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Determination of potential failure Initiation Time using Cumulative Sum Chart

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Abstract: Hard competition forces companies to reduce uncertainty in production planning through, e.g. reducing the probability of failures. In this paper, more accurate data analysis through reducing randomness in vibration measurements is introduced. Quality control tool Cumulative Sum (Cusum) Chart is adapted for monitoring variation in vibration level to determine the time of potential failure initiation. The result confirms the possibility of reducing false alarms arise due to randomness in vibration signals. The major conclusion; applying Cusum chart it is possible to determine the time of initiation of a potential failure for follow up its progression and accurate planning of maintenance.

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Keywords: Condition Monitoring, Failure Consequences, Identification of the Time of a Potential Failure Initiation.

1. INTRODUCTION

Modern manufacturing processes are exposed to rapid and dynamic changes in the operating condition, market demand, customers' wishes, national and international competition. To increase company profitability and competitiveness it demands continues enhancement of the company internal effectiveness. The requirements for increased plant productivity and safety, and reduced production cost to survive harsh and challenging competition in the national and international markets have led to an increasing interest in developing and implementing new methods for condition monitoring (CM) of mechanical systems, Holmberg et al. (2010). Industry interest in new methods and techniques for achieving more accurate maintenance decisions to prolong machine life and increase utilization of component/equipment life before conducting a replacement is also increased, Al-Najjar (2014). Detection, diagnosis and prognosis are more and more involved in maintenance when applying CM and condition-based maintenance (CBM), Collacott (1979), Moore and Starr (2006), Jardine et al. (2006), Al-Najjar (2012a).

In this paper, we do not confine ourselves to a particular CM parameter or system rather than our discussions are addressed to the widely implemented CM parameters, for example vibration, acoustic emission, sound, shock pulse measurements, bearing condition.

In mechanical systems, deterioration is usually associated with symptoms. To enhance the accuracy of maintenance decisions, needed maintenance actions, such as repair or replacement, should be planned depending on the condition of the machine under consideration, Al-Najjar (1997). The accuracy of a maintenance decision is strongly influenced by the type of monitoring parameter(s) used, how frequent measurements are picked up, quality of measured data and the accuracy in interpretation of signals, Bloch and Geither (1994) and Al-Najjar (2000).

2. FAILURES IN MECHANICAL SYSTEMS

The determination of a maintenance action should be based on anticipated failure modes, consequences and failure frequency. Generally, failure consequences are evaluated with respect to safety factors and economics. In general, only components having considerable failure consequences and of a non-negligible failure frequency should be prioritized for maintenance planning. Damage causes, damage developing mechanisms, operational environments and past data are essential sources of information to determine the nature of failures. By means of failure frequency, failure modes and failure consequences, significant components can be identified, Al-Najjar (1997).

Failure is defined in the BS Maintenance Glossary (1993) as: "The termination of the ability of an item to perform its required function" and is defined in RCM, see Nowlan et al. (1978), as: "an unsatisfactory condition". In general, component/equipment deterioration results in an unsatisfactory condition. Thus, it is essential to clarify the boundaries between satisfactory and unsatisfactory conditions in order to indicate the imminence of a failure.

In this paper, the failure in mechanical systems is defined as; a termination of a component's/equipment's ability to perform its required function that can be defined on basis of the machine functions, capability, availability, productivity, production cost, product quality, personnel/machine safety, or any combination of the above, Al-Najjar and Wang (2001).

During the first half of last century, replace at failure (breakdown) strategy was used in most cases, while in other cases age dependent replacement policy was adopted. Four decades ago the main focus was on anticipating failure time of components, Al-Najjar (2012a). But now, the complexity of systems and quality requirements had increased, and so have costs of material and labour. Thus, more attention should be paid to the analytical study of failure progression in connection with replacement policies. Such a study simplifies the selection of a proper CM parameter(s) and a corresponding monitoring technique(s). In order to assess failure consequences of a component/equipment, several

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factors should be considered. These factors are summarised as follows:

1. Component functional nature.
2. Component failure nature.
3. Operational environments.
4. Degree of the adversity effect of a component failure on the assets and staff safety.
5. Economic factors, such as repair or replacement cost, loss of production.

Failure consequences are not always associated with physical evidences obvious to the operator. Thus, failures could, in general, be divided into two major groups, non-hidden and hidden. Non-hidden failures are those which have a direct impact on machine performance. Some of these failures have adverse effect on the machine operating safety, on the safety of human beings, or both. Thus, they may be called safety failures.

Failures whose consequences include an immediate interruption or disturbance of machine operational capability are called operational failures. But, failures resulting in increased maintenance costs rather than disturbing the machine operation are called non-operational failures.

Hidden failures are those which have no direct effect on the machine performance and arise from components whose functions are hidden. More attention should be paid to this type of failures in order to eliminate the possibility of multiple failures which may have an immediate impact on the machinery operational safety. Failures are not always costly or dangerous especially those which can be treated in very short time without exposing machine operating safety for any risk.

A component is considered significant only if its probability of causing a costly or dangerous failure is non-negligible. Usually, it is considered significant if its risk priority number (RPN) exceeds a predetermined value in a particular scale, where for example, RPN = FI (Failure intensity)* FC (Failure criticality) * FDP (Failure detecting probability), Al-Najjar (1997).

3. CONDITION MONITORING AND DATA ANALYSIS

In order to monitor the health of a machine it is important and cost-effective to monitor the condition of the significant components. Therefore, suitable indicators enabling the user to explore what has happened, ongoing problem, follow up damage development and what may be happen, to avoid unexpected drastic changes in the machine state are crucial to retain, Holmberg et al. (2010) and Al-Najjar (2012b). These indicators are often known as condition monitoring (CM) parameters, such as vibration, acoustic emission, pressure, capacity, time and temperature. A CM parameter is defined in this paper as; a measurable variable able to display relevant information describing the condition of equipment at a particular point of time and position. The parameter value is measured in the scales of for example; time, mass, pressure, electrical charge, torque, efficiency, rate of flow, temperature, vibration level, etc. Naturally, a large number of monitoring parameters can be implemented to monitor each deterioration process and machine. But, only some of them are significant indicators and can be related to the occurrence of damage and development of potential failures, Al-Najjar (1997).

Sometimes, more than one parameter can be utilised to monitor the same deterioration process. The difference in the intrinsic information carried by these parameters can be explained by their correlation to the deterioration process and their sensitivities to disturbing factors. Selection of a suitable CM parameter(s) is based on several factors, Al-Najjar and Wang (2001). The factors of importance for this selection that are considered in this paper are:

1. The available knowledge concerning damage cases, damage developing mechanisms, failure modes.
2. Failure consequences.
3. Engineering knowledge in the available CM system.
4. The degree of accuracy in detecting the initiation of damage and follow up its development, i.e. initiation of a potential failure.
5. The degree of accuracy in following up potential failure development
6. The degree of accuracy in predicting time to replacement/failure.

The last three factors can be evaluated on the base of failure consequences.

In order to secure gathering of relevant and high quality data, the sensors implemented for picking-up measurements should possess the following properties:

1. Highly sensitive to the deterioration process.
2. Rugged transducer.
3. Capable of withstanding long period in rough environments.
4. More reliable than the machine itself, see for example, Collacott (1977).

When monitoring the condition of a component/equipment, data analysis often aims to detect as accurate as possible the time of the occurrence of a deviation in a CM parameter value from a prescribed reference, level or mean. In CM, there are two interesting events to be detected as early as possible. These events are the initiation of damage (and its development), and when the level of the monitored CM parameter reaches the maximum allowable level before failure, i.e. the threshold level, x_{th}.

Denote by x_p the level at which a potential failure, i.e. damage has initiated and under development, is assumed to be occurred. When the value of a particular CM parameter, such as vibration level, exceeds this level a potential failure is declared to be occurred. Denote by x_o the mean value of the monitored CM parameter of a component during an operating interval when no damage is initiated. Therefore, all the measurements gathered during this interval are assumed to be sampled from a normal distribution, so that;

$$x_o < x_p < x_{th}$$

Let x_p and x_{th} be warning and action levels, respectively. If the CM parameter value exceeds x_p more care should be paid to the potential failure development to figure out its trend, causes, developing mechanisms and to predict its progression

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