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Predictive Maintenance Modelling for Through-Life Engineering Services

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Abstract

Predictive maintenance needs to forecast the numbers of rejections at any overhaul point before any failure occurs in order to accurately and proactively take adequate maintenance action. In healthcare, prediction has been applied to foretell when and how to administer medication to improve the health condition of the patient. The same is true for maintenance where the application of prognostics can help make better decisions. In this paper, an overview of prognostic maintenance strategies is presented. The proposed data-driven prognostics approach employs a statistical technique of (i) the parameter estimation methods of the time-to-failure data to predict the relevant statistical model parameters and (ii) prognostics modelling incorporating the reliability Weibull Cumulative Distribution Function to predict part rejection, replacement, and reuse. The analysis of the modelling uses synthetic data validated by industry domain experts. The outcome of the prediction can further proffer solution to designers, manufacturers and operators of industrial product-service systems. The novelty in this paper is the development of the through-life performance approach. The approach ascertains when the system needs to undergo maintenance, repair and overhaul before failure occurs.

Keywords: Through-life engineering services; maintenance strategies, data-driven prediction, predictive modelling, parameter estimation

1. Introduction

Through-life Engineering Services (TES) aligns MRO function with the operations strategy of an organisation. TES is important and facilitated by the correct application of technology supported by the efficient use of service knowledge [1]. TES applies advanced technologies for condition monitoring and prognosis to help operators reduce downtime and provide improved availability of products.

In the manufacturing and aerospace domains, time remains a constant independent variable which every other variable depends on. The reliability of the repairable system is essential to help determine the life of the system based on predictive maintenance to reduce failure of an assembly [2]. Application of prognostics approaches in the modelling and simulation of gas turbine engine mechanical components for an assembly can give a better understanding of the behaviour of a system.

The intent of the authors is to convert the observed rejection rate data into an understanding of the underlying parts degradation rate as an issue. The problem is to show the through-life performance of an assembly of mechanical components. The demonstration of the unreliability of modelling and simulation of a set of components within an assembly has become essential because of the difficulty of undertaking physical-model-based prognostics. The historical and current health information as well as expert experience are used in a degradation model to visualise the simulated

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results. The data-driven prognostic approach uses only the available data to model and simulate the deterioration of parts.

The contribution in this paper is applying data-driven model to develop a through-life performance approach that establishes when an asset should be ready for detailed maintenance, repair and overhaul before failure occurs.

The most common prognostic approaches to demonstrate the effectiveness of the predictive maintenance modelling include physical model, data-driven, knowledge and hybrid [3]–[6].

The focus of this article is to develop a predictive maintenance strategy applicable to system reliability in the manufacturing, aerospace gas turbine, and other domains relative to concurrent system operations. The goal of this paper is to model and simulate an engine assembly in order to predict the number of parts expected to fail at a given inspection time. The remainder of this paper includes maintenance strategies, data-driven prognostics maintenance strategy, case study, results and discussion, and conclusion.

2. Maintenance strategies

The maintenance strategies are classified as taxonomy with a focus on the selected strategies in the blue boxes in Figure 1. Maintenance is conducted using different strategies for the management, control, execution and quality of activities to ensure reasonably design levels of availability and performance of assets to meet business objectives [7].

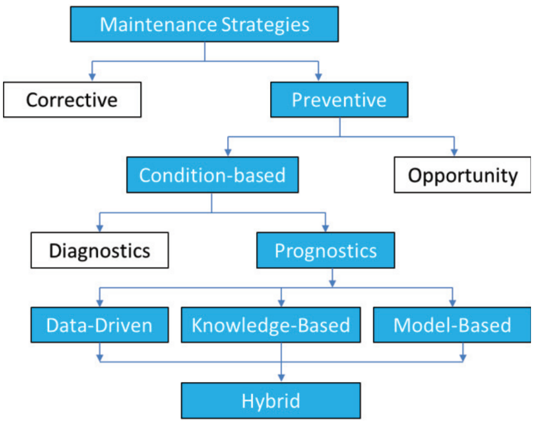

Figure 1 Taxonomy of maintenance strategies

2.1. Classification of Maintenance Strategies

Over the last sixty year the world has transformed the maintenance perspective [7]. Corrective maintenance is often called repair tasks carried out after an asset has failed [2]. Corrective maintenance was the viable option for engineers to fix or replace breakdown equipment. Though, corrective maintenance is still very much in use. However, the corrective maintenance aims only to bring equipment back to its functioning state [2].

Preventive maintenance is described as a planned maintenance performed when an item is functioning properly to prevent future failures [2]. The preventive maintenance strategy consists of opportunity-based and condition-based.

2.2. Classification of Preventive Maintenance Strategies

Condition-based Maintenance (CBM) describes the measurements of one or more condition variables of an asset, which is initiated when a condition variable passes its threshold [2]. Condition-based maintenance is a predictive strategy performed to determine the state of an in-service system to perform maintenance when the need arises [2], [3]. The necessity concept is determined by assessing the health condition of the equipment continuously and extrapolating it to a predefined failure threshold [8], [9]. Condition-based Maintenance refers to predictive maintenance while others are termed traditional or conventional maintenance. However, a predictive maintenance culture can be adopted for on-time decision making to assess the health of a component in-service before system failure.

Opportunity maintenance is another form of preventive maintenance applicable for multi-item systems where maintenance tasks on other items give an opportunity for carrying out maintenance on which were not the cause of opportunity [2]. The opportunity maintenance is the replacement of equipment components that are yet to fail based on available maintenance resources [10]. Opportunity maintenance aims to improve system availability and reduce production loss and results in a reducing operations excellence and increases production efficiency [11].

2.3. Classification of Condition-based Preventive Maintenance Strategies

Diagnostics is the process of checking faults and the health state of sub-systems and units in an operational environment with the aid of sensors. During maintenance, inspection is required to identify components and provide information on the current performance status [12].

In [13], the turbine section of a gas turbine houses singles and multiple stage parts. However, the focus is on the single-stage. The single stage part are superficially inspected using a Borescope for bowing by gaining entrance into the turbine through the combustion chamber areas or by opening inspection access holes

Prognostics is predicting the duration after which a component can no longer perform its intended or expected functionality to improve system safety. The International Standard Organisation (ISO 13381-1:2004) define Prognostics as “the estimated-time-to-failure (ETTF) and the risk of existence or subsequent appearance of one or more failure modes” [14].

2.4. Classification of Prognostics Maintenance strategy

a. **Data-driven:** Data-driven techniques are derived from the configuration, usage, and historical ‘run-to-failure’ data applicable to maintenance decision making. Data-driven techniques are often used for estimation thereby informing the maintenance decision based upon failure threshold. Gåsvik et al. [15] proposed a ‘wavelet packet’ decomposition approach and/or Hidden Markov Models (HMMs) to be used where the time-frequency features allow more precise results than using