. Abuhoza, H. R. Schmidt, S. Biswas, U. Frankenfeld, J. Hehner, and C. J. Schmidt, “Setup optimization toward accurate ageing studies of gas filled detectors,” *Nucl. Instruments Methods Phys. Res. A*, vol. 718, pp. 400–402, Aug. 2013.

[6] P.-C. Chang, S.-H. Chen, and V. Mani, “A note on due-date assignment and single machine scheduling with a learning/aging effect,” *Int. J. Prod. Econ.*, vol. 117, no. 1, pp. 142–149, Jan. 2009.

[7] J. Lee, F. Wu, W. Zhao, M. Ghaffari, L. Liao, and D. Siegel, “Prognostics and health management design for rotary machinery systems—Reviews, methodology and applications,” *Mech. Syst. Signal Process.*, vol. 42, no. 1–2, pp. 314–334, Jan. 2014.

[8] D. Bayram and S. Şeker, “Wavelet based Neuro-Detector for low frequencies of vibration signals in electric motors,” *Appl. Soft Comput.*, vol. 13, no. 5, pp. 2683–2691, May 2013.

[9] H. M. Hashemian, “Wireless sensors for predictive maintenance of rotating equipment in research reactors,” *Ann. Nucl. Energy*, vol. 38, no. 2–3, pp. 665–680, Feb. 2011.

[10] A. Kunz, R. Gellrich, G. Beckmann, and E. Broszeit, “Theoretical and practical aspects of the wear of vane pumps Part B. Analysis of wear behaviour in the vickers vane pump test,” *Wear*, vol. 181–183, pp. 868–875, Mar. 1995.

[11] S. Barella, M. Bellogini, M. Boniardi, and S. Cincera, “Failure analysis of a steam turbine rotor,” *Eng. Fail. Anal.*, vol. 18, no. 6, pp. 1511–1519, Sep. 2011.

[12] M. H. Lim, M. S. Leong, and K. H. Hui, “Blade Faults Classification and Detection Methods : Review,” in *Advanced Materials Research Vol. 845*, 2014, vol. 845, pp. 123–127.

[13] W. Su, F. Wang, H. Zhu, Z. Zhang, and Z. Guo, “Rolling element bearing faults diagnosis based on optimal Morlet wavelet filter and autocorrelation enhancement,” *Mech. Syst. Signal Process.*, vol. 24, no. 5, pp. 1458–1472, Jul. 2010.

[14] Y. Peng and M. Dong, “A prognosis method using age-dependent hidden semi-Markov model for equipment health prediction,” *Mech. Syst. Signal Process.*, vol. 25, no. 1, pp. 237–252, Jan. 2011.

[15] C. Clarotti, A. Lannoy, S. Odin, and H. Procaccia, “Detection of equipment aging and determination of the efficiency of a corrective measure,” *Reliab. Eng. Syst. Saf.*, vol. 84, no. 1, pp. 57–64, Apr. 2004.

[16] M. D. C. Moura, E. Zio, I. D. Lins, and E. Droguett, “Failure and reliability prediction by support vector machines regression of time series data,” *Reliab. Eng. Syst. Saf.*, vol. 96, no. 11, pp. 1527–1534, Nov. 2011.